Research Article

Pricing and Collection Rate for Remanufacturing Industry considering Capacity Constraint in Recycling Channels

Lang Xu,1,2 Jia Shi,1 and Jihong Chen1

1College of Transport and Communications, Shanghai Maritime University, Shanghai, China
2School of Administrative Studies, York University, Toronto, Canada

Correspondence should be addressed to Lang Xu; jerry_langxu@yeah.net

Received 15 March 2019; Revised 17 June 2019; Accepted 11 July 2019; Published 11 June 2020

Guest Editor: Domingo Rosario

Copyright © 2020 Lang Xu et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

This paper explores the decision-making and coordination mechanism of pricing and collection rate in a closed-loop supply chain with capacity constraint in recycling channels, which consists of one manufacturer and one retailer. On the basis of game theory, the equilibriums of decisions and profits in the centralized and decentralized scenarios are obtained and compared. Through the performance analysis of a different scenario, a higher saving production cost and lower competition intensity trigger the members to engage in remanufacturing. Furthermore, we try to propose a two-part tariff contract through bargaining to coordinate supply chain and achieve a Pareto improvement. The results show that when the capacity constraints in recycling channels exceed a threshold, the decisions and profit will change. Additionally, for closed-loop supply chain, the selling price is more susceptible to the influence of capacity constraint in recycling channel than the members’ profit.

1. Introduction

In recent years, the Considering Capacity Constraint in Recycling Channels closed-loop supply chain (CLSC) is a hot topic in the field of logistics and supply chain management, which has been attracting extensive attention from the industrial and theoretical circles. According to the viewpoint of the whole life cycle, products have been manufactured, wholesaled, retailed and used. Then, the end-of-life products are eliminated by consumers, which are classified, cleaned, and disassembled by the collectors; meanwhile, the valuable parts are implemented in the process of remanufacturing [1]. Remanufacturing increases the time of material utilization, and makes it more energy-saving and environmentally friendly. Studies have shown that recycling and reuse of core components can save about 40%–60% of the cost [2, 3]. Therefore, many famous enterprises like Xerox, Robert Bosch, and Hewlett-Packard improve the performance through remanufacturing. However, many companies still have doubts about whether the manufacturing can bring profit. Thus, it is of great significance to quantitatively explore the economics of remanufacturing and give some managerial guidance to collection and remanufacturing strategy for promoting the development of the remanufacturing industry and improving the level of closed-loop supply chain management.

However, the closed-loop supply chain should simultaneously consider operations of forward and reverse flow. The recycling channels of closed-loop supply chain have their corresponding infinite recycling capacity; otherwise, it goes against the realistic conditions like warehouse, routing, and staff. Under these circumstances, the relationship between capacity constraint and supply chain performance has been unpredictable. The remanufacturing capacity of Benz-cummins, an automobile-engine remanufacturer, only 3000 per year for Cummins, Doitz, and Mercedes-Benz. Further, Wuxi diesel-engine factory is located in Jiangsu Province with an annual capacity of 5000 modified vehicles. Obviously, the development strategies of both companies are affected by the production capacity, so they cannot meet the market demand. In other words, if the recycling capacity is reduced at a certain threshold, the capacity constraint results in a huge influence of decision and profit [4, 5]. In general, the less recycling capacity tends to decrease the collection ability in the reverse channel. Note that this situation may result in a phenomenon, which undercuts corporate profit aggravate environmental harm [6–9]. Furthermore, based on managerial insight, realistically, the imposing capacity constraints will
change the manufacturing and remanufacturing process. Managers should also take the recycling capacity into account when they decide the strategies. Thus, the limitation in the recycling capacity impacting the supply chain performance is a major challenge for the operation management era.

Therefore, the behavior of collection and remanufacturing for end-of-life products is crucial to our environment and economic. According to the Stackelberg game, we establish a centralized and decentralized model to obtain the decision of pricing and collection rate in a closed-loop supply chain. Furthermore, we adopt the Nash bargaining theory to propose an improved coordinated contract and discuss the performance of optimal profits and decisions. Different from the above, we mainly fill in the research gap with the influence of the capacity in recycling channel on optimal profits and decisions. In addition, we focus on the design of coordination mechanism in a closed-loop supply chain with a manufacturer recycling channel and a retailer recycling channel to achieve a perfect Pareto improvement. The rest of this paper is organized as follows. Section 2 reviews the relative literature of closed-loop supply chain management and coordinated mechanism. In Section 3, the notation and assumption are provided. We formulate the mathematical model and decision analysis in Section 4. Further, we present the numerical analysis to obtain some managerial insights in Section 5. Section 6 provides the conclusions and suggestions for future research.

2. Literature Review

The several relevant literature should be reviewed here to clarify the need for our paper. In order to demonstrate in detail the contributions, we explore the literature spanning across two subsections. In Section 2.1, we focus on the management of a closed-loop supply chain, which contains network design, collection competition and recycling constraint. Then, we address the coordination mechanism for members to improve the performance and achieve improvement in Section 2.2.

2.1. Closed-Loop Supply Chain Management. Many scholars discussed the remanufacturing strategy in a closed-loop supply chain, including recycling mode and channel choice, which is an academic problem and achieve an efficient decision. Savaskan et al. [10] based on the game theory to establish three recycling channels to compare the differences among manufacturer collection retailer collection and third-party collection. Then, Savaskan et al. [11] took one manufacturer and two competitive retailers into consideration in determining the decisions of pricing and collection. On this basis, Wu [12] introduced the price and service decisions into a two-stage Stackelberg game, which consists of one manufacturer, one remanufacturer, and one retailer. In addition, this model was extended to a dual-channel recycling model in a closed-loop supply chain between retailer and third-party recycling competition [13]. Zhang and Ren [14] discussed differences in optimal decision and profit in the centralized and decentralized closed-loop supply chain, as well as analyzed the influences of channel preference and sales service on performance. Morteza et al. [15] proposed a fuzzy two-objective model with the random interruptions, which is a price-dependent demand, to construct a closed-loop network between the manufacturer and the retailer. Taleizadeh et al. [16] combined pricing, quality, and collection in a closed-loop supply chain, besides explore the impact of channel structure on decision and profit. From the above, previous studies seldom considered the impacts of competitive intensity on different recycling models.

But beyond that, the other branch is recycling competition. Feng et al. [17] introduced consumer preference in establishing a dual-channel collection model for a closed-loop supply chain, which discuss the recycling competition and recycling configuration between the manufacturer and the recycler. He et al. [18] discussed competitive collection in a closed-loop supply chain, which investigated remanufacturing efficiency and consumer acceptance with channel inconvenience. Further, Liu et al. [6] proposed a price- and quality-dependent competition model between the formal and informal recyclers to explore the impact of governmental policy on the four competitive scenarios. Liu et al. [19] introduced the recycling competition into the decisions of pricing and reverse channel choice and also compared three different dual-channel recycling models. Wang et al. [20] combined the Stackelberg game to obtain the pricing strategies for the three individual collection models with the competitive collection market and demand market. From the above, these literature on the remanufacturing strategy in a two-period Stackelberg game is derived by backward induction. Yet, the remanufacturing behavior can be affected by some realistic factors, which lead to a capacity constraint in recycling channel. How to analyze the impact of capacity constraint on the performance in a closed-loop supply chain is an urgent problem.

Capacity constraint in decision-making is becoming increasingly crucial in real-life scenarios. Sereno and Efthimiadis [21] investigated the investment of firms whether to add the capacity or not, besides discussing how capacity constraints and incentive schemes influence firms’ strategies. This is especially circumstance in closed-loop supply chain. Fischetti et al. [22] adopted Benders’ decomposition without separability to design an algorithm and conduct a numerical analysis in deriving the capacitated facility location problems. Mota et al. [23] proposed a multi-objective MIP model, which combines the demand uncertainty and capacity restriction, to guarantee the sustainable development of a closed-loop supply chain through locating the facility. Further, Wang et al. [24] and Dominguez et al. [25] discussed respectively the influences of capacity constraint on low-carbon and closed-loop supply chain. Meanwhile, Zhen et al. [26] and Ljubic and Moreno [27] optimized the network of a closed-loop supply chain from the perspective of capacity constraint to demonstrate several decisions, such as capacity locations, network design and technology allocation. However, they mainly focused on the capacity constraint in distribution centers, which ignores the restriction in recycling channels.

2.2. Coordinated Mechanism in Closed-Loop Supply Chain. The topic of coordinated mechanism in the supply chain has received great attention in the existing literature. From the view of cost and revenue sharing, Cachon and Lariviere [28] compared the revenue-sharing contract, buyback contract, and wholesale price contract to conclude that the optimal coordinated mechanism. Mafakheri and Nasiri [29] focused
on the extracting value from end-of-life products to investigate the distribution of revenue sharing in a closed-loop supply chain. Hu and Feng [30] analyzed the revenue-sharing contract in a supplier buyer supply chain under the demand and supply uncertainties. Beyond that, some scholars provided the buyback contract [12, 31] and, discount schemes [32, 33], and lead time incentive mechanisms [34, 35]. Different from the traditional supply chain, Heydari and Ghasemi [36] proposed a coordinated model in a reverse supply chain based on the uncertainty for member’s risk, which considered the random remanufacturing capacity, to achieve a win–win situation. Further, Li et al. [37] emphatically analyzed the efficiency of a revenue-sharing contract with the perspective of recycling cost as an extra value for the collector. Zhao and Zhu [38] designed a revenue-sharing mechanism to coordinate the manufacturer and retailer considering the uncertainties of remanufacturing rate and market demand. In addition, Xie et al. [39] compared the performance in the centralized and decentralized supply chain, which indicated the influence of channel conflict in a reverse supply chain scenario, to get a revenue-sharing coordinated mechanism. Therefore, for the members in the closed-loop supply chain, eliminating double-marginalization and ensuring profit-maximization has been a urgently problem.

In the coordinated mechanism, profit distribution between the manufacturer and retailer is more and more becoming a hot topic in the field of operation management [7]. Shi and Wu [40] adopted the fuzzy decision theory to the Shapley value for profit distribution, which considered the risk influence and capital appreciation ratio. Dai and Chen [41] designed the mechanism of profit distribution for supplier, manufacturer, and retailer to improve the traditional Shapley value. Zhang and Geng [42] demonstrated a profit allocation model in the evolutionary game model and discussed the impact of relative parameters on the member’s cooperation and performance. Chen et al. [43] compared the different coordinated mechanisms with price- and time-dependent demand, as well as proposed the allocation of individual income for all participants. Wu et al. [44] combined the fairness concern into the coordinated mechanism to incentive the members’ participation in energy saving. Wang et al. [45] proposed a mixed integer-programming model, which combined the transportation expansion, vehicle time, and collection routing to improve the Shapley value to balance the profits.

Outside of this, in order to improve the efficiency of supply chain coordination, some scholars investigated the contract with several methods. Zhang and Ren [14] provided a coordinated contract to balance the manufacturer and the retailer, which contained revenue sharing and cost sharing. Xie et al. [46] discussed the coordinated mechanism with service effect and sale effect based on the perspectives of revenue and expenditure. In total, there are limited points of previous studies, which didn’t achieve perfectly the coordination in a closed-loop supply chain.

Different from the existing literature, this paper focuses on the decision and coordination of a closed-loop supply chain with a manufacturer recycling channel and a retailer recycling channel to obtain managerial insights from the perspective of capacity constraint in recycling channels. The main contributions of this paper are characterized by three fields. The first is to examine the impacts of competitive intensity for recycling channel on optimal decision and profit. The second is to discuss the effectiveness conditions of capacity constraint in recycling channels. Finally, we propose a two-part tariff contract through bargaining to coordinate closed-loop supply chain and achieve a Pareto improvement.

### 3. Problem Description and Assumption

In this paper, we investigate the decision and coordination of a closed-loop supply chain, which consists of one-single manufacturer and one-single retailer under capacity constraints in recycling channel. In the forward channel, the manufacturer sells a certain type of product through the retailer to consumers. Further, the manufacturer and the retailer collect used products in the reverse channel. Since the recycling channels for used products can differ, the demands are divided into two types from both the manufacturer and retailer, which are affected by the competition intensity between the two recycling channels. To discuss the decision behavior and coordination mechanism under capacity constraints in recycling channels, we suppose that the manufacturer follows the “lot-for-lot” policy, which is applied in the existing literature. Notation and explanations are listed in Table 1.

In addition, the following assumptions are considered in our mathematical models under the capacity constraints.

### Table 1: Notations and explanations.

| Notation | Explanation |
|----------|-------------|
| $c_m$    | The production cost manufactured the new product via raw materials |
| $c_r$    | The production cost manufactured the new product via used products |
| $s$      | The saving production cost between the new and the remanufactured product |
| $k$      | The scaling parameter for collection cost in a recycling channel |
| $y$      | The competition intensity between two collection channels |
| $b$      | The transfer price from manufacturer to retailer to collect used product |
| $z_m$    | The available capacity constraint in the manufacturer’s recycling channel |
| $z_r$    | The available capacity constraint in the retailer’s recycling channel |
| $p$      | The retailer’s selling price for unit product |
| $w$      | The manufacturer’s wholesale price for unit product |
| $\tau_m$ | The manufacturer’s collection rate for used production |
| $\tau_r$ | The retailer’s collection rate for used production |
| $\pi_{sc}$ | The profit function for supply chain |
| $\pi_m$  | The profit function for manufacturer |
| $\pi_r$  | The profit function for retailer |
| $\theta_m$ | The bargaining power for manufacturer |
| $\theta_r$ | The bargaining power for retailer |
Assumption 1. Following the existing literature and many others [10, 18, 47], we suppose that there is no significant difference between new and remanufactured product and the market demand is a linear function $D = a - p$, which shows a trend of monotonically decreasing and continuous with respect to the selling price.

Assumption 2. Comparing the new and remanufactured product, we adopt $c$ and $c - s$ to characterize the production cost for two types of products, where the average production cost $\overline{c} = c(1 - \tau_m - \tau_r) + (c - s)(\tau_m + \tau_r)$ represents the saving production cost between the new and the remanufactured product. Thus, we derive the relationship $s < \overline{c} < c$ and $0 < b < s$, which ensure the collection behavior is profitable.

Assumption 3. Considering the recycling competition between manufacturer and retailer, we introduce the competition intensity into our research, which reflects the competition level between two channels in collecting used products. Therefore, the larger the competition intensity is, the more fierce the collection is. Consistent with Zou et al. [48], Xu et al. [49] and Jerbia et al. [50], we get a symmetric influence between two channels. We suppose there exists competition between the two collection channels. This paper refers to the competition intensity between two collection channels and it reflects intense competition level between two collection agents in collecting used products. The collection investments for both the manufacturer and the retailer are a quadratic functions with the collection rate, $k\left(\tau_m^2 + \gamma \tau_r^2\right)/2(1 - \gamma^2)$ and $k\left(\gamma \tau_m^2 + \tau_r^2\right)/2(1 - \gamma^2)$, which is widely used in the literature [13, 19, 51].

Assumption 4. In addition, the recycling quantities from the manufacturer and the retailer are set at a level much lower than the actual levels in collecting used products [5, 52, 53]. To some extent, this is intuitively consistent with reality since the actual conditions often incur a drop recycling quantity. Hence, we adopt $0 \leq \tau_m \leq z_m, 0 \leq \tau_r \leq z_r$, and $0 \leq \tau_m + \tau_r \leq 1$ as the relationship to characterize the collection rates of manufacturer and retailer.

Assumption 5. According to Zhao and Zhu [38], Wang et al. [54], and Zhao and Zhu [55], we consider a symmetric-information Stackelberg game led by the manufacturer and followed by the retailer in closed-loop supply chain, in which the bargaining power of the retailer is limited compared with that of the manufacturer.

### 4. Model Equilibrium

In this section, we explore the decisions of pricing and collection rate for a closed-loop supply chain in the centralized scenario and decentralized scenario. Considering the capacity constraint, the manufacturer and the retailer have two options “$N$” or “$Y$”, which mean that the quantities of used products from different recycling channels exceed the capacity constraint or not. Further, we denote “$P$” or “$F$” to illustrate that a part of used products or full of used products from the manufacturer and the retailer turns remanufacturing. We discuss eight strategies to obtain equilibriums in the centralized scenario and decentralized scenario.

#### 4.1. Centralized Scenario

Initially, we establish a centralized model for a closed-loop supply chain and get the decisions of pricing and collection rate with capacity constraint in the recycling channel. Under this structure, the manufacturer and the retailer as a system aim to maximize the total profit. Therefore, the profit function for a supply chain is given as follows

$$\pi_{ac} = \left[p - c + s(\tau_m + \tau_r)\right](a - p) - \frac{k\left(\tau_m^2 + \tau_r^2\right)}{2(1 - \gamma^2)}$$

subject to $\tau_m \leq z_m, \tau_r \leq z_r, \tau_m + \tau_r \leq 1$. (1)
Table 3: Decisions with different strategies in the decentralized scenario.

| Strategy   | Optimal decisions \( (p, \tau_m, \text{ and } \tau_r) \) |
|------------|-------------------------------------------------|
| N-N-P      | \( p = \frac{k(3a + c) - a \cdot s^2(3 - y)(1 - y^2)}{4k - 3s^2(3 - y)(1 - y^2)} \), \( \tau = \frac{2k(a + c) - s^2(2a - ya + c)(1 - y^2)}{4k - 3s^2(3 - y)(1 - y^2)} \), \( \tau_m = \frac{s(a - c)(1 - y^2)}{4k - 3s^2(3 - y)(1 - y^2)} \), \( \tau_r = \frac{s(a - c)(1 - y^2)}{4k - 3s^2(3 - y)(1 - y^2)} \) |
| N-N-F      | \( p = \frac{k(3a + c - 2s) + as^2(1 - y)(1 + y)^2}{4k + s^2(1 - y)(1 + y)^2} \), \( w = \frac{2k(a + c - 2s) - s^2(1 - y^2)(2a + ya - c + 2s)}{4k + s^2(1 - y)(1 + y)^2} \), \( \tau_m = \frac{4k - s(1 - y^2)[a - c + s(1 - y)]}{4k + s^2(1 - y)(1 + y)^2} \), \( \tau_r = \frac{4k - s(1 - y^2)(a - c + 2s)}{4k + s^2(1 - y)(1 + y)^2} \) |
| Y-N-P      | \( p = \frac{k(3a + c - s \cdot z_m) - as^2(1 - y^2)}{4k - s^2(1 - y^2)} \), \( \tau = \frac{2k(a + c + s \cdot z_r) - s^2(1 - y^2)(a + s \cdot z_r)}{4k - s^2(1 - y^2)} \), \( \tau_m = \frac{s(1 - y^2)(a - c + s \cdot z_r)}{4k - s^2(1 - y^2)} \), \( \tau_r = z_r \) |
| Y-N-F      | \( p = \frac{3a + c - s}{4} \), \( w = \frac{a + c - s(1 - 2z_r)}{2} \), \( \tau_m = 1 - z_r \), \( \tau_r = z_r \) |
| N-Y-P      | \( p = \frac{k(3a + c - s \cdot z_m) - as^2(2 - y)(1 - y^2)}{4k - s^2(2 - y)(1 - y^2)} \), \( \tau = \frac{2k(a + c - s \cdot z_m) - s^2(1 - y^2)(a - ya - c + s \cdot z_m)}{4k - s^2(2 - y)(1 - y^2)} \), \( \tau_m = z_m \), \( \tau_r = \frac{s(1 - y^2)(a - c + s \cdot z_m)}{4k - s^2(2 - y)(1 - y^2)} \) |
| N-Y-F      | \( p = \frac{a - s(1 - y^2) - k(1 - z_m)}{s(1 - y^2)} \), \( \tau = \frac{s(1 - y^2)[a + s(1 - z_m)] - 2k(1 - z_m)}{s(1 - y^2)} \), \( \tau_m = z_m \), \( \tau_r = 1 - z_m \) |
| Y-Y-P      | \( p = \frac{3a + c - s(z_m + z_r)}{4} \), \( w = \frac{a + c - s(z_m + z_r)}{2} \), \( \tau_m = z_m \), \( \tau_r = z_r \) |
| Y-Y-F      | \( p = \frac{3a + c - s}{4} \), \( w = \frac{a + c - s(1 - 2z_r)}{2} \), \( \tau_m = z_m \), \( \tau_r = z_r \) |
Table 4: Optimal decisions and profits in different scenarios.

|                  | \( \theta_m \) | \( F \) | \( p \) | \( w \) | \( r_m \) | \( r_r \) | \( \pi_m \) | \( \pi_r \) | \( \pi_{sc} \) |
|------------------|---------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Centralized scenario | —             | —      | —      | 5.703  | 0.462  | 0.45   | —      | —      | 16.146 |
| Decentralized scenario | —             | —      | —      | 7.843  | 0.313  | 0.313  | 7.947  | 4.105  | 12.052 |
| Coordination contract | 0.5           | 6.725  | —      | 5.703  | 0.462  | 0.45   | 10.567 | 5.579  | 16.146 |
|                  | 0.6           | 6.430  | —      | 5.703  | 0.462  | 0.45   | 10.861 | 5.285  | 16.146 |
|                  | 0.7           | 6.135  | —      | 5.703  | 0.462  | 0.45   | 11.156 | 4.990  | 16.146 |
|                  | 0.8           | 5.840  | —      | 5.703  | 0.462  | 0.45   | 11.451 | 4.695  | 16.146 |
|                  | 0.9           | 5.545  | —      | 5.703  | 0.462  | 0.45   | 11.746 | 4.400  | 16.146 |
|                  | 1.0           | 5.250  | —      | 5.703  | 0.462  | 0.45   | 12.041 | 4.105  | 16.146 |

Proposition 1. In the centralized scenario, the equilibrium can be expressed as in Table 2.

Proof of Proposition 1 is in supplementary materials (available here). Proposition 2 demonstrates the following results: (1) neither the manufacturer’s nor retailer’s collection rates are not affected by the capacity constraints under the conditions \( k < \max (k_3, k_r) \), where \( k_3 = s(1 − \gamma)(a − c + 2s \cdot z_m)/2z_m \) and \( k_r = s(1 − \gamma)(a − c + 2s \cdot z_r)/2z_r \) (2) both the manufacturer’s and retailer’s collection rates are closely associated with the capacity constraints under the conditions \( k < \min (k_3, k_r) \), where \( k_3 = s(1 − \gamma)(a − c + s(z_m + z_r))/2z_m \) and \( k_r = s(1 − \gamma)(a − c + s(z_m + z_r))/2z_r \); (3) only the manufacturer’s collection rate is affected by capacity constraints under the condition \( k_5 < k < k_r \); (4) only the retailer’s collection rate is affected by capacity constraints under the conditions \( k_6 < k < k_r \).

Next, we compare the equilibriums in the decentralized scenario and centralized scenarios to investigate the differences in optimal performance.

Proposition 2. In the decentralized scenario, the equilibrium can be expressed as in Table 3.

Proof of Proposition 2 is in supplementary materials (available here). Proposition 2 demonstrates the following results: (1) neither the manufacturer’s nor retailer’s collection rates are not affected by the capacity constraints under the conditions \( k < \max (k_3, k_r) \), where \( k_3 = s(1 − \gamma)(a − c + 2s \cdot z_m)/2z_m \) and \( k_r = s(1 − \gamma)(a − c + 2s \cdot z_r)/2z_r \) (2) both the manufacturer’s and retailer’s collection rates are closely associated with the capacity constraints under the conditions \( k < \min (k_3, k_r) \), where \( k_3 = s(1 − \gamma)(a − c + s(z_m + z_r))/2z_m \) and \( k_r = s(1 − \gamma)(a − c + s(z_m + z_r))/2z_r \); (3) only the manufacturer’s collection rate is affected by capacity constraints under the condition \( k_5 < k < k_r \); (4) only the retailer’s collection rate is affected by capacity constraints under the conditions \( k_6 < k < k_r \).

In a coordinated contract, we design a two-part tariff contract through bargaining to achieve a Pareto improvement and eliminate the effect of double marginalization. According to the above, we assume that the retailer sells products with the wholesale price set by the manufacturer and the sub-game
Further, the manufacturer pays a fixed fee $F$ to the retailer, which is negotiated by the members’ bargaining powers to supply chain coordination. The bargaining powers for manufacturer and retailer are $\theta_m$ and $\theta_r$. Therefore, the model can be characterized as follows:

\[
\pi_m = \left[w - c_m + c_r (\tau_m + \tau_r) - br_r \right] (a - w) - \frac{k (\tau_m^2 + y \tau_r^2)}{2 (1 - y^2)} - F.
\]

---

**Proposition 4.** In this coordinated contract, the fixed fee should be satisfied as $F = \theta_m \left[ \pi_m^D + C(\tau_r^*) \right] + \theta_r \left( \pi_m^C - \pi_m^D \right)$.

Proof of Proposition 4 is in supplementary materials (available here) discusses the two-part tariff contract coordinates effectively the performances in the decentralized scenario to achieve the best in the centralized scenario. Meanwhile, it also obtains a Pareto improvement, which indicates that the individual members’ profits with the improved two-part tariff contract will be improved.

---

**Proposition 5.** The two-part tariff contract through bargaining can effectively coordinate the decentralized closed-loop supply chain and achieves the performances similar to that in the centralized supply chain as follows $w^* = p^*$, $\tau_m^* = \tau_m^C$, $\tau_r^* = \tau_r^C$ and $\pi_m^* = \pi_m^C$.

Proposition 5 indicates that the two-part tariff can improve the performances of a closed-loop to that of a centralized scenario. The manufacturer and the retailer negotiate the fixed fee $F$ which should ensure the members’ profits are not lower than those in the decentralized scenario. From the retailer’s and manufacturer’s profit function, the retailer benefits from the manufacturer’s payment and the manufacturer covers the input in saving the production cost. Further, the lower the selling price is, the more consumers purchase the more products. In addition, it implies the two-part tariff contract through bargaining is beneficial for economic development and environmental protection in the sustainable operation of a closed-loop supply chain.

### 5. Numerical Analysis

In this section, we provide a numerical example to discuss theoretical results in managerial insights and analyze the influence of relevant parameters on optimal performance. Considering the values of coefficients used in the existing literature [13, 18, 58–60], we suppose that: $a = 10, y = 0.35, c = 2.5, s = 1.2, k = 7.25, z_m = 0.6$, and $z_r = 0.45$.

#### 5.1. Case Analysis

According to the above analysis, the optimal decisions and profits for each effective case in the centralized and decentralized scenarios are shown in Table 4.

From Table 4, we can obtain that:

1. In the centralized supply chain, the optimal profit is obtained when $\lambda_1 > 0$, $\lambda_2 = 0$, and $\lambda_3 = 0$ since the KKT conditions should be satisfied. The supply chain can achieve maximal profit when the manufacturer’s collection rate does not exceed the capacity constraint in the recycling channel and the retailer’s collection rate exceeds the capacity constraint in the recycling channel. The optimal collection strategy is to collect the used product through the manufacturer since the capacity constraint from the manufacturer is greater...
whereas the collection rates and profit are higher. Hence, this means that the centralized system can help to enhance the overall efficiency of the supply chain. In addition, the contract can coordinate the members in the profit’s distribution, which means that the profits of the manufacturer and the retailer are higher than those of the decentralized supply chain, and the selling price is lower and the collection rates are higher.

than that of the retailer. However, in the decentralized scenario, the collection rates from the manufacturer and the retailer are equal because of the value of the capacity constraint in the two channels.

(2) Compared with the decentralized scenario, the centralized supply chain can result in improved performances. From this point, the selling price is lower in the centralized scenario than in the decentralized scenario, whereas the collection rates and profit are higher. Hence, this means that the centralized system can help to enhance the overall efficiency of the supply chain. In addition, the contract can coordinate the members in the profit’s distribution, which means that the profits of the manufacturer and the retailer are higher than those of the decentralized supply chain, and the selling price is lower and the collection rates are higher.

| Centralized scenario | Case 3 | Case 7 | Case 7 | Case 5 | Case 5 | Case 5 | Case 5 | Case 5 | Case 5 |
|----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| \( p \)              | 5.837  | 5.782  | 5.728  | 5.703  | 5.703  | 5.703  | 5.703  | 5.703  | 5.703  |
| \( \tau_m \)         | 0.24   | 0.33   | 0.42   | 0.462  | 0.462  | 0.462  | 0.462  | 0.462  | 0.462  |
| \( \tau_r \)         | 0.448  | 0.45   | 0.45   | 0.45   | 0.45   | 0.45   | 0.45   | 0.45   | 0.45   |
| \( \pi_{sc} \)       | 15.888 | 16.055 | 16.137 | 16.146 | 16.146 | 16.146 | 16.146 | 16.146 | 16.146 |
| \( \lambda_1 \)      | 0      | +      | +      | +      | +      | +      | +      | +      | +      |
| \( \lambda_2 \)      | +      | +      | +      | 0      | 0      | 0      | 0      | 0      | 0      |
| \( \lambda_3 \)      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |

| Decentralized scenario | Case 3 | Case 1 | Case 1 | Case 1 | Case 1 | Case 1 | Case 1 | Case 1 | Case 1 |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| \( p \)                | 7.867  | 7.843  | 7.843  | 7.843  | 7.843  | 7.843  | 7.843  | 7.843  | 7.843  |
| \( w \)                | 6.106  | 6.062  | 6.062  | 6.062  | 6.062  | 6.062  | 6.062  | 6.062  | 6.062  |
| \( \tau_m \)           | 0.24   | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  |
| \( \tau_r \)           | 0.310  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  | 0.313  |
| \( \pi_{m} \)          | 7.929  | 7.947  | 7.947  | 7.947  | 7.947  | 7.947  | 7.947  | 7.947  | 7.947  |
| \( \pi_{r} \)          | 4.069  | 4.105  | 4.105  | 4.105  | 4.105  | 4.105  | 4.105  | 4.105  | 4.105  |
| \( \pi_{sc} \)         | 12.098 | 12.052 | 12.052 | 12.052 | 12.052 | 12.052 | 12.052 | 12.052 | 12.052 |
| \( \lambda_1 \)        | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| \( \lambda_2 \)        | +      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| \( \lambda_3 \)        | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |

| (b) Sensitivity analysis for \( z_m \) on the optimal decision and profit. |

| Fluctuation of \( z_m \) | −60% | −45% | −30% | −15% | 0%  | 15%  | 30%  | 45%  | 60%  |
|--------------------------|------|------|------|------|-----|------|------|------|------|
| Centralized scenario     |      |      |      |      |     |      |      |      |      |
| \( p \)                  | 5.876 | 5.832 | 5.789 | 5.746 | 5.703| 5.694| 5.694| 5.694| 5.694|
| \( \tau_m \)             | 0.444 | 0.448 | 0.453 | 0.458 | 0.462| 0.463| 0.463| 0.463| 0.463|
| \( \tau_r \)             | 0.18  | 0.248 | 0.315 | 0.383 | 0.45 | 0.463| 0.463| 0.463| 0.463|
| \( \pi_{sc} \)           | 15.731| 15.906| 16.033| 16.113| 16.146| 16.147| 16.147| 16.147| 16.147|
| \( \lambda_1 \)          | +    | +    | +    | +    | 0   | 0    | 0    | 0    | 0    |
| \( \lambda_2 \)          | 0    | 0    | 0    | 0    | 0   | 0    | 0    | 0    | 0    |
| \( \lambda_3 \)          | 0    | 0    | 0    | 0    | 0   | 0    | 0    | 0    | 0    |

| Decentralized scenario   |      |      |      |      |     |      |      |      |      |
| \( p \)                  | 7.893 | 7.962 | 7.843 | 7.843 | 7.843| 7.843| 7.843| 7.843| 7.843|
| \( w \)                  | 6.182 | 6.221 | 6.062 | 6.062 | 6.062| 6.062| 6.062| 6.062| 6.062|
| \( \tau_m \)             | 0.293 | 0.296 | 0.313 | 0.313 | 0.313| 0.313| 0.313| 0.313| 0.313|
| \( \tau_r \)             | 0.18  | 0.248 | 0.313 | 0.313 | 0.313| 0.313| 0.313| 0.313| 0.313|
| \( \pi_{m} \)            | 7.734 | 7.857 | 7.947 | 7.947 | 7.947| 7.947| 7.947| 7.947| 7.947|
| \( \pi_{r} \)            | 3.810 | 3.774 | 4.105 | 4.105 | 4.105| 4.105| 4.105| 4.105| 4.105|
| \( \pi_{sc} \)           | 11.544| 11.631| 12.052| 12.052| 12.052|12.052|12.052|12.052|12.052|
| \( \lambda_1 \)          | +    | +    | 0    | 0    | 0   | 0    | 0    | 0    | 0    |
| \( \lambda_2 \)          | 0    | 0    | 0    | 0    | 0   | 0    | 0    | 0    | 0    |
| \( \lambda_3 \)          | 0    | 0    | 0    | 0    | 0   | 0    | 0    | 0    | 0    |
(3) The two-part tariff contract through bargaining has a significant implication for improving the economic performance and environmental benefit. Therefore, the optimal profits are improved to achieve the performance of a centralized scenario and create a win–win situation for the manufacturer and the retailer through the coordinated contract if the incentive compatibility constraint is guaranteed. Moreover, the profit of supply chain in the coordinated contract is constant. When the manufacturer and the retailer integrate as a whole system, the fluctuations of bargaining powers do not influence the total profit. However, under this coordinated contract, the manufacturer's profit and retailer's profit increase as the one's own bargaining power increases. Intuitively, we find that the capacity of recycling channel plays a critical role in the decision and coordination from the above case analysis. From a managerial viewpoint, we suggest that the closed-loop supply chain can integrate the capacity constraints in both recycling channels, to fulfill consumers' demand with a cost-effective method.

5.2. Sensitivity Analysis. To illustrate the effects of competitive intensity in a recycling channel on optimal performance, we provide the impact of competitive intensity on performance. Therefore, we assume that the maximal fluctuation of $\gamma$ is $\pm 50\%$ of the baseline values, the results of which are presented in Table 5.

From Table 5, we can conclude that:

1. In the centralized scenario, changes in the optimal decisions and profit are larger (more than 3.6% and 7.2%) when the value of $\gamma$ fluctuates in the range of $[-50\%, 50\%]$. This means that the selling price and collection rate are sensitive to the competitive intensity in the centralized scenario. Moreover, the selling price appears as monotonic increasing trend and the profits show a monotonic decreasing trend with the competitive intensity in recycling channels. However, the difference in the collection rates for members first increases and then decreases with competitive intensity increasing.

2. In the decentralized scenario, the difference between the collection rates for the manufacturer and the retailer is more insensitive to the fluctuation of $\gamma$, which shows that the manufacturer and the retailer achieve the same collection rates. This is because, compared with the recycling channels in a no competitive situation, the larger the competition intensity is, the more expensive in collection has been invested in to obtain a same collection rate. Therefore, the decreasing collection rate with the competition intensity increasing results in a rise in the production cost, which directly leads to the higher wholesale price and selling price.

Comparing the above situations, we evaluate how the effect of competitive intensity determines the operational performance of the whole supply chain system by measuring the capacity constraint of recycling channels. Interestingly, due to the double marginal effect, the centralized supply chain is more adaptable to the changes in capacity constraints. In other words, centralized supply is more conducive to the improvement of performance between the manufacturer and the retailer to achieve a higher profit. Further, we demonstrate the effect of capacity constraint in recycling channel on the optimal decisions and profits in closed-loop supply chain and give a sensitivity analysis for the capacity constraint. Considering the maximal fluctuations of $z_m$ and $z_c$ are respectively $\pm 60\%$ of the baseline values, the calculation results are as presented in Table 6.

From Table 6, we can obtain that:

1. In the centralized scenario, when $z_m$ decreases by 30%, the total profit for the supply chain drops by at most 1.6% and the selling price rises by at most 2.3%, the collection rates decrease by at most 49.1% and 0.6% respectively. Meanwhile, the total profit for the supply chain drops by at most 2.6% and the selling price rises by at most 3.1%, and the collection rates decreases by at most 4.3% and 61.3% when $z_c$ decreases by 30%. Obviously, this means that the selling price is more sensitive than the total profit for the supply chain to capacity constraint in recycling channels. Further, the manufacturer's collection rate is more affected and the retailer's collection rate is not much affected by $z_m$, whereas the situation in the change of $z_c$ demonstrates the opposite. Additionally, the optimal decisions and profits will change if the capacity constraint in recycling channels exceeds a certain threshold.

2. In the decentralized scenario, when $\lambda_1 = 0, \lambda_2 = 0$, and $\lambda_1 = 0$, the optimal decision and profit are not affected by the change of $z_m$ and $z_c$. However, the collection rate for the manufacturer shows a significant declining trend and the collection rate for the retailer is negligible with the value of $z_m$ when $\lambda_1 = 0, \lambda_2 > 0$ and $\lambda_3 = 0$; this situation is the contrary with the change of $z_c$ when $\lambda_1 = 0, \lambda_2 > 0$ and $\lambda_3 = 0$. It indicates that the members in the decentralized scenario result in a double marginalization effect, that is, the members determines a higher selling price and a lower collection rate. Therefore, only if the capacity constraint in recycling channels has a huge reduction can the decision and profit be effected. This indicates that the government should provide a more attention to ensure the recycling capacity for members in closed-loop supply chain. Specifically, the capacity constraints in recycling channels may cause a smoothing effect in the fabrication of both the manufacturing ability and the market demand.
6. Conclusions

This paper studies the decision and coordination in a closed-loop supply chain considering capacity constraints in recycling channels, which the manufacturer and retailer should determine the optimal selling prices and collection rate to balance their profits. Comparing the performances in the centralized scenario and decentralized scenario, we obtain the following results: (1) The centralized scenario results in a lower selling price and a higher collection rate, while the minimal profit occurs under the decentralized scenario without coordination and the maximal profit occurs under the centralized scenario. (2) A higher saving production cost and lower competition intensity trigger the manufacturer and the retailer to engage in remanufacturing. To coordinate closed-loop supply chain, we propose a two-part tariff contract and combine the bargaining theory to achieve a Pareto improvement. In addition, the numerical analysis discussed the following managerial insights; (1) The optimal decisions and profits will change when the capacity constraint in recycling channel exceeds a certain threshold. Further, the selling price is more sensitive than the total profit for supply chain to capacity constraint in recycling channels. Hence, the closed-loop supply chain should find ways, through environmental propaganda and remanufacturing technologies to expand the capacity of recycling channels. (2) The optimal collection strategy is to collect the used product through the manufacturer since the capacity constraint from the manufacturer is greater than that of the retailer. Moreover, the difference in the centralized scenario between the collection rates from the manufacturer and the retailer are not equal to that of the centralized scenario because of the value of the capacity constraint in the two channels. Obviously, it is significantly important that the cooperation between the manufacturer and the retailer avoids the double marginal effect. (3) Specifically, the capacity constraints in recycling channels create a smoothing effect in the fabrication of both the manufacturing ability and market demand. Further, the two-part tariff contract through bargaining has a significant implication for improving the economic performance and environmental benefit, which improves the optimal profit to achieve the performance of centralized scenario and make a win–win situation for members via the coordinated contract if the incentive compatibility constraint is guaranteed.

This paper does not consider the uncertainty of market demand and asymmetric information, which are the future research to explore the equilibrium of a closed-loop supply chain with capacity constraints. In addition, introducing the insight of government into the decision and coordination for a closed-loop supply chain is another significant topic.

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This research was supported in part by the National Nature Science Foundation of China (Nos. 71373157 and 51879156).

Supplementary Materials

The proof for propositions. (Supplementary Materials)

References

[1] A. S. Margarete and P. Ken, “Meeting the closed-loop challenge: The case of remanufacturing,” California Management Review, vol. 46, no. 2, pp. 74–89, 2004.
[2] J.-M. Chen and C.-I. Chang, ”The cooperative strategy of a closed-loop supply chain with remanufacturing,” Transportation Research Part E: Logistics and Transportation Review, vol. 48, no. 2, pp. 387–400, 2012.
[3] R. Giuntini and K. Gaudette, “Remanufacturing: the next great opportunity for boosting US productivity,” Business Horizons, vol. 46, no. 6, pp. 41–48, 2003.
[4] J. Heydari, K. Govindan, and R. Sadeghi, “Reverse supply chain coordination under stochastic remanufacturing capacity,” International Journal of Production Economics, vol. 202, pp. 1–11, 2018.
[5] D. Mohammaditabar, S. H. Ghodsypour, and A. Hafezalkotob, “A game theoretic analysis in capacity-constrained supplier-selection and cooperation by considering the total supply chain inventory costs,” International Journal of Production Economics, vol. 181, pp. 87–97, 2016.
[6] H. H. Liu, M. Lei, H. H. Deng, G. Keoeng Leong, and T. Huang, “A dual channel, quality-based price competition model for the WEEE recycling market with government subsidy,” Omega, vol. 59, pp. 290–302, 2016.
[7] L. Xu and C. X. Wang, “Sustainable manufacturing in a closed-loop supply chain considering emission reduction and remanufacturing,” Resources, Conservation and Recycling, vol. 131, pp. 297–304, 2018.
[8] L. Xu, F. Xie, Q. Yuan, and J. Chen, “Pricing and carbon footprint in a two-echelon supply chain under cap-and-trade regulation,” International Journal of Low-carbon Technologies, vol. 14, no. 2, pp. 212–221, 2019.
[9] Q. Zhu, Y. Feng, and S.-B. Choi, “The role of customer relational governance in environmental and economic performance improvement through green supply chain management,” Journal of Cleaner Production, vol. 155, pp. 46–53, 2018.
[10] R. C. Savaskan, S. Bhattacharya, and L. N. Wassenhove, “Closed-loop supply chain models with product remanufacturing,” Management Science, vol. 50, pp. 239–252, 2004.
[11] R. C. Savaskan and L. N. Van Wassenhove, “Reverse Channel Design: The Case of Competing Retailers,” Management Science, vol. 50, no. 2, pp. 1–14, 2006.
[12] D. S. Wu, “Coordination of competing supply chains with news-vendor and buyback contract,” International Journal of Production Economics, vol. 144, no. 1, pp. 1–13, 2013.
[13] M. Huang, M. Song, L. H. Lee, and W. K. Ching, “Analysis for strategy of closed-loop supply chain with dual recycling channel,” International Journal of Production Economics, vol. 144, no. 2, pp. 510–520, 2013.
[14] C.-T. Zhang and M.-L. Ren, “Closed-loop supply chain coordination strategy for the manufacture of patented products
under competitive demand,” Applied Mathematical Modelling, vol. 40, no. 13–14, pp. 6243–6255, 2016.

[15] G. A. Morteza, G. Seyed, T. M. Reza, and A. Jabbarzadeh, “A fuzzy pricing model for a green competitive closed-loop supply chain network design in the presence of disruptions,” Journal of Cleaner Production, vol. 188, pp. 425–442, 2018.

[16] A. A. Taleizadeh, N. Alizadeh-Asbas, and B. R. Sarker, “Coordinated contracts in a two-echelon green supply chain considering pricing strategy,” Computers & Industrial Engineering, vol. 124, pp. 249–275, 2018.

[17] L. P. Feng, K. Govindan, and C. F. Li, “Strategic planning: design and coordination for dual-recycling channel reverse supply chain considering consumer behavior,” European Journal of Operational Research, vol. 260, no. 2, pp. 601–612, 2017.

[18] Q. D. He, N. M. Wang, Z. Yang, Z. He, and B. Jiang, “Competitive collection under channel inconvenience in closed-loop supply chain,” European Journal of Operational Research, vol. 275, no. 1, pp. 155–166, 2019.

[19] L. W. Liu, Z. J. Wang, L. Xu, X. Hong, and K. Govindan, “Collection effort and reverse channel choices in a closed-loop supply chain,” Journal of Cleaner Production, vol. 144, pp. 492–500, 2017.

[20] J. Wang, Z. Zhou, and M. Yu, “Pricing models in a sustainable supply chain with capacity constraint,” Journal of Cleaner Production, vol. 222, pp. 57–76, 2019.

[21] L. Sereno and T. Efthimiadis, “Capacity constraints, transmission investments and incentive schemes,” Energy policy, vol. 119, pp. 8–27, 2018.

[22] M. Fischetti, I. Ljubic, and M. Sinnl, “Benders decomposition without separability: a computational study for capacitated facility location problems,” European Journal of Operational Research, vol. 253, no. 3, pp. 557–569, 2016.

[23] B. Mota, M. I. Gomes, A. Carvalho, and A. P. Barbosa-Povoa, “Sustainable supply chains: an integrated modelling approach under uncertainty,” Omega, vol. 77, pp. 32–57, 2018.

[24] N. M. Wang, Q. D. He, and B. Jiang, “Hybrid closed-loop supply chains with competition in recycling and product markets,” International Journal of Production Economics, 2019.

[25] R. Dominguez, B. Ponte, S. Cannella, and M. J. Framinan, “On the dynamics of closed-loop supply chains with capacity constraints,” Computers & Industrial Engineering, vol. 128, pp. 91–103, 2019.

[26] L. Zhen, Y. Wu, S. Wang, Y. Hu, and W. Yi, “Capacitated closed-loop supply chain network design under uncertainty,” Advanced Engineering Informatics, vol. 38, pp. 306–315, 2018.

[27] I. Ljubic and E. Moreno, “Outer approximation and submodular cuts for maximum capture facility location problems with random utilities,” European Journal of Operational Research, vol. 266, no. 1, pp. 45–56, 2018.

[28] 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.

[29] F. Mafakheri and F. Nasiri, “Revenue sharing coordination in reverse logistics,” Journal of Cleaner Production, vol. 59, pp. 185–196, 2013.

[30] B. Hu and Y. Feng, “Optimization and coordination of supply chain with revenue sharing contracts and service requirement under supply and demand uncertainty,” International Journal of Production Economics, vol. 183, pp. 185–193, 2017.

[31] J. Heydari, T. M. Choi, and S. Radkhah, “Pareto improving supply chain coordination under a money-back guarantee service program,” Service Science, vol. 9, no. 2, pp. 91–105, 2017.

[32] S. K. Chaharsoghi, J. Heydari, and I. N. Kamalabadi, “Simultaneous coordination of order quantity and reorder point in a two-stage supply chain,” Computers & Operations Research, vol. 38, no. 12, pp. 1667–1677, 2011.

[33] Z. Dimitris, I. George, and B. Apostolos, “Supply chain coordination under discrete information asymmetries and quantity discounts,” Omega, vol. 53, pp. 21–29, 2015.

[34] J. Heydari, “Coordinating supplier’s reorder point: a coordination mechanism for supply chains with long supplier lead time,” Computers & Operations Research, vol. 48, pp. 89–101, 2014.

[35] J. Heydari, Z. A. Payam, and T. M. Choi, “Coordinating supply chains with stochastic demand by crashing lead times,” Computers & Operations Research, vol. 100, pp. 394–403, 2018.

[36] J. Heydari and M. Ghasemi, “A revenue sharing contract for reverse supply chain coordination under stochastic quality of returned products and uncertain remanufacturing capacity,” Journal of Cleaner Production, vol. 197, pp. 607–615, 2018.

[37] S. Li, Z. Zhu, and L. Huang, “Supply chain coordination and decision making under consignment contract with revenue sharing,” International Journal of Production Economics, vol. 120, no. 1, pp. 88–99, 2009.

[38] S. Zhao and Q. Zhu, “Remanufacturing supply chain coordination under the stochastic remanufacturability rate and the random demand,” Annals of Operations Research, vol. 257, no. 1–2, pp. 661–695, 2017.

[39] J. Xie, L. Liang, L. Liu, and P. Jeromonachou, “Coordination contracts of dual-channel with cooperation advertising in closed-loop supply chains,” International Journal of Production Economics, vol. 183, pp. 528–538, 2017.

[40] J. G. Shi and G. D. Wu, “Study on the supply chain alliance profit allocation based on improved Shapely value,” International Conference on Management Science, vol. 50, pp. 7–512, 2009.

[41] B. Dai and H. X. Chen, “Profit allocation mechanism for carrier collaboration in pickup and delivery service,” Computers & Industrial Engineering, vol. 62, no. 2, pp. 633–643, 2012.

[42] Y. Zhang and H. Geng, “An analysis on distribution of cooperative profit in supply chain based on multi-agent,” International Conference on Medical Physics and Biomedical Engineering, vol. 33, pp. 698–704, 2012.

[43] W. Y. Chen, B. Kucukyazici, V. Verter, and M. J. Sáenz, “Supply chain design for unlocking the value of remanufacturing under uncertainty,” European Journal of Operational Research, vol. 247, no. 3, pp. 804–819, 2015.

[44] Q. Wu, H. Ren, W. Gao, J. Ren, and C. Lao, “Profit allocation analysis among the distributed energy network participants based on game-theory,” Energy, vol. 118, pp. 783–794, 2017.

[45] C. Wang, W. Wang, and R. Huang, “Supply chain enterprise operations and government carbon tax decisions considering carbon emissions,” Journal of Cleaner Production, vol. 152, pp. 271–280, 2017.

[46] J. Xie, W. Zhang, L. Liang, Y. Xia, J. Yin, and G. Yang, “The revenue and cost sharing contract of pricing and servicing policies in a dual-channel closed-loop supply chain,” Journal of Cleaner Production, vol. 191, pp. 361–383, 2018.

[47] X. Hong, Z. Wang, D. Wang, and Z. Zhang, “Decision models of closed-loop supply chain with remanufacturing under hybrid dual-channel collection,” International Journal of Advanced Manufacturing Technology, vol. 68, no. 5–8, pp. 1851–1865, 2013.

[48] Z.-B. Zou, J.-J. Wang, G.-S. Deng, and H. Chen, “Third-party remanufacturing mode selection: outsourcing or authorization,”
Transportation Research Part E: Logistics and Transportation Review, vol. 87, pp. 1–19, 2016.

[49] L. Xu, C. Wang, Z. Miao, and J. Chen, "Governmental subsidy policies and supply chain decisions with carbon emission limit and consumer's environmental awareness," RAIRO-Operations Research, vol. 53, pp. 1675–1690, 2019.

[50] R. Jerbia, M. K. Boujelben, M. A. Sehli, and Z. Jemai, "A stochastic closed-loop supply chain network design problem with multiple recovery options," Computers & Industrial Engineering, vol. 118, pp. 23–32, 2018.

[51] 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.

[52] S. Cannella, R. Dominguez, B. Ponte, and J. M. Framinan, "Capacity restrictions and supply chain performance: Modelling and analyzing load-dependent lead times," International Journal of Production Economics, vol. 204, pp. 264–277, 2018.

[53] J. Wu, F. Jiang, and Y. He, "Pricing and horizontal information sharing in a supply chain with capacity constraint," Operations Research Letters, vol. 46, pp. 402–408, 2018.

[54] Y. Wang, X. Ma, Z. Li, Y. Liu, M. Xu, and Y. Wang, "Profit distribution in collaborative multiple center vehicle routing problem," Journal of Cleaner Production, vol. 144, pp. 203–219, 2017.

[55] S. L. Zhao and Q. H. Zhu, "A risk-averse marketing strategy and its effect on coordination activities in a remanufacturing supply chain under market fluctuation," Journal of Cleaner Production, vol. 171, pp. 1290–1299, 2018.

[56] J. H. Gao, H. S. Han, L. T. Hou, and H. Wang, "Pricing and effort decisions in a closed-loop supply chain under different channel power structures," Journal of Cleaner Production, vol. 112, pp. 2043–2057, 2016.

[57] D. Ghosh and J. Shah, "Supply chain analysis under green sensitive consumer demand and cost sharing contract," International Journal of Production Economics, vol. 164, pp. 319–329, 2015.

[58] J. Xu, Y. Chen, and Q. Bai, "A two-echelon sustainable supply chain coordination under cap-and-trade regulation," Journal of Cleaner Production, vol. 135, pp. 42–56, 2016.

[59] X. P. Hong, L. Xu, P. Du, and Wenjuan Wang, "Joint advertising, pricing and collection decisions in a closed-loop supply chain," International Journal of Production Economics, vol. 167, pp. 12–22, 2015.

[60] L. Xu, C. Wang, and J. Zhao, "Decision and coordination in the dual-channel supply chain considering cap-and-trade regulation," Journal of Cleaner Production, vol. 197, pp. 551–561, 2018.
Author(s) Name(s)

It is very important to confirm the author(s) last and first names in order to be displayed correctly on our website as well as in the indexing databases:

**Author 1**
Given Names: Lang
Last Name: Xu

**Author 2**
Given Names: Jia
Last Name: Shi

**Author 3**
Given Names: Jihong
Last Name: Chen

It is also very important for each author to provide an ORCID (Open Researcher and Contributor ID). ORCID aims to solve the name ambiguity problem in scholarly communications by creating a registry of persistent unique identifiers for individual researchers.

To register an ORCID, please go to the Account Update page (http://mts.hindawi.com/update/) in our Manuscript Tracking System and after you have logged in click on the ORCID link at the top of the page. This link will take you to the ORCID website where you will be able to create an account for yourself. Once you have done so, your new ORCID will be saved in our Manuscript Tracking System automatically.