OPTIMAL RECYCLING PRICE STRATEGY OF CLOTHING ENTERPRISES BASED ON CLOSED-LOOP SUPPLY CHAIN

HUAQING CAO
College of textile science and engineering
Zhejiang Sci-Tech University, Hangzhou 310000, China

XIAOFEN JI*
School of International Education
Zhejiang Sci-Tech University, Hangzhou 310000, China

(Communicated by Stefan Wolfgang Pickl)

ABSTRACT. More and more garment enterprises begin to pay attention to the importance of recycling, take the corresponding recycling strategy to recycle garment products and remanufacture, forming a closed-loop supply chain (CLSC). In reality, recycling is a complex system, the recycling strategy of clothing brands will not only affect the reverse channel of closed-loop supply chain, but also affect the consumer demand of forward channel, and then affect the profit of supply chain. In order to solve this problem, we propose a CLSC composed of a manufacturer, a retailer and a collector, establish three different Stackelberg leadership models, and derive the optimal recycling strategy. Our results show that consumers’ sensitivity to the recycling price will affect the optimal decision of supply chain members. The increase of the recycling market is not always beneficial to the profits of supply chain members. By comparing the profits of the three models, it is found that the retailer leadership model is the most effective scenario of CLCS. The results of this paper provide a reference for garment enterprises to formulate recycling strategies.

1. Introduction. Textile and clothing industry is of great significance to the economy in terms of trade, employment, investment and income all over the world. However, the characteristics of this industry are that on the one hand, the manufacturer has overcapacity, on the other hand, it has caused great losses due to the “abandonment” culture. This shows that it is necessary to recover textiles[1]. Recycling and reuse have become a hot topic in the textile and clothing industry. According to the report of circular fashion: China new textile economic outlook issued by China Textile Industry Federation, under the influence of “fast fashion”, the global clothing utilization rate has decreased by 36% from 2000 to 2015, and more than 50% of fast fashion clothing will be discarded within one year[2]. Although the original textile production has made significant technological progress in environmental protection, low recovery rate and consumer awareness have an impact on the sustainability level of the textile industry[3]. The reuse and recycling of textiles...
can be seen as a way to obtain social and economic benefits and to promote the economic development of a country\cite{4}. Reuse and recycling have generally reduced the impact on the environment, mainly because of the reduction in demand for primary resources. Compared with incineration and landfill, textile reuse and recycling generally reduce the impact on the environment, and reuse is more beneficial than recycling\cite{5}. Recycling textiles, even reuse of textiles, can reduce the production of new textiles from raw materials, thereby reducing the use of water, energy and chemicals in the production chain\cite{6}. By establishing recovery units, some of the waste generated in the textile and textile fields can be transferred to the recovery unit where fibers are recovered\cite{7}. Combining with the view of “slow fashion”, Freudenreich proposed a framework for efficiency-oriented business offering, aiming to reduce the total amount of clothing produced, used and discarded\cite{8}.

On the other hand, clothing reuse is a kind of consumer disposal behavior that has not been fully exploited, but it has an important impact on society. The survey shows that 75\% of consumers think sustainability is extremely important; More than one-third of consumers are willing to choose brands with practices in environmental and social improvement, even if it may not be their preferred brand\cite{2}. From the perspective of customer led logic, clothing reuse is a kind of consumer value creation behavior\cite{9}. The results of another study show that people have moderate interest in various clothing related product service systems, and the highest interest in clothing recycling, exchange and consultation, indicating that there is a certain potential for the development of clothing recycling market\cite{10}. Nowadays, major brands are more and more willing to launch products containing recycled fiber ingredients. Some products made of 100\% recycled materials have appeared in the market, which is undoubtedly a step towards circular economy. Many retailers are involved in recycling programs (including UNIQLO, Adidas, PUMA, etc.), and they are often willing to exchange coupons for returned clothing. Fashion enterprises need to provide more detailed and transparent sustainable fashion production information to stimulate sustainable fashion consumption and consumer purchase decisions. Fashion companies should strive to produce sustainable fashion to enhance their image of social responsibility and attract fashion leaders to buy and wear\cite{11}. Research shows that second hand retail and product recycling plan are the main methods of address post-retail responsibility of fashion companies, and recycling seems to be the most important platform to inform consumers of sustainability and circular economy\cite{12}. If companies that are competitive in price and quality can create social environmental certification for their brands, labels and products (such as organic, recyclable, durable, waste reduction or carbon footprint reduction), Chinese environmentally conscious consumers will be more willing to buy their products, recommend them to their relatives and friends, and show higher satisfaction with the products\cite{13}. It can be seen from the literature and practical experience that the recycling strategy of supply chain will have an impact on consumers’ purchasing behavior. Based on this, this paper establishes a closed-loop supply chain composed of the manufacturer, retailer and collector. The manufacturer is responsible for manufacturing new products and remanufacturing with recycled materials, the retailer is responsible for selling products, and the collector recycles products in reverse channel. This paper attempts to study the following three questions:

(1) What is the optimal decision of closed-loop supply chain members under the
three channel leaders when considering the impact of the recycling price on demand and recycling quantity?

(2) What is the impact of different channel leaders on the optimal decision?
(3) What is the impact of different market parameters, such as consumer sensitivity to retail price and the recycling price, on the optimal decision of supply chain?

The rest of this paper is arranged as follows. The second section is literature review. The third section establishes a basic profit model of closed-loop supply chain. The fourth section analyzes three kinds of CLCS optimal decisions under Stackelberg leadership. The fifth section compares the optimal decisions under the three modes, analyzes the influence of different market parameters on the optimal decisions. The sixth section presents the results, discusses the significance of the research and puts forward the future research direction.

2. Literature review. This section deals with the relevant literature considering two different streams of research: closed-loop supply chain and Stackelberg leaders.

2.1. Closed-loop supply chain. The manufacturer produces clothing products, sells them to consumers through retailers, and then returns to the manufacturers through recycling channels, forming a closed-loop supply chain. Many scholars have done research on closed-loop supply chain. As an early scholar of CLSC, Savaskan compared three CLSC recycling modes: Manufacturer recycling, retailer recycling and third-party recycling. They found that when members of the supply chain are closer to consumers, it is the most effective undertaking of product collection activity. In addition, they designed a coordination mechanism to make the CLSC profit of decentralized decision-making the same as that of centralized decision-making[14]. Furthermore, Savaskan studies two competing retailer recycling channels in CLSC[15]. The uncertainty of procurement, processing and market in closed-loop supply chain greatly increases the complexity of remanufacturing and reduces the process efficiency. Peng analyzed the causes of uncertainty in different stages, and determined appropriate methods to quantify the impact of uncertainty on the production process, so as to ensure the sustainable development of closed-loop supply chain and clean production[16]. Mukhopadhyay uses modularity in product design to solve the return policy based on build to order product, establishes a profit maximization model, and obtains the optimal strategy of recovery rate and modularity level under certain market reaction parameters[17]. Liu constructs an analysis model with uncertainty of demand and income, and studies the optimal strategy of three-dimensional decision-making with pricing, consumer return rate and modularization level under the mean square error formula[18]. Choi’s research is divided into two cases: risk neutral and risk averse mass customization companies. By comparing the two cases, they reveal the impact of the risk aversion level of service providers on the optimal return service charge policy. Finally, the optimal condition of zero return service charge (free return, full refund) is obtained. These conditions provide free return service for some fashion companies in real life, but not for every customer[19]. Chen studied a three-level closed-loop supply chain composed of a manufacturer, a retailer and a third-party logistics supplier, led by a retailer. The results show that whether it is forward logistics or reverse logistics, the higher the manufacturer’s share in logistics cost, the lower the profit of each member[20]. Wang draws on variational inequalities to model the closed-loop
supply chain network. Research find that it is necessary to regulate a medium collection rate and a certain minimum recovery rate. The impact of collection rate and recovery rate on manufacturers are greater than that on retailers. Consumers can benefit from the increase of the recovery rate as well as the collection rate[21]. Chen extended the closed-loop supply chain to a newsvendor model, which simply includes supply uncertainty and external government influence. It is found that the return uncertain lower both the manufacturers’ profits and retail price, where as its effects on the governments optimal subsequences and the manufacturers optimal return effects are indicative[22]. Another study considers how the growth factor of consumer returns affects order quantity, profit and supply chain coordination. By modeling and analyzing the wholesale price contract and buy back contract between manufacturer and retailer with random demand and external given retail price, two decision strategies are compared. One is to consider the consumer return when calculating the decision variables of manufacturer and retailer, the other is to ignore the consumer return in the optimization model[23].

2.2. Stackelberg leader. With large retailers such as Nike, UNIQLO and SHEIN becoming channel leaders, the structure of closed-loop supply chain is no longer a single manufacturer. Choi studies a supply chain composed of retailers, collectors and manufacturers, and investigates the supply chain performance under different channel leadership. Through systematic comparison, the author finds that the retailer led model provides the most effective customer satisfaction. In addition, the author finds that the efficiency of remanufacturing system is closely related to the proximity of supply chain agents to the market. Finally, it is concluded that the mode dominated by recyclers is not the most effective mode for collecting products[24]. Edirisinghe studies the influence of channel power on the stability of supply chain when multiple suppliers sell substitutable products through the same retailer. It is found that neither manufacturer leader nor retailer leader is a stable supply chain structure, but the structure of equally distributing power among agents provides the best stability and performance[25]. Wang studied the responsibility sharing between manufacturers and recyclers in the recycling process of waste electronic and electrical appliances, and found that from the collection rate improvement perspective, the collector led is a better channel structure of CLSC compared with centralized and manufacturer led channel structure[26]. Gao established a CLSC centralized and decentralized game model of one manufacturer and one retailer, to investigate optimal decisions of collection effort, sales effort and pricing under different channel power structures, they found that the best power structure for a CLSC varieties with the market demand, as influenced by the collection effort[27]. Ranjbar takes a TV manufacturer as an example to study a three-tier closed-loop supply chain composed of manufacturer, retailer and third-party collector. The main purpose is to evaluate the optimal pricing and collection decision under two competitive recycling channels (including retailer collection and third-party collection). The test results from two aspects of environment and consumer welfare show that the decentralized model of retailer leadership is often the most effective scenario in the closed-loop supply chain. Considering the overall benefits of the supply chain between the decentralized models, the retailer leadership model is the best and closest model to the centralized model[28]. Wu studied a CLSC composed of a single manufacturer and a single retailer. They have three recycling channels: manufacturer, retailer and the third party. They studied CLSC performance under different channel leadership and recycling channel combinations.
The results show that M channel is the most effective recycling channel, and the retailer-led structure is as good as manufacture-led structure[29]. Zheng established the centralized, manufacturer-led, and retailer-led CLSC models, and analyze the equilibrium solutions of channel members and the government. Results show that the manufacturer exists the market earlier in the retailer-led model with regulation compared with the manufacturer-led model. The government’s optimal collection target is the same under manufacturer-led and retailer-led models when the regulation comes into force[30].

2.3. Research gaps. However, these studies did not consider the impact of recycling strategy on consumer demand and recycling quantity, because most of the previous studies were from the perspective of consumer returns, and did not consider the recycling strategy of supply chain from the perspective of active recycling. In the clothing closed-loop supply chain, the recycling price not only affects the recycling quantity, but also affects the demand and the profits of the members of the supply chain because of the stimulation of the recycling price on the purchase intention of consumers. On the other hand, most of these studies take the manufacturer as the Stackelberg leader, without considering the situation of the retailer and the collector as the leader. The innovation of this paper is to consider the impact of the recycling price on consumer demand and recycling quantity. When consumers see the recycling advertisement of the retailer, their purchase intention will increase. The higher the recycling price, the higher the possibility of consumers to buy clothing products. Therefore, how to determine the optimal recycling strategy in a complex closed-loop supply chain is the goal of this paper.

3. Problem description and assumptions.

3.1. Problem description. As shown in Figure 1, we consider a closed-loop supply chain composed of four members: a manufacturer, a retailer, a collector and consumer. In the forward channel, the manufacturer produces clothing products and sells them to the retailer at the wholesale price. The retailer sells clothing products to the consumer at the retail price. In the reverse channel, the collector is responsible for recycling products and transferring them to the manufacturer, and the manufacturer pays the collector a certain transfer fee. Based on Stackelberg game theory, this paper establishes three CLSC models of different channel leaders, including manufacturer leader (M-led), retailer leader (R-led) and collector leader (C-led). Different leaders have different decision-making order in CLSC.

Figure 1. Different power structures of CLSC
3.2. **Assumptions.** In this paper, we make the following assumptions:

**Assumption 1.** It should be noted that in reality, demand may be stochastic. According to the literature on remanufacturing related topics in production economics and operation management [14, 24, 28], because our model composed of a manufacturer, a retailer and a collector, and the optimality of the strategy depends on the convexity of the demand function. In order to facilitate analysis, we must use this deterministic and linear requirement in the model, otherwise we will not have any closed form solution. Therefore, the demand function can be written as:

\[ D(p) = \varphi - \beta p + \varepsilon b \]

The recycling quantity function can be written as:

\[ R(b, e) = a + lb \]

The meanings of all symbols are given in Table 1.

**Assumption 2.** We assume that \( c_m > c_r \), ensure that the cost of remanufacturing a recycled product is less than the cost of manufacturing a new one, and the quality of remanufactured products is the same as that of new products and they are sold in the same market at the same price. Note that \( p > w > c_m > c_r \).

**Assumption 3.** We consider a closed-loop supply chain with a single manufacturer, a single retailer and a single collector in the market, and the CLSC decision is considered in a single cycle. Each agent is an independent decision-maker, and each of them intends to maximize their profits.

| Table 1. Symbols and definitions |
|----------------------------------|
| Model parameters                |
| \( \varphi \) & Basic demand, and \( \varphi > 0 \) |
| \( \beta \) & The sensitivity coefficient of demand to the retail price, and \( \beta > 0 \) |
| \( \varepsilon \) & The sensitivity coefficient of demand to the recycling price, and \( \varepsilon > 0 \) |
| \( a \) & Basic recycling quantity, and \( a > 0 \) |
| \( l \) & The sensitivity coefficient of recycling quantity to the recycling price, and \( l > 0 \) |
| \( c_m \) & The cost of a new product produced by the manufacturer |
| \( c_r \) & The cost of remanufacturing a new product using recycled products |
| \( \Delta \) & \( \Delta = c_m - c_r \), represents the cost saved per unit product during remanufacturing |
| \( \Pi \) & Profit function symbol, and \( \Pi^{M}_{\Pi} \) represents the retailer’s profit under the manufacturer’s leadership mode |
| \( w \) & The wholesale price given by the manufacturer to the retailer |
| \( p \) & The retailer’s retail price |
| \( b \) & The recycling price provided by the collector to the consumer |
| \( A \) & The transfer price of a single product provided by the manufacturer to the collector |

4. **Model analysis.** In this section, we study the optimal wholesale price, retail price, recycling price and transfer price in the closed-loop supply chain under three kinds of Stackelberg game: Manufacturer leader, retailer leader and collector leader.
4.1. The manufacturer as Stackelberg leader. A large number of scholars have studied the supply chain of the manufacturer as Stackelberg leader, their production decisions directly affect the strategy of downstream members. In this model, the manufacturer is Stackelberg leader, the retailer and the collector are followers. Here we use L represent leader and F represent follower and their profits can be expressed as follows:

\[ \begin{align*}
L : \quad & \text{Max } \Pi_M^L = (w_M - c_m)(\varphi - \beta p_M + \varepsilon b_M) + (\Delta - A_M)(a + lb_M) \\
F : \quad & \text{Max } \Pi_R^F = (p_M - w_M)(\varphi - \beta p_M + \varepsilon b_M) \\
F : \quad & \text{Max } \Pi_C^F = (A_M - b_M)(a + lb_M)
\end{align*} \]

In order to ensure that the manufacturer’s profit function is concave and has a unique maximum, we have lemma 4.1. 

**Lemma 4.1.** When \(16\beta - \varepsilon^2 > 0\), the manufacturer’s profit function is concave and has a unique maximum.

**Proof.** All the proofs in this section are given in Appendix. \(\square\)

We use reverse induction to obtain the equilibrium decision of each CLSC member. First, the retailer decides the retail price \(p\) and the collector decides the recycling price \(b\). Then, the manufacturer decides the wholesale price \(w\) and the transfer price \(A\).

**Proposition 1.** By solving the first partial derivatives of \(\Pi_M^L\), \(\Pi_R^F\) and \(\Pi_C^F\), we can get the optimal strategy of the CLSC under the manufacturer leadership mode:

\[ \begin{align*}
b^*_M &= \frac{\varphi \varepsilon - \beta \varepsilon c_m + 4l\beta \Delta - 12l\beta a}{16l\beta - \varepsilon^2} \\
p^*_M &= \frac{12l\varphi - c_m \varepsilon^2 + 3l\varepsilon \Delta - 9a \varepsilon + 4l\beta c_m}{16l\beta - \varepsilon^2} \\
w^*_M &= \frac{8l\varphi - c_m \varepsilon^2 + 2l\varepsilon \Delta - 6a \varepsilon + 8l\beta c_m}{16l\beta - \varepsilon^2} \\
A^*_M &= \frac{2l\varphi \varepsilon - 2l\beta \varepsilon c_m + 8l^2 \beta \Delta - 8l\beta a - a \varepsilon^2}{16l^2 \beta - l^2 \varepsilon^2}
\end{align*} \]

**Proposition 2.** Bringing \(b^*_M, p^*_M, w^*_M\) and \(A^*_M\) into (1), (2), (3), we can get that in M-led model the profits of the manufacturer, retailer and collector are respectively:

\[ \begin{align*}
\Pi_M^L &= \frac{2a^2 \beta l + a^2 \varepsilon^2 + 3a\beta c_m \varepsilon l + 4a\beta \Delta l^2 - a\Delta \varepsilon l - 3a\varepsilon l \varphi + 2\beta^2 c_m \varepsilon l^2 - \beta c_m \varepsilon l^2 + 2\beta^3 \Delta^2 + \beta c_m c_r \varepsilon l^2 - 4\beta c_m l^2 \varphi + \Delta \varepsilon l^2 \varphi + 2l^2 \varphi^2}{l(16l\beta - \varepsilon^2)} \\
\Pi_R^F &= \frac{\beta(3a \varepsilon - 4l \varphi + 43c_m l - \varepsilon l \Delta)^2}{(16l\beta - \varepsilon^2)^2} \\
\Pi_C^F &= \frac{(a \varepsilon^2 - 4a\beta l - \varepsilon l \varphi - 4\beta^2 \Delta + \beta c_m \varepsilon l)^2}{l(16l\beta - \varepsilon^2)^2}
\end{align*} \]
4.2. The retailer as Stackelberg leader. Nowadays, more and more retailers have become leaders in the fashion supply chain, such as SHEIN in China and UNIQLO in Japan. They often assign a large number of orders to various manufacturers, and have a dominant position in the supply chain. The wholesale price of the manufacturer is also affected by the retail price. They can lead the supply chain to maintain their margins while limiting the profits of their manufacturers. In the retailer leadership model, the retailer is the Stackelberg leader, and the manufacturer and the collector are the followers:

\[ L : \max_{p_R} \Pi_R = (p_R - w_R)(\varphi - \beta p_R + \varepsilon b_R) \quad (11) \]

\[ F : \max_{(w_R, A_R)} \Pi_M^R = (w_R - c_m)(\varphi - \beta p_R + \varepsilon b_R) + (\Delta - A_R)(a + l b_R) \quad (12) \]

\[ F : \max_{(b_R)} \Pi_C^R = (A_R - b_R)(a + l b_R) \quad (13) \]

We use reverse induction to obtain the equilibrium decision of each CLSC member. First, the collector decides the recycling price \( b \), then the manufacturer decides the wholesale price \( w \) and the transfer price \( A \), and finally the retailer decides the retail price \( p \). Here, we need to note that the decision of the collector does not include any \( w \), so the profit of the manufacturer can increase with the increase of the wholesale price. Because \( p > w \), the wholesale price \( w \) cannot equal the retail price \( p \). In this case, if the manufacturer maximizes its profit function, then \( p = w \), the retailer’s profit is zero. Therefore, we use the same method as previous studies[28, 31, 32, 33, 34], assuming that the manufacturer’s unit marginal profit is equal to the retailer’s unit marginal profit, that is, \( w = (c_m + p)/2 \).

**Proposition 3.** By solving the first partial derivatives of \( \Pi_M^R \), \( \Pi_R^R \) and \( \Pi_C^R \), we can get the optimal strategy of the CLSC under the retailer leadership mode:

\[ b_R^* = \frac{4l \varphi - 4l \beta c_m l - 1 \Delta \varepsilon^2 + 3 \alpha \varepsilon^2 - 48l \beta a + 16l^2 \beta \Delta}{(8l \beta - \varepsilon^2) 8l} \quad (14) \]

\[ A_R^* = \frac{4l \varphi - 4l \beta c_m l - 1 \Delta \varepsilon^2 - 3 \alpha \varepsilon^2 - 16l \beta a + 16l^2 \beta \Delta}{(8l \beta - \varepsilon^2) 4l} \quad (15) \]

\[ w_R^* = \frac{4l \varphi - 2c_m \varepsilon^2 + \varepsilon \Delta - 3 \alpha \varepsilon + 12l \beta c_m}{16l \beta - 2 \varepsilon^2} \quad (16) \]

\[ p_R^* = \frac{4l \varphi - c_m \varepsilon^2 + \varepsilon \Delta - 3 \alpha \varepsilon + 4l \beta c_m}{8l \beta - \varepsilon^2} \quad (17) \]

**Proposition 4.** By solving the first partial derivatives of \( \Pi_M^R \), \( \Pi_R^R \) and \( \Pi_C^R \), we can get that in R-led model the profits of the manufacturer, retailer and collector are respectively:

\[ \Pi_M^R = \frac{(3a \varepsilon - 4l \varphi + 4l \beta c_m l - \varepsilon l \Delta)^2 - 16l(8l \beta - \varepsilon^2)}{(a \varepsilon^2 + 16a \beta l - 4a \varepsilon l + 16l^2 \Delta - 3l^2 \Delta + 4l \beta c_m l)(5a \varepsilon^2 - 16a \beta l - 4a \varepsilon l - 16l^2 \Delta + \varepsilon^2 l \Delta + 4l \beta c_m l)^2}{32l(8l \beta - \varepsilon^2)^2} \quad (18) \]

\[ \Pi_R^R = \frac{(3a \varepsilon - 4l \varphi + 4l \beta c_m l - \varepsilon l \Delta)^2}{16l(8l \beta - \varepsilon^2)} \quad (19) \]

\[ \Pi_C^R = \frac{(5a \varepsilon^2 - 16a \beta l - 4a \varepsilon l - 16l^2 \Delta + \varepsilon^2 l \Delta + 4l \beta c_m l)^2}{64l(8l \beta - \varepsilon^2)^2} \quad (20) \]
4.3. The collector as Stackelberg leader. Nowadays, in other industries such as metals (Sims Metal Management) and electronic products (IBM’s Global Asset Recovery Services), collectors can be channel leaders. With the development of textile recycling, we believe that textile recycling will be popular, and there will be large textile collectors in the future. In this model, the collector is Stackelberg leader, and the manufacturer and the retailer are followers:

\[ L : \max_{(bC)} \Pi_C^L = (A_C - bC)(a + lbC) \]  

\[ F : \max_{(wC, A_C)} \Pi_M^C = (wC - c_m)(\varphi - \beta p_C + \varepsilon bC) + (\Delta - A_C)(a + lbC) \]  

\[ F : \max_{(pc)} \Pi_R^C = (pC - wC)(\varphi - \beta p_C + \varepsilon bC) \]

We use reverse induction to obtain the equilibrium decision of each CLSC member. First, the retailer decides the retail price \( p \), then the manufacturer decides the wholesale price \( w \) and the transfer price \( A \), and finally the collector decides the recycling price \( b \). Here, we need to note that the retailer’s decision does not include any \( A \), so the manufacturer’s profit can increase with the decrease of the transfer price \( A \). Because \( A < b \), the transfer price \( A \) cannot be equal to the recycling price \( b \). In this case, if the manufacturer maximizes its profit function, then \( A = b \), resulting in zero profit for the collector. Therefore, we adopt the same method as in 4.2, assuming that the unit marginal profit of the manufacturer in the reverse channel is equal to the unit marginal profit of the collector, that is, \( A = (\Delta + b)/2 \).

**Proposition 5.** By solving the first partial derivatives of \( \Pi_M^C \), \( \Pi_R^C \) and \( \Pi_C^C \), we can get the optimal strategy of the CLSC under the collector leadership mode:

\[ p_C^* = \frac{6l\varphi + 3l\varepsilon\Delta - 3a\varepsilon + 2l\beta c_m}{8l\beta} \]  

\[ A_C^* = \frac{3l\Delta - a}{4l} \]  

\[ w_C^* = \frac{2l\varphi + l\varepsilon\Delta - a\varepsilon + 2l\beta c_m}{4l\beta} \]  

\[ b_C^* = \frac{l\Delta - a}{2l} \]

**Proposition 6.** Bringing \( b_C^*, p_C^*, w_C^* \) and \( A_C^* \) into (21), (22), (23), we can get that in C-led model the profits of the manufacturer, retailer and collector are respectively:

\[ \Pi_M^C = \frac{4l(a + l\Delta)^2 + (a\varepsilon - 2l\varphi + 2l\beta c_m l - \varepsilon l\Delta)\varepsilon}{32l\beta^2} \]  

\[ \Pi_R^C = \frac{(a\varepsilon - 2l\varphi + 2l\beta c_m l - \varepsilon l\Delta)^2}{64l\beta^2} \]  

\[ \Pi_C^C = \frac{(a + l\Delta)^2}{8l} \]
5. Model comparison and sensitivity analysis. In this section, in order to compare the results of different models and illustrate the sensitivity of CLSC members’ optimal decisions to different market parameters, we use numerical analysis to simulate the results of the previous section. Data is collected through interviews with relevant experts and studying existing data of a garment enterprise in Hangzhou. The market parameters are as follows:

\[ \varphi = 1000; \beta = 5; \varepsilon = 5; a = 10; l = 10; c_m = 100; c_r = 50. \]

5.1. Comparison among M-led, R-led and C-led models. In section 4, we analyze the optimal decision of CLCS under three leadership models and the profits of each supply chain member. Further, in this section, using the results of numerical analysis, we will compare CLCS decisions and profits under different supply chain leadership structures and different game scenarios.

**Corollary 1.** (a) The optimal wholesale prices \( w \) under M-led, R-led and C-led models satisfy the following relationship: \( w_C > w_M > w_R \). (b) The optimal retail prices \( p \) under M-led, R-led and C-led models satisfy the following relationship: \( p_C > p_M > p_R \).

Obviously, the wholesale price is smallest in R-led model, because the retailer has a strong incentive to minimize the wholesale price. Interestingly, the optimal wholesale price in C-led model is larger than that in M-led model. This is because when the collector becomes channel leader, there is a “repeated double marginal effect”, that is, between the collector and the manufacturer, the manufacturer and the retailer, which makes the wholesale price and retail price double increase. The wholesale price has a direct impact on the retail price. In C-led model, the wholesale price is largest, so the retail price is also largest.

**Corollary 2.** The optimal recycling prices \( b \) under M-led, R-led and C-led models satisfy the following relationship: \( b_C > b_R > b_M \).

The recycling price is largest when the collector is the channel leader, because the collector has enough motivation to increase the recycle quantity by increasing the recycling price to increase profit. However, in proposal 5.4, we will see that this approach is not always beneficial to the collector. The recycling price is smallest in M-led model.

**Corollary 3.** Let \( 16l\beta(\Delta + a) - 4\varepsilon^2(l\Delta - a) = A \), \( 16l\beta(\Delta + a) - \varepsilon^2(3l\Delta - 5a) = B \). The optimal transfer prices \( A \) under M-led, R-led and C-led models satisfy the following relationships: when \( 8\varepsilon(\varphi - \beta c_m) < A, A_M < A_R < A_C \); when \( 8\varepsilon(\varphi - \beta c_m) > B, A_C < A_M < A_R \); when \( A < 8\varepsilon(\varphi - \beta c_m) < B, A_M < A_C < A_R \).

If the manufacturer assigns a larger transfer price, the collector will collect more products, but at the same time, the manufacturer’s remanufacturing cost will also increase. Therefore, the manufacturer faces tradeoff of the transfer price. Under different leadership models, the transfer price changes with the change of market parameters. When the purchase demand is strong and the recycling demand is weak, that is, \( \varphi \) and \( \varepsilon \) decrease and \( \beta, a \) and \( l \) increase, the transfer price of C-led model is the largest. When the recycling demand is strong and the purchase demand is weak, the transfer price of R-led model is largest.

**Corollary 4.** The profits of manufacturer, retailer and collector in M-led, R-led and C-led models satisfy the following relationships: (a) \( \Pi_{CM}^R < \Pi_{CM}^M < \Pi_{CM}^C \); (b)
Let \((1 + \sqrt{2})16l\beta(l\Delta + a) = C\), \((1 + \sqrt{2})16l\beta(l\Delta + a) - \varepsilon^2[\sqrt{2}l\Delta - (4 + \sqrt{2})a] = D\), the profits of the collector satisfy the following relationships: when \(4l\varepsilon(\beta c_m - \varphi) < C\), \(\Pi_M^C < \Pi_R^C < \Pi_C^C\); when \(4l\varepsilon(\varphi - \beta c_m) > D\), \(\Pi_C^C < \Pi_M^C < \Pi_R^C\); when \(C < 8l\varepsilon(\varphi - \beta c_m) < D\), \(\Pi_M^C < \Pi_C^C < \Pi_R^C\).

Interestingly, the manufacturer’s profit is largest in C-led model. This is because the recycling price is largest in C-led model, so the sales quantity and recycling quantity are also the largest. Obviously, the retailer’s profit is largest under R-led model. The collector’s profit varies with market parameters. Similar to the transfer price, when the purchase demand is strong and the recycling demand is weak, that is, \(\varphi\) and \(\varepsilon\) decrease and \(\beta\), \(a\) and \(l\) increase, the collector has the largest profit in C-led model. On the contrary, if the recycling demand is strong and the purchase demand is weak, the collector’s profit is largest in M-led model.

5.2. **Sensitivity analysis.** In this section, we analyze the changes of optimal decision and profit with market size \(\varphi\), demand sensitivity to retail price \(\beta\), demand sensitivity to recycling price \(\varepsilon\), basic recycling quantity \(a\) and recycling quantity sensitivity to recycling price \(l\) under the three models.

5.2.1 The influence of market size on optimal decision. As shown in Figure 2, the horizontal axis is the market size \(\varphi\), ranging from 800 to 1000, and the vertical axis is the wholesale price \(w\), retail price \(p\), recycling price \(b\), transfer price \(A\), manufacturer’s profit, retailer’s profit, collector’s profit and total supply chain profit, respectively. When the market size increases, due to the high purchase intention of consumers, the supply chain does not need to reduce the retail price to increase the sales, on the contrary, it can increase its profit by increasing the retail price. In M-led model and R-led model, \(w\), \(p\), \(b\), \(A\) will increase. The profits of manufacturer and retailer also increase with the increase of market size. In C-led model, \(w\) and \(p\) increase, but the basic sales have no effect on \(b\) and \(A\) in reverse channel. Therefore, in C-led model, retailer’s profit is not affected.

5.2.2 The influence of demand sensitivity to retail price on the optimal decision. As shown in Figure 3, the horizontal axis is demand sensitivity to retail price, ranging from 5 to 8, and the vertical axis is the wholesale price \(w\), retail price \(p\), recycling price \(b\), transfer price \(A\), manufacturer’s profit, retailer’s profit, collector’s profit and total supply chain profit, respectively. When the demand sensitivity to
retail price increases, the supply chain has to reduce the retail price to increase the sales quantity. In this case, $w$ and $p$ in M-led model and R-led model will decrease. Due to the transmission of supply chain cost, $A$ and $b$ in reverse channel will also decrease. The profits of manufacturer and retailer also decrease with the increase of $\beta$. In C-led model, $w$ and $p$ decrease. However, because the collector is leader, $\beta$ has no effect on $b$ and $A$ in reverse channel. Therefore, the profit of collector in C-led model is not affected.

Figure 3. The influence of the demand sensitivity to retail price on optimal decision.

5.2.3 The influence of demand sensitivity to recycling price on the optimal decision. As shown in Figure 4, the horizontal axis is the demand sensitivity to recycling price, ranging from 2 to 5, and the vertical axis is the wholesale price $w$, retail price $p$, recycling price $b$, transfer price $A$, manufacturer’s profit, retailer’s profit, collector’s profit and total supply chain profit, respectively. When the demand sensitivity to recycling price increases, the higher the recycling price is, although the recycling cost increases, the increase of sales quantity can make the supply chain gain more profits. Therefore, $w$, $p$, $b$ and $A$ will increase in M-led model and R-led model. The profits of manufacturer and retailer also increase with the increase of $\varepsilon$. In C-led model, $w$ and $p$ increase as well. However, because the collector is leader, the impact of demand sensitivity to recycling price on the supply chain at the purchase stage cannot be transferred to the recycling price and transfer price in the reverse channel. Therefore, the profit of collector in C-led model is not affected.

5.2.4 The influence of basic recycling quantity on optimal decision. As shown in Figure 5, the horizontal axis is the basic recycling quantity, ranging from 10 to 50, and the vertical axis is the wholesale price $w$, retail price $p$, recycling price $b$, transfer price $A$, manufacturer’s profit, retailer’s profit, collector’s profit and total supply chain profit, respectively. When the basic recycling quantity increases, the manufacturer will reduce the transfer price to increase the recycling profit, and the collector’s recycling price will be reduced accordingly. As the demand is affected by the recycling price, $p$ and $w$ also decrease. Therefore, the profits of manufacturer and retailer are reduced. Benefiting from the increase of basic recycling quantity, the collector’s profit increases.

5.2.5 The influence of the recycling quantity sensitivity to recycling price on the optimal decision. As shown in Figure 6, the horizontal axis is the recycling quantity sensitivity to recycling price, ranging from 5 to 8, and the vertical axis is the
In M-led model and R-led model, similar to the change of $a$, all decisions decrease with the increase of $l$. Benefiting from the significant increase of recycling quantity, the profits of the manufacturer and collector increase with the increase of $l$, while the retailer do not participate in recycling activities, and the profit decrease with the increase of $l$. In C-led model, the situation is different. The collector become channel leader and makes decisions first. When $l$ increases, the recycling quantity is more significantly affected by the recycling price. If the recycling price increases slightly, the unit recycle profit decreases slightly, but the recycling quantity increase significantly, and the collector’s total profit increases. The decisions of all members in C-led model are affected by $b$, so $A$, $p$ and $w$ increase, and the profits of supply chain members increase with $l$. By comparing figure 6, we can find the impact of $l$ on $w$ and $p$ is not significant, while in the reverse channel, the impact of $l$ on $b$ and $A$ is significant.

6. **Conclusions.** This paper discusses the optimal strategy of different members in the closed-loop supply chain when the recycling price affects the consumer demand under three leader models. Closed-loop supply chain is a complex system,
each parameter will affect the optimal strategy. Based on Stackelberg game theory, we discuss the optimal strategy of three different models: Manufacturer leadership, retailer leadership and collector leadership. For each case, we derive the optimal wholesale price, retail price, recycling price and transfer price by using the reverse induction method. Furthermore, through numerical analysis, we compare the optimal strategies of the three models and study sensitivity analysis on the optimal strategy, and explain the influence of different parameters on the strategy. In terms of consumer value, environmental impact and profit, our main findings are as follows:

- In the purchase stage, the larger the sensitivity of consumer demand to the recycling price, the larger the sales volume, and the larger the profits of the manufacturer and retailer. This shows the importance of the retailer developing recycling advertising and improving consumers’ awareness of environmental protection. Although the retailer do not participate in recycling activities, they can still benefit from it;

- In the recycling stage, when the recycling market increases, it is not always beneficial to the manufacturer and retailer. When the basic recycling quantity increases, the collector will reduce the recycling price to increase the unit recycle profit, which leads to the reduction of market demand in the positive channel. In this case, the retailer should make consumers understand the recycling strategy through advertising, improve the sensitivity of consumer demand to recycling price, and increase sales, otherwise the profits of the retailer will decrease with the increase of recycling market;

- When the retailer becomes leader, supply chain efficiency is higher and members can get larger profits. This is an interesting finding. Most of the literature assumes that the manufacturer are the leader, which seems natural because the manufacturer are involved in manufacturing and remanufacturing at the same time. However, as an upstream member of the supply chain, the manufacturer often can not consider the information of consumers when making decisions, which may be the reason for the higher efficiency of the supply chain under the retailer leadership model;

- Although the recycling price is the highest when the collector is the leader, the retail price is also the highest. When the retailer is the channel leader,
the difference between the retail price and the recycling price is the smallest, and consumers can get the greatest welfare. This is because the retailer is the member of the supply chain closest to consumers. This result is similar to previous studies [24, 28].

Although this paper obtains the optimal strategy under different channel leadership models, there are still many problems worth exploring in the future. First of all, future research can explore the change of forward and reverse channel supply chain when there are multiple retailers competing. Secondly, when the retailer or the manufacturer also participate in recycling activities, how does the optimal strategy of supply chain change. Finally, it can study the performance of consumers of different clothing brands (such as luxury and fast fashion) in recycling, so as to help the clothing supply chain to make better recycling strategy.

Acknowledgment. This research is supported by Zhejiang Soft Science Foundation Project Grant No. 2020C35038.

Appendix.

Proof of Lemma 4.1. The second-order Hessian matrix of manufacturer’s profit function with respect to wholesale price w and transfer price A is:

$$H = \begin{bmatrix}
\frac{\partial^2 \Pi^M}{\partial w^2} & \frac{\partial^2 \Pi^M}{\partial w \partial A} \\
\frac{\partial^2 \Pi^M}{\partial A \partial w} & \frac{\partial^2 \Pi^M}{\partial A^2}
\end{bmatrix} = \begin{bmatrix}
-\beta & \frac{\varepsilon}{4} \\
\frac{\varepsilon}{4} & -l
\end{bmatrix}
$$

In order to guarantee the existence of the optimal solution, $H$ must be negative, so we have $16\beta - \varepsilon^2 > 0$.

Proof of Proposition 1. The profit function of the collector is: $\Pi_C^M = (A_M - b_M)(a + lb_M)$. By solving the first derivative $\frac{\partial \Pi_C^M}{\partial b_M} = 0$, we can get $b_M = \frac{A_M - a}{2l}$. Introducing $b_M$ into the retailer’s profit function, we can get $\Pi_R^M = (p_m - w_m)(\varphi - \beta p_m + \varepsilon \frac{A_M - a}{2l})$. By solving the first derivative $\frac{\partial \Pi_R^M}{\partial p_m} = 0$, we can get $p_m = \frac{2\varphi + (A_M - a) + 2l\beta w_m}{4l\beta + \varepsilon a}$.

Introducing $b_M$ and $p_m$ into the manufacturer’s profit function, we can get $\Pi_M^M = (w_m - c_m)(\varphi - \frac{2\varphi + (A_M - a) + 2l\beta w_m}{4l\beta + \varepsilon a} + \varepsilon \frac{A_M - a}{2l}) + (\Delta - A_M)(a + \frac{A_M - a}{2l})$. By solving the partial derivative $\frac{\partial \Pi_M^M}{\partial b_M} = 0$ and $\frac{\partial \Pi_M^M}{\partial A_M} = 0$, we can get $w_M^\ast = \frac{8l(\varphi - c_m)\varepsilon^2 + 8\varphi \Delta - 9\alpha \varepsilon + 4l\beta c_m}{16l\beta - \varepsilon^2}$, $A_M^\ast = \frac{2\varphi - 2l(\varphi - c_m)\varepsilon^2 + 8\varphi \Delta - 9\alpha \varepsilon + 4l\beta c_m}{16l\beta - \varepsilon^2}$. By introducing $w_M^\ast$ and $A_M^\ast$ into $p_M$ and $b_M$, we can get $p_M^\ast = \frac{12l(\varphi - c_m)\varepsilon^2 + 3l\Delta - 9\alpha \varepsilon + 4l\beta c_m}{16l\beta - \varepsilon^2}$, $b_M^\ast = \frac{\varphi - \beta c_m + 3l\Delta - 9\alpha \varepsilon + 4l\beta c_m}{16l\beta - \varepsilon^2}$.

Proof of Proposition 3. The profit function of the collector is: $\Pi_C^R = (A_R - b_R)(a + lb_R)$. By solving the first derivative $\frac{\partial \Pi_C^R}{\partial b_R} = 0$, we can get $b_R = \frac{A_R - a}{2l}$. Introducing $b_R$ into the manufacturer’s profit function, we can get $\Pi_M^R = (w_R - c_m)\varphi - \beta p_R + \varepsilon \frac{A_R - a}{2l} + (\Delta - A_R)(a + \frac{A_R - a}{2l})$. Here because $b_R$ does not include any $w$, we use the same method as [28, 31-34], let $w_R = \frac{c_m + p_R}{2l}$. By solving the partial derivative $\frac{\partial \Pi_M^R}{\partial A_R} = 0$, we can get $A_R = \frac{(p_m - c_m)\varphi - 2a + 2l\Delta}{4l}$. Introducing $A_R$ into $b_R$, we can get $b_R = \frac{\varepsilon(p_m - c_m)\varphi - 2l\Delta - 6a}{8l}$. Introducing $w_R$ and $b_R$ into the retailer’s profit function, we can get $\Pi_R^R = (p_m - c_m)(\varphi - \beta p_R + \varepsilon \frac{(p_m - c_m)\varphi - 2l\Delta - 6a}{8l})$. By solving the first derivative $\frac{\partial \Pi_R^R}{\partial p_R} = 0$, we can get $p_R^\ast = \frac{4l(\varphi - c_m)\varepsilon^2 + 3l\Delta - 9\alpha \varepsilon + 4l\beta c_m}{8l\beta - \varepsilon^2}$. By introducing $p_R^\ast$
into \( b_R \), \( A_R \) and \( w_R \), we can get \( b^*_R = \frac{4f_1e_1 - 4f_2e_2 + e_2c_m - l\Delta^2 - 3ae^2 - 48b_1a + 16b^2_1\Delta}{(8b_1 - c_m)^2} \), \( A^*_R = \frac{2(e_1^2 - 2c_m^2 + 3e_1 + 12b_1c_m)}{16b_1 - 2e^2} \), \( w^*_R = \frac{4f_1 + e_1c_m - l\Delta^2 - 3ae_2 - 48b_1a + 16b^2_1\Delta}{(8b_1 - c_m)^2} \).

**Proof of Proposition 5.** The profit function of the retailer is: \( \Pi^C_R = (p_C - w_C)(\varphi - \beta p_C + e b_C) \). By solving the first derivative \( \frac{\partial \Pi^C_R}{\partial p_C} = 0 \), we can get \( p_C = \frac{\varphi + \beta e b_C + \beta w_C}{2b} \). Introducing \( p_C \) into the manufacturer’s profit function, we can get \( \Pi^C_M = (w_C - c_m)(\varphi - \beta e b_C + \beta w_C) + (\Delta - A_R)(a + b^*_C) \). Here because \( p_C \) does not include any \( A \), we use the same method as Proposition 3, let \( A_C = \frac{\Delta + h_C}{2} \). By solving the partial derivative \( \frac{\partial \Pi^C_M}{\partial w_C} = 0 \), we can get \( w_C = \frac{\varphi + e b_C + \beta c_m}{2b} \). Introducing \( w_C \) into \( p_C \), we can get \( p_C = \frac{3\varphi + 2e b_C + \beta w_C}{2b} \). Introducing \( A_C \) into the collector’s profit function, we can get \( \Pi^C_C = (\frac{\Delta + h_C}{2} - b_C)(a + b^*_C) \). By solving the first derivative \( \frac{\partial \Pi^C_C}{\partial e b_C} = 0 \), we can get \( b^*_C = \frac{\Delta - a}{2b} \). By introducing \( b^*_C \) into \( p_C \), \( A_C \) and \( w_C \), we can get \( p^*_C = \frac{3\varphi + 3e_1\Delta - 3ae_2 - 2b_1c_m}{8b_1}, A^*_C = \frac{3\varphi + 3e_1\Delta - 3ae_2 - 2b_1c_m}{4b_1}, w^*_C = \frac{2\varphi + 3e_1\Delta - 3ae_2 - 2b_1c_m}{4b_1} \).

**REFERENCES**

[1] C. M. Armstrong, K. Niinimäki, S. Kujala, E. Karell and C. Lang, Sustainable product-service systems for clothing: Exploring consumer perceptions of consumption alternatives in Finland, *Journal of Cleaner Production*, 97 (2015), 30–39.

[2] X. H. Chen, K. Li, F. Q. Wang and X. H. Li, Optimal production, pricing and government subsidy policies for a closed loop supply chain with uncertain returns, *J. Ind. Manag. Optim.*, 16 (2020), 1389–1414.

[3] X. H. Chen, P. Xu, J. J. Li, T. Walker and G. Q. Yang, Decision-making in a retailer-led closed-loop supply chain involving a third-party logistics provider, *J. Ind. Manag. Optim.*, 2020.

[4] T. Chi, Consumer perceived value of environmentally friendly apparel: An empirical study of Chinese consumers, *The Journal of The Textile Institute*, 106 (2015), 1038–1050.

[5] T. M. Choi, Optimal return service charging policy for a fashion mass customization program, *Service Science*, 5 (2013), 56–68.

[6] T. M. Choi, Y. Li and L. Xu, Channel leadership, performance and coordination in closed loop supply chains, *International Journal of Production Economics*, 146 (2013), 371–380.

[7] J. Cruz-Cárdenas, J. Guadalupe-Lanas and M. Velín-Fárez, Consumer value creation through clothing reuse: A mixed methods approach to determining influential factors, *Journal of Business Research*, 101 (2019), 846–853.

[8] S. Cuc and M. Vidovic, Environmental sustainability through clothing recycling, *Operations and Supply Chain Management: An International Journal*, (2014), 108–115.

[9] H. Dahlbo, K. Aalto, H. Eskelinen and H. Salmenperä, Increasing textile circulation—Consequences and requirements, *Sustainable Production and Consumption*, 9 (2017), 24–47.

[10] N. C. P. Edirisinghe, B. Bichescu and X. Shi, Equilibrium analysis of supply chain structures under power imbalance, *European J. Oper. Res.*, 214 (2011), 568–578.

[11] B. Freudenreich and S. Schaltegger, Developing sufficiency-oriented offerings for clothing users: Business approaches to support consumption reduction, *Journal of Cleaner Production*, 247 (2020), 119589.

[12] J. Gao, H. Han, L. Hou and H. Wang, Pricing and effort decisions in a closed-loop supply chain under different channel power structures, *Journal of Cleaner Production*, 112 (2016), 2043–2057.

[13] B. C. Giri, A. Chakraborty and T. Maiti, Pricing and return product collection decisions in a closed-loop supply chain with dual-channel in both forward and reverse logistics, *Journal of Manufacturing Systems*, 42 (2017), 104–123.

[14] G. Hole and A. S. Hole, Recycling as the way to greener production: A mini review, *Journal of Cleaner Production*, 212 (2019), 910–915.

[15] S. Jørgensen and G. Zaccour, Equilibrium pricing and advertising strategies in a marketing channel, *J. Optim. Theory Appl.*, 102 (1999), 111–125.
OPTIMAL RECYCLING PRICE STRATEGY BASED ON CLOSED-LOOP SUPPLY CHAIN

[16] K. Kant Hvass, Post-retail responsibility of garments—a fashion industry perspective, *Journal of Fashion Marketing and Management*, 18 (2014), 413–430.

[17] W. Leal Filho, D. Ellams, S. Han, D. Tyler, V. J. Boiten, A. Paço, H. Moora and A. L. Balogun, A review of the socio-economic advantages of textile recycling, *Journal of Cleaner Production*, 218 (2019), 10–20.

[18] N. Liu, T. Choi, C. M. Yuen and F. Ng, Optimal pricing, modularity, and return policy under mass customization, *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, 42 (2012), 604–614.

[19] T. Maiti and B. C. Giri, A closed loop supply chain under retail price and product quality dependent demand, *Journal of Manufacturing Systems*, 37 (2015), 624–637.

[20] S. K. Mukhopadhyay and R. Setoputro, Optimal return policy and modular design for build-to-order products, *Journal of Operations Management*, 37 (2015), 624–637.

[21] L. J. R. Nunes, R. Godina, J. C. O. Matias and J. P. S. Catalião, Economic and environmental benefits of using textile waste for the production of thermal energy, *Journal of Cleaner Production*, 171 (2018), 1353–1360.

[22] H. Peng, N. Shen, H. Liao, H. Xue and Q. Wang, Uncertainty factors, methods, and solutions of closed-loop supply chain—A review for current situation and future prospects, *Journal of Cleaner Production*, 254 (2020), 120032.

[23] Y. Ranjbar, H. Sahebi, J. Ashayeri and A. Teymouri, A competitive dual recycling channel in a three-level closed loop supply chain under different power structures: Pricing and collecting decisions, *Journal of Cleaner Production*, 272 (2020), 122623.

[24] R. Ruiz-Benitez and A. Muriel, Consumer returns in a decentralized supply chain, *International Journal of Production Economics*, 147 (2014), 573–592.

[25] G. Sandin and G. M. Peters, Environmental impact of textile reuse and recycling—A review, *Journal of Cleaner Production*, 184 (2018), 353–365.

[26] R. C. Savaskan, S. Bhattacharya and L. N. Van Wassenhove, Closed-loop supply chain models with product remanufacturing, *Management Science*, 50 (2004), 239–252.

[27] R. C. Savaskan and L. N. Van Wassenhove, Reverse channel design: The case of competing retailers, *Management Science*, 52 (2006), 1–14.

[28] B. Shen, J. H. Zheng, P. S. Chow and K. Y. Chow, Perception of fashion sustainability in online community, *The Journal of The Textile Institute*, 105 (2014), 971–979.

[29] W. B. Wang, P. Zhang, J. F. Ding, J. Li, H. Sun and L. Y. He, Closed-loop supply chain network equilibrium model with retailer-collection under legislation, *J. Ind. Manag. Optim.*, 15 (2019), 199–219.

[30] W. Wang, Y. Zhang, K. Zhang, T. Bai and J. Shang, Reward–penalty mechanism for closed-loop supply chains under responsibility-sharing and different power structures, *International Journal of Production Economics*, 170 (2015), 178–190.

[31] Z. D. Wu, X. H. Qian, M. Huang, W. K. Ching, H. B. Kuang and X. W. Wang, Channel leadership and recycling channel in closed-loop supply chain: The case of recycling price by the recycling party, *J. Ind. Manag. Optim.*, 17 (2020), 3247–3268.

[32] J. Xie and A. Neyret, Co-op advertising and pricing models in manufacturer-retailer supply chains, *Computers & Industrial Engineering*, 56 (2009), 1375–1385.

[33] B. R. Zheng and X. P. Hong, Make Fashion Circular: Outlook for a New Textile Economy in China, Report of China National Textile, 2020. Available from: http://sdgstewardship.org/circular/.

Received July 2021; revised October 2021; early access January 2022.

E-mail address: owencho@163.com
E-mail address: xiaofenji@zstu.edu.cn