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Research Article

Game Models for Closed-Supply Chain with Different Competition-Cooperation Relationships under Fairness Preference

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Considering the complex problem of competition and cooperation among enterprises in the process of product selling and recycling, different coopetition game models of closed-loop supply chain with the fairness preference of a manufacturer and retailers are constructed according to the actual investigation. Then, this study primarily used fairness preference theory and game theory to analyze the impact of fairness preference on the pricing decision, recycling and remanufacturing strategy, and coopetition model selection. The results show that (1) enterprises' fairness preference would increase the wholesale price and retail price, and the stronger the degree of fairness preference is, the more obvious the trend is; (2) enterprises' fairness preference is not conducive to recycling and remanufacturing, and the higher level of fairness preference is associated with the lower recycling rate of waste products; (3) enterprises' fairness preference would not affect the model selection but would benefit the overall profit.

1. Introduction

Closed-loop supply chain (CLSC) focuses on taking back products from customers and recovering added value by reusing the entire product and/or certain of its modules, components, and parts. Nowadays, enterprises are paying more and more attention to the CLSC management that combines the traditional forward supply chain and the reverse supply chain. To face the increasingly complex market environment, some enterprises begin to establish alliances in product sales and recycling channels from the original competitive relationship, such as Huawei, HP, and Dell, which have set up a reverse supply chain and consumer recycling program through establishing cooperative relationship with retailers to recycle discarded computers, to achieve complementary advantages and gain additional benefits. Not only did Haier and Changhong, especially, set up their own subsidiaries that primarily engage in collecting and handling used products but also they established a coalition with large competitive retailers (e.g., Suning and Gome) in China [1–3]. The competition-cooperation relationships in the supply chain play an important role in strengthening the core competitiveness of the enterprise. However, the coexistence of competition and cooperation also further leads to the conflicts of interest between the maximization of its own profits and the maximization of the profit of the cooperative alliance, which would trigger the company's fairness preference. Not only does the cooperative company pay attention to its own profit, but also it considers whether it is fair to other members' profit in the supply chain. Therefore, how does fairness preference affect the coopetition game of a closed-loop supply chain? How does fairness preference affect the coopetition relationships among companies and the optimal decision-making in CLSC? These have become new problems in theoretical research and practical management.

This study involves the coopetition game and fairness preference of CLSC.

In recent years, the CLSC, as a new supply chain management model, has attracted wide attention. Savaskan et al. studied the pricing problem of different recycling channels in the retailer's competitive environment in a CLSC and proposed the optimal pricing decision and profit coordination strategy [1]. Nie studied the impact of different cooperation structures on third-party recycling of CLSC [4]. Si and Ma used game theory to analyze the influence of different cooperation relationships on the pricing decision of CLSC under different strategies [5]. Wu and Zhou studied the conditions for remanufacturers to enter the market and further analyzed the profit of different partnerships between a manufacturer and third-party remanufacturers [6]. Wu explored optimal game strategy of manufacturers and remanufacturers under different cooperation modes [7]. Yao and Teng researched the impact of different advertising cooperation models on the CLSC of third-party recycling and found that the joint advertising model was only beneficial to the leading retailers and was unfavorable to other members [8]. Zheng et al. studied the decision-making and coordination of CLSC with a leading retailer, two competing manufacturers, and a third-party recycler and showed that the increase of competition intensity among manufacturers was beneficial to the expansive sales of new products and the recycling of waste products [9]. Most of the above researches on coopetition game assume that participant is completely rational and has not taken into account the decision-making preferences of enterprises in the CLSC. In real life, coopetition companies often pay more attention to their own fairness of profit because they often invest a lot of cooperative costs. Some companies would even take action to punish each other at the expense of their own profit when they feel unfair in order to achieve a more equitable outcome. Therefore, it is necessary to research the fairness preference between coopetition companies in the CLSC.

Since competition and cooperation relationship would trigger the conflicts of interest between maximizing its own profits and the profit of the cooperative alliance, it would trigger fair concern. Introducing fairness preference in the supply chain is also a hot issue studied by scholars in recent years [10–12]. Fahimnia et al. considered the existence of two-way fairness preference among channel vendors and found that supply chain coordination could also be achieved through volume discount contracts and manufacturing payment of a fixed fee [13]. Guan et al. discussed cooperative advertising strategies and found that retailers' fairness preference would affect the profit level of the entire supply chain [14]. Ho et al. studied the supply chain system consisting of two retailers and one supplier and studied profit coordination problem with horizontal and vertical equity from an experimental perspective [16]. Zheng et al. analyzed the optimal decision-making problem of CLSC members under the fair neutral and fairness preference of retailers and found that the fairness preference of leading retailer was beneficial to the maximization of their own utilities and unfavorable to maximize the profits of the manufacturer and third parties [12]. Wang et al. analyzed the situation of fairness preference among manufacturers and retailers in the CLSC and constructed four decision-making modes when there was no fairness preference, manufacturers, and online retailers fairness preference and studied the sales and recycle under different modes [16]. Huang studied the optimal differential pricing decision and coordination strategy of members and the whole system under the condition of considering the fairness concern of members in the CLSC and analyzed the impact of fairness concern on the decision by comparing the results under the condition of fairness neutrality and fairness concern [17]. Wu et al. established a revenue-sharing contract coordination model with both risk aversion and equity preference between suppliers and retailers. By modifying and expanding the FS utility benefit model, they successively investigated and analyzed the coordination state of the supply chain under decentralized and centralized decision-making model [18]. The above literature only focuses on the impact of fairness preference on manufacturers or retailers in the supply chain, but the actual situation of competition and cooperation between upstream and downstream enterprises in the CLSC is not involved.

This paper takes the CLSC as a research object, considers the impact of fairness preference on different horizontal and vertical competition and cooperation among CLSC nodes, and builds a dynamic coopetition game model. In view of competition and cooperation among enterprises, we build different models when enterprises have fairness preference. Then, in order to provide support for establishing a "win-win relationship," the optimal decision-making of different coopetition games with fairness preference has been studied. Moreover, the optimal retail price, wholesale price, recycling rate, and supply chain profit under different horizontal and vertical coopetition game in the CLSC are presented. Finally, the impact of fairness preference is analyzed on prices, recycling rate, and profits in the CLSC by an numerical simulation.

2. Problem Description and Assumptions

In reality, in order to cope with the increasingly complex market environment, obtain the competitive advantage of the market, and achieve the mutual complementation of information, resources, and advantages among enterprises, enterprises in the supply chain often choose to establish strategic alliances. The relationship among enterprises involved in the CLSC is more complicated. According to Savaskan et al. and Dong et al. [1, 19], this paper describes the CLSC composed of manufacturer and two competing retailers, where the manufacturer is responsible for the production of new products and the recycling of used products and retailers are responsible for the sales of products. According to the actual investigation and literature review, this paper mainly studies those different coopetition game models [1–3], and the coopetition relationships mainly include the horizontal competitive game between retailers. In case (1), there is a Bertrand competition between retailers; that is, two retailers have their own pricing strategies while maximizing their respective profits, which is also called manufacturer-led CLSC with a Bertrand competition between retailers, RBS for short. In case (2), two retailers have reached a cooperative relationship, that is, two retailers jointly set the price and optimize the overall interests of the partners. The vertical competitive game among manufacturer and retailers is also called manufacturer-led CLSC with retailers collaboration, RCS for short. In case (3), manufacturers, as the market leader, prioritize pricing strategies and recycling strategies, and retailers build a coalition, which is also called retailer-led CLSC with retailers collaboration, RCR for short. In case (4), retailer is dominant to make decisions, which is also called retailer-led CLSC with competitive retailers, RBR for short. In case (5), manufacturer and retailer cooperate to maximize the overall profits and then compete with another retailer, which is also called manufacturer-led CLSC with manufacturer-retailer collaboration, MRC for short. Those models are showed in Figure 1.

The definition and assumptions of specific parameter symbols are listed as follows:

(1) The cost of remanufactured products and new products can be denoted as c_{r} and c_{m}, respectively, and let $\Delta = c_{\mathrm{m}} - c_{\mathrm{r}} > 0$ represent the saving cost of producing remanufactured products.

(2) The market demand function is $q_1 = \phi - \alpha p_1 + \beta p_2$, $q_2 = \phi - \alpha p_2 + \beta p_1$, $q = q_1 + q_2$. Let q_1 and q_2 be the market demand of retailer R_1 and retailer R_2, respectively. Let q be the total market demand; p_1 and p_2 are the retail prices of retailer R_1 and retailer R_2, respectively; ϕ denotes the total capacity of the whole market; α denotes the price elasticity; β denotes the coefficient of competitive substitution, which satisfies $0 < \beta < \alpha$. To obtain $q_i > 0$, it must satisfy $q = \phi - \alpha c_{\mathrm{m}} + \beta c_{\mathrm{m}} > 0$, so $\phi - c_{\mathrm{m}}(\alpha - \beta) > 0$ can be obtained.

(3) The cost of recycling the waste products by the manufacturer is $c(\tau) = B\tau^2 + A\tau q$ and τ represents the proportion of the recycled waste products; B is the cost coefficient of the recycled investment; τq is the quantity of recycled waste productsfrom the total market demand. A represents the unit cost paid by the manufacturer for the consumer who provided the used product, $A < \Delta$. The unit cost paid by the manufacturer to the consumer is less than the unit cost saved by the production of the remanufactured product.

(4) The CLSC cooperation alliance uses the profit of other participants as the decision-making criterion for judging whether it is fair, $\lambda(\lambda \geq 0)$ is the coefficient of fairness preference, where $\lambda = 0$ expresses fairness and neutrality $\lambda(\lambda \geq 0)$ and $\lambda \longrightarrow +\infty$ expresses extreme concern for fairness.

(5) The wholesale price is w; U_j^k indicates the utility of the enterprise j in the alliance k; $\prod_j^k$ indicates the profit of the j enterprise in alliance k, in which k represents RBS, RCS, RCR, RBR, and MRC and j represents the manufacturer M, retailer R_1, and retailer R_2.

When manufacturer and retailers play a game in the CLSC, the manufacturer determines the wholesale price, and the retailers determine the retail price. According to the demand function of that mentioned above, the profit functions of manufacturer and retailers are as follows:

$$\begin{aligned}
\Pi_M &= (w - c_m + \Delta\tau)q - A\tau q - B\tau^2,\\
\Pi_{R_1} &= (p_1 - w)(\phi - \alpha p_1 + \beta p_2),\\
\Pi_{R_2} &= (p_2 - w)(\phi - \alpha p_2 + \beta p_1).
\end{aligned} \tag{1}$$

3. CLSC under Fairness Preference

3.1. RBS Model under Fairness Preference. In this model, the supply chain decision-makers do not adopt a cooperative strategy, the manufacturer as the market leader and the retailer launched the Stackelberg game, and the retailers formed a horizontal competition. Because the retailer's substitution model is the same, the manufacturer's utility function is the same when any retailer is set as a fairness preference reference point; it is assumed that the manufacturer uses the profit of the retailer R_1 as a fairness preference reference point to measure its utility. According to [16], the manufacturer's utility function can be expressed as

$$U_M^{\mathrm{RBS}} = \Pi_M - \lambda\left(\Pi_{R_1} - \Pi_M\right). \tag{2}$$

Based on the profit functions, the RBS model under fairness preference is established:

$$\begin{aligned}
&\mathrm{Max}\quad U_M^{\mathrm{RBS}} = \Pi_M - \lambda\left(\Pi_{R_1} - \Pi_M\right),\\
&\mathrm{S.t}\quad \begin{cases} \mathrm{Max}\Pi_{R_1} = (p_1 - w)(\phi - \alpha p_1 + \beta p_2),\\ \mathrm{Max}\Pi_{R_2} = (p_2 - w)(\phi - \alpha p_2 + \beta p_1).\end{cases}
\end{aligned} \tag{3}$$

Solved by the inverse induction method, first, the retailer's response function is obtained by the first-order condition of the retailer's profit function, which is substituted into the manufacturer's utility function, and the optimal wholesale price $w^{*\,\mathrm{RBS}}$ and the recycling rate $\tau^{*\,\mathrm{RBS}}$ are calculated:

$$w^{*\,\mathrm{RBS}} = \frac{-Bc_{\mathrm{m}}\left(2\alpha^2 - 3\alpha\beta + \beta^2\right)(1+\lambda) + \alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda)\phi + B(\beta + 2\beta\lambda - \alpha(2+3\lambda))\phi}{(\alpha-\beta)\left(\alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda) + B(\beta(2+3\lambda) - \alpha(4+5\lambda))\right)}, \tag{4}$$

$$\tau^{*\,\mathrm{RBS}} = -\frac{\alpha(A-\Delta)(1+\lambda)\left(c_{\mathrm{m}}(\alpha-\beta) - \phi\right)}{\alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda) + B(\beta(2+3\lambda) - \alpha(4+5\lambda))}. \tag{5}$$

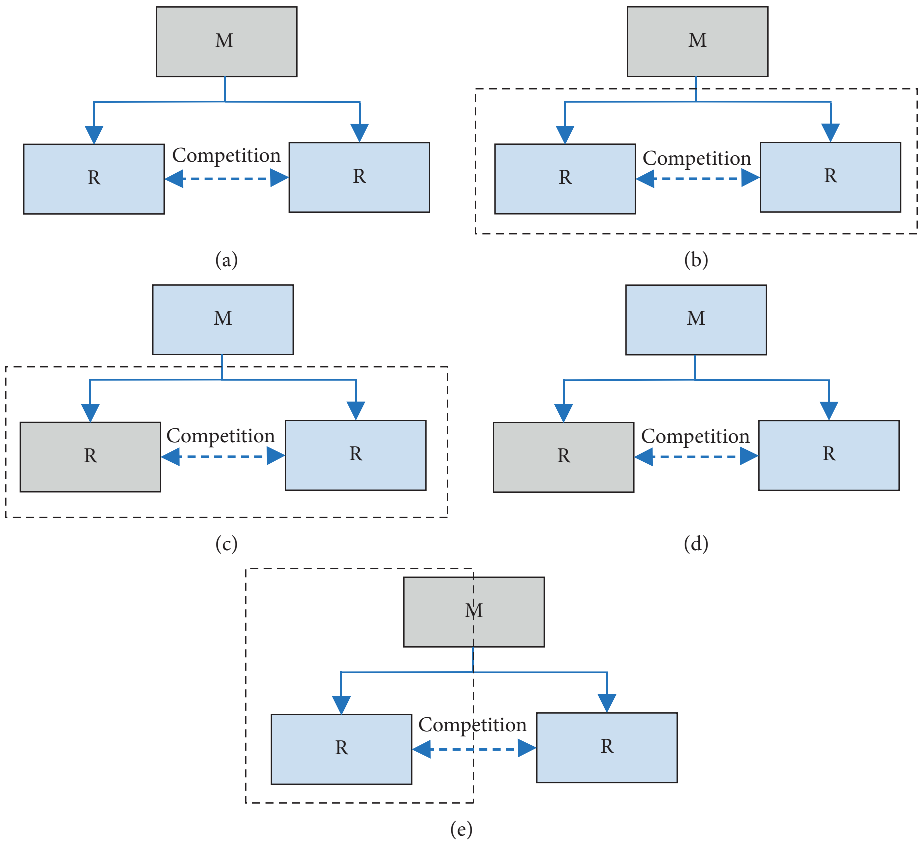

FIGURE 1: Different competitive cooperation game models. (a) RBS, (b) RCS, (c) RCR, (d) RBR, and (e) MRC.

Second, the optimal retail price of the retailer obtained by replacing (4) and (5) with (3) is

$$p_1^{*\,\mathrm{RBS}} = p_2^{*\,\mathrm{RBS}} = \frac{-Bc_{\mathrm{m}}\alpha(\alpha-\beta)(1+\lambda)+\alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda)\phi+B(\beta(2+3\lambda)-\alpha(3+4\lambda))\phi}{(\alpha-\beta)\left(\alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda)+B(\beta(2+3\lambda)-\alpha(4+5\lambda))\right)}. \tag{6}$$

Last, the overall optimal profit of the RBS model under fairness preference is

$$\Pi_{M+R_1+R_2}^{*\,\mathrm{RBS}} = \frac{\left(B\alpha(1+\lambda)^2\left(-\alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda)+B(-\beta(4+3\lambda)+\alpha(6+5\lambda))\right)\left(c_{\mathrm{m}}(-\alpha+\beta)+\phi\right)^2\right)}{\left((\alpha-\beta)\left(\alpha(\alpha-\beta)(A-\Delta)^2(1+\lambda)+B(\beta(2+3\lambda)-\alpha(4+5\lambda))\right)^2\right)}. \tag{7}$$

Proposition 1. *In the RBS model, with the fairness preference factor increasing, the manufacturer's level of fairness preference is increased, but the selling price, the total profit of the CLSC system, and the wholesale price would increase. However, the recycling rate of waste products would reduce, finding that* $(\partial p_i^{*\,RBS}/\partial\lambda) > 0$, $(\partial w^{*\,RBS}/\partial\lambda) > 0$, $(\partial \Pi_{M+R_1+R_2}^{*\,RBS}/\partial\lambda) > 0$, *and* $(\partial \tau^{*\,RBS}/\partial\lambda) < 0$.

Proposition 1 shows the following: (1) The manufacturer's wholesale price increases with the fairness preference coefficient, and the manufacturer's recycling rate of waste products decreases with the fairness preference coefficient. The result shows that when the manufacturer concerns more about fairness preference, the manufacturer would increase its wholesale prices and reduce the recycle cost to obtain high profit. (2) The sale price of competing retailers increases with the fairness preference coefficient. The result shows that when retailers face the manufacturer with increasing levels of fairness preference, they often have to raise the sale price to compensate for higher wholesale price to obtain higher profit. (3) The overall profit of the CLSC increases with the fairness preference coefficient, indicating that fairness preference has a positive effect on promoting the overall profit of the supply chain.

3.2. RCS Model under Fairness Preference. In this model, two retailers adopt a cooperative strategy, and manufacturer acts as the market leader and pays more attention to the fairness of vertical profit distribution, which uses the profit of retailers' cooperation as a point of fairness preference reference to measure utility. The utility function of manufacturer with fairness preference is as follows:

$$U_M^{\mathrm{RCS}} = \Pi_M - \lambda\left(\left(\Pi_{R_1} + \Pi_{R_2}\right) - \Pi_M\right). \tag{8}$$

Based on the profit functions, the RCS model under fairness preference is established:

$$\begin{aligned} &\mathrm{Max} \quad U_M^{\mathrm{RCS}} = \Pi_M - \lambda\left(\left(\Pi_{R_1} + \Pi_{R_2}\right) - \Pi_M\right), \\ &\mathrm{S.t} \quad \left\{\mathrm{Max}\Pi_M = (w - c_m + \Delta\tau)q - A\tau q - B\tau^2\right. \end{aligned} \tag{9}$$

Using the inverse induction method to solve the optimal retail price, wholesale price, recycling rate, and overall optimal profit are as follows:

$$w^{*\,\mathrm{RCS}} = \frac{(\alpha-\beta)(A-\Delta)^2(1+\lambda)f - 2B\left(c_{\mathrm{m}}(\alpha-\beta)(1+\lambda) + f + 2\lambda f\right)}{(\alpha-\beta)\left((\alpha-\beta)(A-\Delta)^2(1+\lambda) - 2B(2+3\lambda)\right)}, \tag{10}$$

$$\tau^{*\,\mathrm{RCS}} = \frac{(A-\Delta)(1+\lambda)\left(c_{\mathrm{m}}(\alpha-\beta) - \phi\right)}{-(\alpha-\beta)(A-\Delta)^2(1+\lambda) + B(4+6\lambda)}, \tag{11}$$

$$p_1^{*\,\mathrm{RCS}} = p_2^{*\,\mathrm{RCS}} = \frac{(\alpha-\beta)(A-\Delta)^2(1+\lambda)\phi - B\left(c_{\mathrm{m}}(\alpha-\beta)(1+\lambda) + (3+5\lambda)\phi\right)}{(\alpha-\beta)\left((\alpha-\beta)(A-\Delta)^2(1+\lambda) - 2B(2+3\lambda)\right)}, \tag{12}$$

$$\prod_{M+R_1+R_2}^{*\,\mathrm{RCS}} = \frac{B\left(6B - (\alpha-\beta)(A-\Delta)^2\right)(1+\lambda)^3\left(c_{\mathrm{m}}(-\alpha+\beta) + \phi\right)^2}{(\alpha-\beta)\left((\alpha-\beta)(A-\Delta)^2(1+\lambda) - 2B(2+3\lambda)\right)^2}. \tag{13}$$

Proposition 2. *In the RCS model, as the manufacturer's fairness preference increases, the selling price and the wholesale price would increase. However, the recycling rate of wasting products would reduce. In particular, when the manufacturer's fairness preference coefficient is greater than zero and less than the threshold, the overall profit of the supply chain decreases with the increasing of fairness preference; when the manufacturer's fairness preference coefficient is greater than the threshold, the overall profit of the supply chain increases as the fairness preference increases. The expression is as follows:*

(1) $(\partial p_i^{*\,RCS}/\partial\lambda) > 0$, $(\partial w^{*\,RCS}/\partial\lambda) > 0$, *and* $(\partial \tau^{*\,RCS}/\partial\lambda) > 0$ *are obtained*

(2) When $0 < \lambda < ((\alpha-\beta)(A-\Delta)^2)/(6B - (\alpha-\beta)(A-\Delta)^2)$, $(\partial \Pi_{M+R_1+R_2}^{*\,RCS}/\partial\lambda) > 0$ *is obtained; when* $\lambda > ((\alpha-\beta)(A-\Delta)^2)/(6B - (\alpha-\beta)(A-\Delta)^2)$, $(\partial \Pi_{M+R_1+R_2}^{*\,RCS}/\partial\lambda) > 0$ *is obtained*

Proposition 2 shows the following: (1) The wholesale price of the manufacturer increases with the coefficient of fairness preference, and the recycling rate of waste products decreases with the coefficient of fairness preference. When the manufacturer's fairness preference is stronger, the company would increase the wholesale price and reduce the cost of recycling and remanufacturing to obtain high profits, so as to ensure that its own profits have a greater advantage than the retailer alliance. (2) The selling price of the cooperative retailer increases with the fairness preference coefficient. When retailers face the manufacturer with increasing of fairness preference, even a cooperative strategy cannot shake the dominant position of the manufacturer. (3) For the CLSC, when the manufacturer's fairness preference is low, manufacturer's higher wholesale prices and lower recycling rate are not enough to compensate for the lower demand and lower profits caused by higher retail prices, so the overall profit of the supply chain decreases with the increase of fairness preference; when the manufacturer's fairness preference is greater, the increase in profits through higher wholesale prices is enough to make up for the loss of profits in the sales market. Therefore, the overall profit of the supply chain would increase.

3.3. RCR Model under Fairness Preference. In this model, two retailers form a cooperative relationship that pays attention not only to alliance profits but also to the fairness of their own profit distribution compared with the manufacturer. Therefore, the manufacturer's profit is used as a reference point of fairness preference to measure its own utility:

$$U_{R_1+R_2}^{\mathrm{RCR}} = \left(\Pi_{R_1} + \Pi_{R_2}\right) - \lambda\left(\Pi_M - \left(\Pi_{R_1} + \Pi_{R_2}\right)\right). \tag{14}$$

Based on the profit functions, the RCR model under fairness preference is established:

$$\begin{aligned}&\text{Max}\quad U_{R_1+R_2}^{\text{RCR}} = \left(\Pi_{R_1} + \Pi_{R_2}\right) - \lambda\left(\Pi_M - \left(\Pi_{R_1} + \Pi_{R_2}\right)\right),\\ &\text{S.t}\quad \{\text{Max}\Pi_M = (w - c_m + \Delta\tau)q - A\tau q - B\tau^2.\end{aligned} \tag{15}$$

In the same way, using the inverse induction method to solve the optimal retail price, wholesale price, recycling rate, and optimal overall profit is as follows:

$$p_1^{*\,\text{RCR}} = p_2^{*\,\text{RCR}} = \frac{(\alpha-\beta)(A-\Delta)^2(2+3\lambda)\phi - B\left(c_{\text{m}}(\alpha-\beta)(1+\lambda)+(3+5\lambda)\phi\right)}{(\alpha-\beta)\left(-2B+(\alpha-\beta)(A-\Delta)^2\right)(2+3\lambda)}, \tag{16}$$

$$w^{*\,\text{RCR}} = \frac{\left((\alpha-\beta)(A-\Delta)^2\left(c_{\text{m}}(\alpha-\beta)(1+2\lambda)+\phi+\lambda\phi\right) - B\left(c_{\text{m}}(\alpha-\beta)(3+5\lambda)+\phi+\lambda\phi\right)\right)}{\left((\alpha-\beta)\left(-2B+(\alpha-\beta)(A-\Delta)^2\right)(2+3\lambda)\right)}, \tag{17}$$

$$\tau^{*\,\text{RCR}} = \frac{(A-\Delta)(1+\lambda)\left(c_{\text{m}}(\alpha-\beta)-\phi\right)}{\left(2B-(\alpha-\beta)(A-\Delta)^2\right)(2+3\lambda)}, \tag{18}$$

$$\Pi_{M+R_1+R_2}^{*\,\text{RCR}} = -\frac{3B(1+\lambda)^3\left(c_{\text{m}}(-\alpha+\beta)+\phi\right)^2}{(\alpha-\beta)\left(2B-(\alpha-\beta)(A-\Delta)^2\right)(2+3\lambda)^2}. \tag{19}$$

Proposition 3. *In the RCR model, as the coefficient of fairness preference increases, when the retailer's fairness preference is increased, the sales price would increase, but the wholesale price would decrease, and the recycling rate of waste products would reduce. The total profit of the CLSC system would increase, as follows:* $(\partial p_i^{*\,RCR}/\partial\lambda) > 0$, $(\partial w^{*\,RCR}/\partial\lambda) < 0$, $(\partial\tau^{*\,RCR}/\partial\lambda) < 0$, $(\partial\Pi_{M+R_1+R_2}^{*\,RCR}/\partial\lambda) > 0$ *are obtained.*

Proposition 3 shows the following: (1) For retailers with fairness preference, retail prices increase with the fairness preference factor. This shows that when the retailer's fairness preference is stronger, more attention is paid to its dominant position in the supply chain, so the retailer would actively enhance its own position in the supply chain by increasing the selling price. (2) For the manufacturer, the wholesale price and the recycling rate of waste products are both decreasing with the fairness preference coefficient. Because retailers have a strong position in the supply chain, retailers use the power of market dominance and fairness preference to drive down the wholesale prices of the manufacturer to achieve higher profits. At the same time, in order to make up for the loss caused by the reduction of the wholesale price, the manufacturer can only reduce the cost of waste products to avoid greater profit reduction. (3) For the CLSC system, the retailer cooperative model can obtain stable profits compared with the competitive model, and the profit increased by the higher price can make up for the lost profit of the manufacturer, so the overall profit of the supply chain always increases with the increase of fairness preference coefficient.

3.4. RBR Model under Fairness Preference. In this model, the retailer has a dominant role and the retailers form a horizontal competition, so there is no cooperation among the retailers and the manufacturer. Suppose that retailer R_1 and retailer R_2 use the manufacturer's profit as a fairness preference point to measure their effectiveness [20]. The decision function of retailers with fairness preference is described:

$$U_{R_i}^{\text{RBR}} = \Pi_{R_i} - \lambda\left(\Pi_M - \Pi_{R_i}\right), \quad i = 1,2. \tag{20}$$

The Π_M and $\Pi_{R_i}(i = 1,2)$ are the profit functions of the manufacturer and retailers with a fairness preference. Based on the profit functions, the RBR model under fairness preference is established:

$$\begin{aligned}&\text{Max}\quad U_{R_1}^{\text{RBR}} = \Pi_{R_1} - \lambda\left(\Pi_M - \Pi_{R_1}\right),\\ &\text{S.t}\quad \begin{cases}\text{Max}\Pi_M = (w - c_{\text{m}} + \Delta\tau)q - A\tau q - B\tau^2,\\ \text{Max}\Pi_{R_2} = (p_2 - w)(\phi - \alpha p_2 + \beta p_1).\end{cases}\end{aligned} \tag{21}$$

Solving the model by the inverse induction method, first, the retailer determines the retail price according to the manufacturer's response function by the first-order condition, and then the retailer's utility function is used to calculate the optimal retail prices $p_1^{*\,\text{RBR}}$ and $p_2^{*\,\text{RBR}}$ under fairness preference:

$$p_1^{*\,\text{RBR}} = p_2^{*\,\text{RBR}} = \frac{\left(-2Bc_{\text{m}}\alpha(\alpha-\beta)(1+\lambda)+(\alpha-\beta)(A-\Delta)^2(-\beta(1+3\lambda)+\alpha(3+5\lambda))\phi+B(\beta(3+7\lambda)-\alpha(5+9\lambda))\phi\right)}{\left((\alpha-\beta)\left((\alpha-\beta)(A-\Delta)^2(-\beta(1+3\lambda)+\alpha(3+5\lambda))+B(\beta(3+7\lambda)-\alpha(7+11\lambda))\right)\right)}. \tag{22}$$

The optimal retail price is substituted into the manufacturer's profit function, and the optimal wholesale price $w^{*\,\mathrm{RBR}}$ and recycling rate $\tau^{*\,\mathrm{RBR}}$ are calculated as

$$w^{*\,\mathrm{RBR}} = \frac{-Bc_{\mathrm{m}}(\alpha-\beta)(\alpha(5+9\lambda)-\beta(3+7\lambda)) - 2B\alpha(1+\lambda)\phi + (\alpha-\beta)(A-\Delta)^2\left(C_{\mathrm{m}}(\alpha-\beta)^2(1+3\lambda)+2\alpha(1+\lambda)\phi\right)}{\left((\alpha-\beta)\left((\alpha-\beta)(A-\Delta)^2(\alpha(3+5\lambda))-\beta(1+3\lambda)+B(\beta(3+7\lambda)-\alpha(7+11\lambda))\right)\right)}, \quad (23)$$

$$\tau^{*\,\mathrm{RBR}} = \frac{-\left(2\alpha(A-\Delta)(1+\lambda)(c_{\mathrm{m}}(\alpha-\beta)-\phi)\right)}{\left((\alpha-\beta)(A-\Delta)^2(-\beta(1+3\lambda)+\alpha(3+5\lambda))+B(\beta(3+7\lambda)-\alpha(7+11\lambda))\right)}. \quad (24)$$

Finally, the overall optimal profit is obtained based on the above optimal solutions:

$$\Pi^{*\,\mathrm{RBR}}_{M+R_1+R_2} = \frac{\left(4B\alpha(1+\lambda)^2\left(-(\alpha-\beta)(A-\Delta)^2(\alpha(2+\lambda)-\beta(1+3\lambda))+B(\alpha(5+3\lambda)-\beta(3+7\lambda))\right)\left(c_{\mathrm{m}}(-\alpha+\beta)+\phi\right)^2\right)}{\left((\alpha-\beta)\left((\alpha-\beta)(A-\Delta)^2(-\beta(1+3\lambda)+\alpha(3+5\lambda))+B(\beta(3+7\lambda)-\alpha(7+11\lambda))\right)^2\right)}. \quad (25)$$

Proposition 4. *In the RBR model, with the retailer's fairness preference increasing, the selling price would increase, but the wholesale price would decrease, and the recycling rate would also reduce. When the retailer's fairness concern coefficient is greater than zero and less than the threshold, the overall profit of the supply chain decreases with increasing of fairness preference. When the retailer's fairness preference coefficient is greater than the threshold, the overall profit of the supply chain increases with increasing of fairness preference. The specific expression is as follows:*

(1) $(\partial p_i^{*\,RBR}/\partial\lambda) > 0$, $(\partial w^{*\,RBR}/\partial\lambda) < 0$, *and* $(\partial\tau^{*\,RBR}/\partial\lambda) < 0$ *are obtained.*

(2) When $0 < \lambda < (-a_{RBR}b_{RBR} + \sqrt{c_{RBR}})/(d_{RBR}e_{RBR})$, $(\partial\Pi^{*\,RBR}_{M+R_1+R_2}/\partial\lambda) < 0$ *is obtained; when* $\lambda < (-a_{RBR}b_{RBR} + \sqrt{c_{RBR}})/(d_{RBR}e_{RBR})$ *is obtained*

$$\begin{cases} a_{\mathrm{RBR}} = B(5\alpha-\beta) - 2\alpha(\alpha-\beta)(A-\Delta)^2, \\ b_{\mathrm{RBR}} = B(3\alpha-7\beta) - (\alpha-3\beta)(\alpha-\beta)(A-\Delta)^2, \\ c_{\mathrm{RBR}} = (\alpha-\beta)\left(-2B+(\alpha-\beta)(A-\Delta)^2\right)^2\left(B(3\alpha-7\beta)-(\alpha-3\beta)(\alpha-\beta)(A-\Delta)^2\right)\left(\left(B\left(71\alpha^2-30\alpha\beta+7\beta^2\right)-(\alpha-\beta)\left(29\alpha^2-8\alpha\beta+3\beta^2\right)(A-\Delta)^2\right)\right), \\ d_{\mathrm{RBR}} = B(3\alpha-7\beta) - (\alpha-3\beta)(\alpha-\beta)(A-\Delta)^2, \\ e_{\mathrm{RBR}} = B(11\alpha-7\beta) - (5\alpha-3\beta)(\alpha-\beta)(A-\Delta)^2. \end{cases} \quad (26)$$

Proposition 4 shows the following: (1) The retail prices increase with the coefficient of fairness preference. The stronger the level of fairness preference of retailers is, the more attention they place on their dominant position in the supply chain. (2) The wholesale price of the manufacturer and the recycling and remanufacturing rate of waste products decrease with the coefficient of fairness preference because retailers have a strong position in the supply chain. The retailer uses its market dominance and fairness preference to lower the manufacturers' wholesale price and takes advantage of negotiate price to force the manufacturer to cut wholesale price and thus achieve higher profits. At the same time, in order to reduce recycling investment, the manufacturer reduces the recycling rate to avoid greater loss of profit. (3) For the CLSC, when the level of retailer's fairness preference is low, the profit advantage formed by the retailer's higher selling price is not enough to make up for the loss caused by the manufacturer's lower wholesale price, so the overall profit of supply chain decreases with the increase of fairness preference. When the level of retailer's fairness preference is greater, the retailer's increased profit is enough to make up for the manufacturer's profit loss, and the overall profit increases.

3.5. MRC Model under Fairness Preference. In this model, we assumed that manufacturer and retailer R_1 form partnerships, where the association focuses not only on their own profits but also on the fairness of profit distribution compared to another retailer. When the partner uses the profit of the retailer R_2 as a point of fairness preference reference to measure their utility, the partner's fairness preference utility function can be described:

$$U_{M+R_1}^{\mathrm{MRC}} = \left(\Pi_M + \Pi_{R_1}\right) - \lambda\left(\Pi_{R_2} - \left(\Pi_M + \Pi_{R_1}\right)\right). \tag{27}$$

Based on the profit functions, the MRC model under fairness preference is established:

$$\begin{aligned} &\text{Max} \quad U_{M+R_1}^{\mathrm{MRC}} = \left(\Pi_M + \Pi_{R_1}\right) - \lambda\left(\Pi_{R_2} - \left(\Pi_M + \Pi_{R_1}\right)\right),\\ &\text{S.t} \quad \left\{\text{Max}\Pi_{R_2} = \left(p_2 - w\right)\left(\phi - \alpha p_2 + \beta p_1\right).\right. \end{aligned} \tag{28}$$

Solving the model by the inverse induction method, using the backward induction method to solve the optimal retail price, wholesale price, recycling rate, and overall optimal profit is as follows:

$$p_1^{*\,\mathrm{MRC}} = \frac{\left((\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\phi - 2B\alpha(2+3\lambda)\left(c_{\mathrm{m}}(\alpha-\beta)+\phi\right)\right)}{\left((\alpha-\beta)\left(-4B\alpha(2+3\lambda)+(\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\right)\right)}, \tag{29}$$

$$p_2^{*\,\mathrm{MRC}} = \frac{-2Bc_{\mathrm{m}}(\alpha-\beta)(\alpha+\beta+\alpha\lambda+2\beta\lambda) + 2B(\beta+2\beta\lambda-\alpha(3+5\lambda))\phi + (\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\phi}{\left((\alpha-\beta)\left(-4B\alpha(2+3\lambda)+(\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\right)\right)}, \tag{30}$$

$$w^{*\,\mathrm{MRC}} = \frac{\left(-2Bc_{\mathrm{m}}(\alpha-\beta)(\beta\lambda+2\alpha(1+\lambda)) + 2B(\beta\lambda-2\alpha(1+2\lambda))\phi + (\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\phi\right)}{\left((\alpha-\beta)\left(-4B\alpha(2+3\lambda)+(\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\right)\right)}, \tag{31}$$

$$\tau^{*\,\mathrm{MRC}} = \frac{(A-\Delta)(\beta+2\beta\lambda+\alpha(3+4\lambda))\left(c_{\mathrm{m}}(-\alpha+\beta)+\phi\right)}{-4B\alpha(2+3\lambda)+(\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))}, \tag{32}$$

$$\prod_{M+R_1+R_2}^{*\,\mathrm{MRC}} = \frac{\left(B(1+\lambda)\left(-(\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))^2 + 4B\alpha\left(\beta\left(1+6\lambda+6\lambda^2\right)+\alpha\left(7+18\lambda+12\lambda^2\right)\right)\right)\left(c_{\mathrm{m}}(-\alpha+\beta)+\phi\right)^2\right)}{\left((\alpha-\beta)\left(-4B\alpha(2+3\lambda)+(\alpha-\beta)(A-\Delta)^2(\beta+2\beta\lambda+\alpha(3+4\lambda))\right)^2\right)}. \tag{33}$$

Proposition 5. *In the MRC model, when the fairness preference between the manufacturer and the cooperative community of profit increases, the selling price and wholesale price would increase, but the recycling rate of waste products would be reduced and the total profit of the CLSC system would increase as follows:* $(\partial p_1^{*\,MRC}/\partial\lambda) > 0$, $(\partial p_2^{*\,MRC}/\partial\lambda) > 0$, $(\partial w^{*\,MRC}/\partial\lambda) > 0$, $(\partial \tau^{*\,MRC}/\partial\lambda) > 0$, *and* $(\partial \Pi_{M+R_1+R_2}^{*\,MRC}/\partial\lambda) > 0$ *are obtained.*

Proposition 5 shows the following: (1) For manufacturer and cooperative retailer, as the fairness preference increases, they pay more attention to the profits of other participants in the supply chain. Manufacturer and cooperative retailer would join to leverage their strong position and synergies to achieve high alliance profits by increasing wholesale price and retail prices and reducing the cost of recycling rate. (2) For other noncooperative participants in the supply chain, such as retailers, they often have to increase the selling price to make up for lost profits in the supply chain when the fairness preference between the manufacturer and the retailer increases. (3) The overall profit of the CLSC increases with the fairness preference coefficient, which indicates that the cooperation model between the manufacturer and retailers has a positive effect on promoting the overall profit of the supply chain under the fairness preference.

4. Numerical Simulation

Based on observations of current practice and literature [1, 19], we assume that the values of ϕ, α, β, c_{m}, Δ, A, and B are 600, 15, 6, 50, 10, 8, and 600, in order to intuitively analyze the impact of fairness preference on prices, recycling rate, profits, and so forth. And the numerical experiments are used to verify those propositions and also intuitively display the conclusions.

It can be seen from Figure 2 that the retail prices in the five coopetition game models all increase with the fairness preference coefficient. And when decision-makers in the CLSC have fairness preference, the manufacturer-retailer cooperative model (MRC) has the lowest retail price, followed by the retailer competitive model (RBS and RBR), and the highest retail price is the situation under the retailer cooperative model (RCS and RCR). The results show that even if there is a fairness preference in the company, the

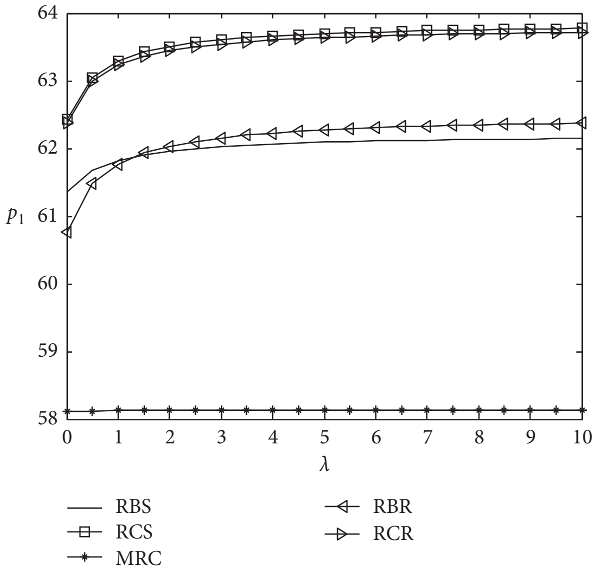

Figure 2: Effect of fairness preference coefficient on retail price.

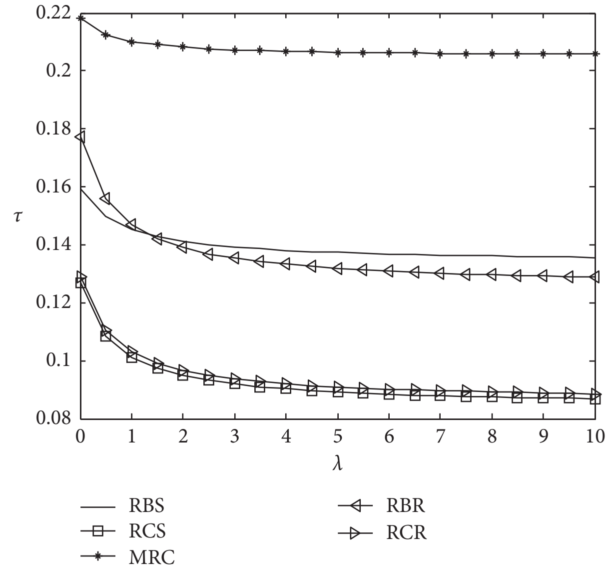

Figure 4: Effect of fairness preference on recycling rate.

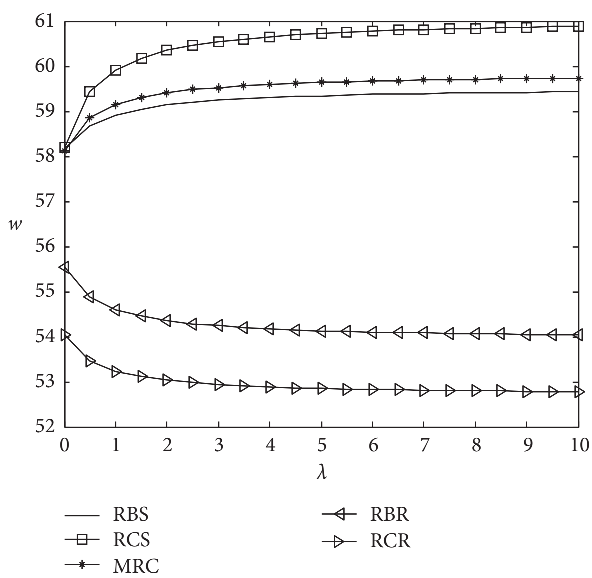

Figure 3: Effect of fairness preference coefficient on the wholesale price.

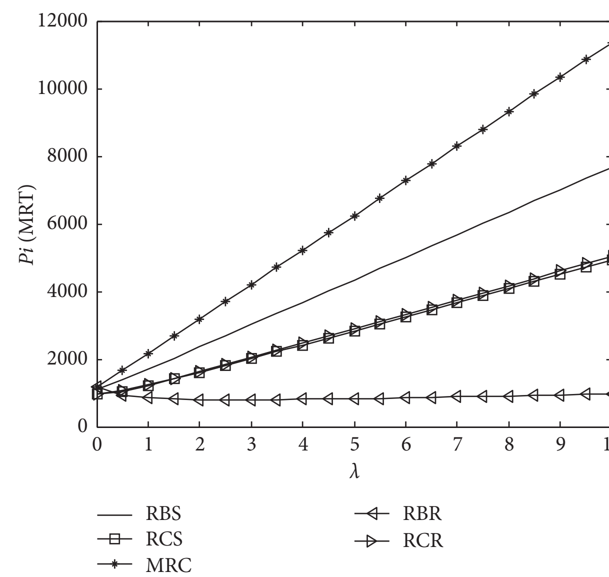

Figure 5: Effect of fairness preference coefficient on the overall profit.

selling price in the supply chain where the manufacturer and the retailer cooperate with each other is lower, which is more conducive to consumers.

As shown in Figure 3, when retailers are dominant in the market and have fairness preference (RBR and RCR), wholesale prices decrease with fairness preference coefficient. And when the manufacturer is market-dominant and has fairness preference (RBS, MRC, and RCS), wholesale price increases with the fairness preference coefficient. When there is fairness preference among the decision-makers in the CLSC, the wholesale price under the manufacturer-led model is higher than that under the retailer-led model. The results show that leaders can gain leadership advantages, which would stimulate more companies to develop rapidly and thus occupy the dominant position in the supply chain. Leadership advantage is the decisive factor of enterprise to keep competing advantage, which ensures technological leadership and competitive advantage.

According to Figure 4, in the five competing models, the recycling rates decrease with the fairness preference coefficient because when manufacturers have fairness preference, they would ensure their own benefits by reducing the cost of recycling and remanufacturing. When retailers have fairness preference, manufacturers face the retailer's suppression of wholesale price and have to reduce the amount of recycled and remanufactured products to compensate for the loss of wholesale products. Moreover, Figure 4 also shows that when decision-makers in the CLSC have fairness preference, the recycling rate of waste products (MRC, RBS, and RCS) under the manufacturer-led model is higher than that under the retailer-led model. The situation shows that government should encourage and support manufacturing companies to participate in recycling and remanufacturing. Many countries have put forward extended producer responsibility, which is an important regulatory policy instrument and extends a producers responsibility for a product to the postconsumption stage and the waste disposition stage.

As shown in Figure 5, for most of the coopetition game models, the overall profit of the CLSC increases with the fairness preference coefficient, but for the retailer-led retailer competition model (RBR). As the coefficient of fairness preference increases, the overall profit of the CLSC decreases, or it remains unchanged. It is found that when the decision-makers in the CLSC system have fairness preference, the manufacturer and retailer's cooperative model (MRC) has the highest total system profit, which indicates that cooperation is better than competition from a benefit perspective and enterprises should be encouraged to maintain good communication with upstream and downstream enterprises and to establish a stable "strategic partnership" with partners. Enterprise strategic alliances also widely exist in reality.

5. Conclusion

This article studies coopetition relationships on the CLSC, composed of the manufacturer and competing retailers. Then, five coopetition game models have been constructed according to the actual investigation. Furthermore, the impact of fairness preference on optimal selection of pricing and recycling strategies and coopetition models for enterprises in a CLSC is analyzed. The study found the following: (1) policymakers with fairness preference would obtain high profits by raising wholesale price or retail price and the stronger the degree of fairness preference among policymakers, the more obvious the trend; (2) the fairness preference of enterprises is not conducive to recycle and remanufacture, and the higher the level of fairness preference is, the lower the recycling rate of waste product is. (3) The fairness preference of the companies would not affect decision-makers' choice of coopetition game models, but it would have a positive effect on the overall profit. In further research, issues such as decision-making and coordination with multiple competitive manufacturers under fairness preference can be considered in the green CLSC.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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