Impact of Retailer’s Bidirectional Fairness Concern on Closed-loop Supply Chain

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Abstract. Build a closed-loop supply chain which consists of the manufacturer, the remanufacturer and the retailer, taking the patent protection factor as the basic variable of the closed-loop supply chain decision-making model, introducing the retailer’s bidirectional fairness concerns factor. The influence of the manufacturer and the remanufacturer considering or not considering the retailer’s fairness concerns to the demand of products and the profit of the closed-loop supply chain is researched by using game theory. The results show that: the retailer’s bidirectional fairness concerns does not affect the demand of products and the profit of system when the manufacturer and the remanufacturer consider the retailer’s fairness concerns. The retailer’s bidirectional fairness concern will reduce the demand of products and the profit of system when the manufacturer and the remanufacturer do not consider the retailer’s fairness concerns. where, the retailer’s fairness concerns about the manufacturer impact on the demand of products and the profit of system is higher than its fairness concerns about the remanufacturer.

Keywords: Closed-loop supply chain; bidirectional fairness concerns; patent licensing

AMS Mathematics Subject Classification (2010): 90B05

1. Introduction

As an important part of the economic cycle development, the remanufacturing industry has the unique advantages of cost saving, energy saving, material saving and emission reduction, which has attracted great attention from the business community and academia. Companies typically have two models for remanufacturing activities: one is a remanufacturing activity by an original equipment manufacturer; and the other is a remanufacturing activity by a third-party remanufacturer. Research shows that remanufacturing by the remanufacturer is more conducive to increasing consumers’ perceived value of new products compared to the manufacturer remanufacturing¹. Therefore, more and more original equipment manufacturers are beginning to outsource remanufacturing activities to remanufacturers. However, the sales of remanufactured products will invaded the market share of new products to a certain extent. In order to maintain the market share of new products and gain more profits, OEMs began to delegate
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remanufacturing activities to remanufacturers in the form of patent licenses (such as Apple). The introduction of remanufacturers has changed the original profit distribution pattern of the closed-loop supply chain. Research by behavioral economist Kehnema et al. shows that people tend to show great attention to the distribution of profits, which leads to fairness concerns [2]. Therefore, when manufacturers introduce remanufacturers into the closed-loop supply chain through patent licensing, it is important to study the impact of fairness concerns on the closed-loop supply chain.

The decision-making research on the closed-loop supply chain under patent protection has achieved fruitful results. Zhong-kai et al. studied the product pricing strategy under the patent protection, and realized the coordination of the closed-loop supply chain by using the revenue-cost sharing mechanism [3]. Cheng-ran et al. have further promoted Zhong-kai's research [4]. Jian-ming et al. studied the impact of patent protection on closed-loop supply chain pricing strategies under differential pricing [5]. Ben-rong et al. introduced patent protection in the research of closed-loop supply chain channel strategy, which further enriched the research in this field [6].

All above literatures assume that the decision makers in the closed-loop supply chain are completely rational, but the behavioral economics research shows that the decision makers are often not completely rational, especially sensitive to the unfairness of the distribution of benefits. Ho et al. first used empirical research to show that there is fairness concerns in the supply chain [7]. Then, the scholars' research on the behavior of fairness concerns in the supply chain is mainly divided into: channel coordination under fairness concerns [8-9], supply chain coordination [10], etc. Ke-yong et al. first introduced the behavior of fairness concerns into the closed-loop supply chain and studied the impact of fairness concerns on product pricing strategies [11]. Subsequently, the scholars studied the pricing and coordination strategies of the closed-loop supply chain based on the manufacturer's fairness concerns [12-14], the remanufacturer's fairness concerns [15] and the retailer's fairness concerns [16-17], where, Zhang-yue et al. scholars studied the impact of the manufacturer's bidirectional fairness concerns on the bargaining power of the decision makers of the closed-loop supply chain, but ignored the possibility of patent protection in closed-loop supply chain.

In summary, firstly, the research on the impact of patent protection on the closed-loop supply chain has achieved fruitful research results. However, in the context of patent protection in the closed-loop supply chain, further discussion on the impact of other factors (such as: fairness concerns) on the closed-loop supply chain remains to be further explored. Secondly, when the system is constructed from three subjects, a single subject tends to have fairness concerns at the same time for the other two subjects. The existing research mainly discusses the impact of one-way fairness concerns on the closed-loop supply chain, but the research on the bidirectional fairness concerns in the closed-loop supply chain is not deep enough. Therefore, there is an urgent need to expand the object of fairness concerns from one-way to bidirectional for further research.

Different from previous researches, this paper constructs a closed-loop supply chain consists of the manufacturer, the remanufacturer and the retailer, and takes patent protection factors as the basic variables of the closed-loop supply chain decision-making model. To focus on: under the bidirectional fairness concerns of the retailer, the effect and extent of the impact of each one-way fairness concerns (including the retailer’s fairness concerns to the manufacturer and the retailer’s fairness concerns to the remanufacturer) on
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the demand of products and profits of the closed-loop supply chain. To assist the supply
chain to control and manage each one-way fairness concerns, and minimize the adverse
impact of the retailer’s bidirectional fairness concerns on the closed-loop supply chain.

2. Problem description and assumption
Research in a closed-loop supply chain consists of the manufacturer, the remanufacturer,
and the retailer, when the manufacturer patent licensing to the remanufacturer, to study the
impact of the retailer’s bidirectional fairness concerns on the demand of products and the
profit of closed-loop supply chain. The Stackelberg game with the manufacturer as the
leader in the closed-loop supply chain system. The manufacturer and the remanufacturer
are unfairness concerns, where the manufacturer is responsible for the production of new
products, and the remanufacturer is responsible for recycling and producing
remanufactured products, the retailer has bidirectional fairness concerns and is responsible
for selling new and remanufactured products. Figure 1 shows the closed-loop supply chain
decision structure model.

Figure 1: Closed-loop supply chain decision structure

Based on the above basic description, the following describes the symbols and basic
assumptions of this article.

(1) The recycled old products can all be used for remanufacturing, and the output of new
products and remanufactured products can exactly meet the needs of the market.
(2) The unit cost, wholesale price, and sales price of the products are: $c_i, w_i, p_i$, where
$i = (n, r)$ denotes the new product and the remanufactured product respectively. To ensure
that all members of the closed-loop supply chain system are profitable, they must be
satisfied: $p_n > w_n > c_n, p_r > w_r > c_r$.
(3) The unit patent fee is $f$; the unit cost of recycling old products is $p$.
(4) Assume that consumers have heterogeneous demands for new products and
remanufactured products: Consumers’ willingness to pay for new products is $\theta \in [0,1]$.
Compared to new products, consumers’ willingness to pay for remanufactured products is
$\theta \in [0,1]$. Assume that the market’s total demand is $Q = 1$, in order to enable consumers
to have the desire to purchase remanufactured products, this article only analyzes the
situation of $\theta p_n > p_r$. According to the utility function derivation: $q_n = 1 - \frac{p_n - p_r}{1 - \theta}, q_r = \frac{\theta p_n - p_r}{\theta(1 - \theta)}$, where $q_n$ represents the market demand for new products, $q_r$ represents the
market demand for remanufactured products.
(5) $\Pi^k_j$ represents the profit of system member $j$ in model $k$, where $j = (N, R, r)$
represents the manufacturer, the remanufacturer, and the retailer respectively. And
$k = (t, D, F, NF)$ represents the centralized decision-making model, the decentralized
decision-making model, the decentralized decision model under the manufacturer and the
remanufacturer consider the retailer’s fairness concerns and the decentralized decision.

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model under the manufacturer and the remanufacturer not consider the retailer’s fairness concerns. All the profits in this article are the theoretical profits when the product sales exactly meet the demand of products.

(6) $\zeta_1$ indicates the retailer’s fairness concerns factor for the manufacturer, and $\zeta_2$ indicates the retailer’s fairness concerns for the remanufacturer.

(7) To make the study meaningful, we assume $(1 - \theta_c)(1 - \theta) > \theta c_n - c_r - p$.

3. The decision of closed-loop supply chain under unfairness concerns

3.1. The centralized decision model

Under the centralized decision model, the manufacturer, the remanufacturer and the retailer build a decision-making system to determine pricing strategies for new products and remanufactured products to maximize system’s profits. The profits of the system is:

$$\Pi_c^I = (p_n - c_n)q_n + (p_r - c_r - p)q_r$$  (1)

To solution $\frac{\partial \Pi_c^I}{\partial p_n} = 0, \frac{\partial \Pi_c^I}{\partial p_r} = 0$ simultaneously: $p_n^I = \frac{1 + c_n}{2}, p_r^I = \frac{\theta c_n + c_r + p}{2}$.

Therefore, the demand for new and remanufactured products and the profits of system are:

$$q_n^I = \frac{1 - \theta c_n + c_r + p}{2(1 - \theta)}, q_r^I = \frac{\theta c_n - c_r - p}{2\theta(1 - \theta)}; \quad \Pi_c^I = \frac{(1 - c_n)^2}{4} + \frac{(\theta c_n - c_r - p)^2}{4\theta(1 - \theta)};$$

3.2. The decentralized decision model

Under the decentralized decision model, relevant decisions of each members of the system are based on maximizing their own profits.

The profit function for the manufacturer, the remanufacturer and the retailer are:

$$\Pi_M = (w_n - c_n)q_n + f q_r$$  (2)

$$\Pi_R = (w_r - c_r - p - f)q_r$$  (3)

$$\Pi_F = (p_n - w_n)q_n + (p_r - w_r)q_r$$  (4)

In a stackelberg game with the manufacturer as the leader, solving the above profit function inversely according to the game sequence can be obtained:

$$p_n^D = \frac{3 + c_n}{4}, \quad p_r^D = \frac{6\theta + \theta c_n + c_r + p}{8}, \quad w_r^D = \frac{\theta c_n + c_r + p + 2\theta}{4}, \quad w_n^D = \frac{1 + c_n}{2}; \quad f^D = \frac{\theta - c_r - p}{2};$$

Therefore, the demand of new and remanufactured products are:

$$q_n^D = \frac{2(1 - \theta c_n + \theta c_n + c_r + p)}{8(1 - \theta)}, q_r^D = \frac{\theta c_n - c_r - p}{8\theta(1 - \theta)};$$

The profits of the manufacturer, the remanufacturer and the retailer are:

$$\Pi_M^D = \frac{2\theta - 2\theta^2 - 4\theta c_n + 4\theta^2 c_n + 2\theta c_n^2 - 2\theta c_n (c_r + p) + (c_r + p)^2}{16\theta(1 - \theta)};$$

$$\Pi_R^D = \frac{(\theta c_n - c_r - p)^2}{32\theta(1 - \theta)};$$

$$\Pi_F^D = \frac{4\theta - 4\theta^2 - 8\theta c_n + 8\theta^2 c_n + 4\theta c_n^2 - 3\theta^2 c_n^2 - 2\theta c_n (c_r + p) + (c_r + p)^2}{64\theta(1 - \theta)};$$

4. The decision of closed-loop supply chain under the retailer's bidirectional fairness concerns

This article assumes that in the closed-loop supply chain system, the manufacturer and the remanufacturer are unfairness concerns, the retailer have bidirectional fairness concerns, where the retailer has fairness concerns for the manufacturer(called it below: vertical one fairness concerns) and fairness concerns for the remanufacturer(called it below: vertical two fairness concerns). In this paper, we refer to the studies of Shao-fu[13] and Zhang-yue[14],
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assuming that the retailer’s fairness concerns utility function is:

\[ U_r = \Pi_r - \zeta_1 (\Pi_M - \Pi_r) - \zeta_2 (\Pi_R - \Pi_r) \quad (5) \]

The retailer’s fairness concerns utility function is divided into three parts: the first part is the retailer’s profit function, the second part is the retailer’s fairness concerns utility function for the manufacturer, and the third part is the retailer’s fairness concerns utility function for the remanufacturer, where \( \zeta_i \in [0,1] \) (\( i = 1, 2 \)) indicates the retailer’s degree of fairness concerns, and the more \( \zeta_i \) tends to 0, the lower the fairness concerns of the retailer, the more it tends to 1, the higher the fairness concerns of the retailer\(^{17}\).

4.1 The manufacturer and the remanufacturer consider the retailer’s fairness concerns

When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, the retailer’s fairness concerns will directly influence the manufacturer’s and the remanufacturer’s pricing decisions. At this point, the retailer's strategy is based on the maximization of the utility function, and the strategy of the manufacturer and the remanufacturer are based on maximizing the profit function. The same as the game order under the decentralized decision, using the inverse solution method:

- \( p_n^F = \frac{3 + c_n}{4}, p_r^F = \frac{\theta c_n + \sigma + p}{8} + \frac{3 \theta}{4} F = \frac{(\theta - c_r - p)(1 + \zeta_1 + \zeta_2)}{2 + 4 \zeta_1 + 2 \zeta_2} = F; \)
- \( w_n^F = \frac{1 + \zeta_1 + \zeta_2 + c_n(1 + 3 \zeta_1 + \zeta_2)}{2 + 4 \zeta_1 + 2 \zeta_2}, w_r^F = \frac{\theta (1 + 2 \zeta_1 + \zeta_2)}{2 + 4 \zeta_1 + 4 \zeta_2} E + \frac{1 + 3 \zeta_1 + 2 \zeta_2}{2 + 4 \zeta_1 + 4 \zeta_2} E' + G; \)

where \( G = \frac{(c_r + p)(1 + \zeta_1 + 3 \zeta_2) - \theta c_n \zeta_1}{2 + 2 \zeta_1 + 4 \zeta_2} \), the demand of products are:

\[ q_n^F = \frac{\theta c_n - 2 c_n + c_r + p - 2 \theta + 2}{2 \theta (1 - \theta)}, q_r^F = \frac{\theta c_n - c_r - p}{2 \theta (1 - \theta)}. \]

Bringing product pricing and demand into the profit function can earn the profits of each member and system, omitted here.

**Proposition 1.** When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, \( p_n^F = p_n^D, p_r^F = p_r^D, q_n^F = q_n^D, q_r^F = q_r^D. \)

**Proof:** omission.

Proposition 1 indicates that: When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, product pricing and demand are not affected by the retailer’s fairness concerns. Therefore, the retailer’s fairness concerns will only affect the profit distribution among the members and will not affect the profits of the system.

**Proposition 2.** When the manufacturer and the remanufacturer consider the retailer’s fairness concerns:

1. \( \frac{\partial \Pi_n^F}{\partial \zeta_1} < 0, \frac{\partial \Pi_n^F}{\partial \zeta_2} > 0, \frac{\partial \Pi_m^F}{\partial \zeta_1} > \frac{\partial \Pi_m^F}{\partial \zeta_2} \);
2. \( \frac{\partial \Pi_m^F}{\partial \zeta_1} > 0, \frac{\partial \Pi_m^F}{\partial \zeta_2} < 0; \frac{\partial \Pi_r^F}{\partial \zeta_1} < \frac{\partial \Pi_r^F}{\partial \zeta_2} \);
3. \( \frac{\partial \Pi_r^F}{\partial \zeta_1} > 0, \frac{\partial \Pi_r^F}{\partial \zeta_2} < 0; \frac{\partial \Pi_n^F}{\partial \zeta_1} > \frac{\partial \Pi_n^F}{\partial \zeta_2} \);
4. \( \frac{\partial \Pi_n^F}{\partial \zeta_1} = 0, \frac{\partial \Pi_n^F}{\partial \zeta_2} = 0 \)

**Proof:** Find the partial derivative of the profit of each members and system with respect to
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the factor of fairness concerns $\xi_1$ and $\xi_2$ respectively. Take manufacturer as an example:

$$\frac{\partial \Pi_{M,F}}{\partial \xi_1} = \frac{\partial w_{n,F}}{\partial \xi_1} q_n + \frac{\partial f_p}{\partial \xi_1} q_r, \frac{\partial \Pi_{M,F}}{\partial \xi_2} = \frac{\partial w_{n,F}}{\partial \xi_2} q_n + \frac{\partial f_p}{\partial \xi_2} q_r;$$

Because:

$$\frac{\partial w_{n,F}}{\partial \xi_1} = \frac{2(1+\xi_2)(n-1)}{(2+4\xi_1+2\xi_2)^2} < 0, \frac{\partial w_{n,F}}{\partial \xi_2} = \frac{2\xi_1(1-c_0)}{(2+4\xi_1+2\xi_2)^2} > 0, \left| \frac{\partial w_{n,F}}{\partial \xi_1} \right| > \left| \frac{\partial w_{n,F}}{\partial \xi_2} \right|.$$

based on proposition 1, obviously:

$$\frac{\partial \Pi_{M,F}}{\partial \xi_1} < 0, \frac{\partial \Pi_{M,F}}{\partial \xi_2} > 0; \frac{\partial \Pi_{M,F}}{\partial \xi_1} > \frac{\partial \Pi_{M,F}}{\partial \xi_2}.$$

The certification of other members and system is the same as manufacturer. The proposition 2 is proved.

Proposition 2 indicates that: When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, the manufacturer’s profits decrease with vertical one fairness concerns and increase with vertical two fairness concerns, vertical one fairness concerns has a higher impact on the profits of the manufacturer than vertical two fairness concerns, therefore, the retailer’s bidirectional fairness concerns reduces the manufacturer’s profits. The remanufacturer’s profits increase with vertical one fairness concerns and decrease with vertical two fairness concerns, vertical two fairness concerns has a higher impact on the profits of the remanufacturer than vertical one fairness concerns, therefore, the retailer’s bidirectional fairness concerns reduces the remanufacturer’s profits.

The retailer’s profits increase with vertical one fairness concerns and decrease with vertical two fairness concerns, vertical one fairness concerns has a higher impact on the profits of the retailer than vertical two fairness concerns, therefore, the retailer’s bidirectional fairness concerns increases the retailer’s profits.

4.2. The manufacturer and the remanufacturer not consider the retailer’s fairness concerns

Due to the lack of information circulation in the closed-supply chain, or the manufacturer and the remanufacturer completely dominate the market, will cause the manufacturer and the remanufacturer to disregard the retailer’s fairness concerns\[15\]. Therefore, it is necessary to make a specific analysis of the decision of the closed-loop supply chain under this situation.

When the manufacturer and the remanufacturer not consider the retailer’s fairness concerns, the manufacturer and the remanufacturer make decision based on non-fairness concerns in the system. Their pricing decision are the same as the pricing decision under unfairness concerns decentralized decision, where:

$$w_n^N = w_n^D = \frac{1+c_n}{2} w_r^N = w_r^D = \frac{\theta c_n+q_c+p+2\theta}{4}, f_n^N = f_r^D = \frac{\theta-c_r-p}{2}.$$

But the retailer’s decision is also based on maximizing its fairness utility function. Then:

$$p_n^N = \frac{c_n(1+\xi_1+2\xi_2) + q_n(1-\xi_1) + \theta(1+\xi_1+\xi_2)}{4}, q_n^N = \frac{\theta c_n(1+\xi_1+2\xi_2) + (c_r+p)(1-\xi_1) + \theta c_n+q_c+p+2\theta}{\theta(1-\xi_1)(1+\xi_1+\xi_2)}.$$

Bringing product pricing and demand into the profit function can earn the profits of each members and system, omitted here.

Proposition 3. When the manufacturer and the remanufacturer not consider the retailer’s fairness concerns:

$$\frac{\partial q_{n,F}}{\partial \xi_1} < 0, \frac{\partial q_{n,F}}{\partial \xi_2} > 0; \frac{\partial q_{r,F}}{\partial \xi_1} > \frac{\partial q_{r,F}}{\partial \xi_2};$$

$$\frac{\partial q_{n,F}}{\partial \xi_1} < 0, \frac{\partial q_{n,F}}{\partial \xi_2} < 0; \frac{\partial q_{r,F}}{\partial \xi_1} > \frac{\partial q_{r,F}}{\partial \xi_2};$$
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**Proof:** Find the partial derivative of the demand of products with respect to the factor of fairness concerns $\xi_1$ and $\xi_2$ respectively,

$$\frac{\partial q_n^N}{\partial \xi_1} = (\theta c_n-c_r-p)\frac{\partial \zeta_2}{\partial \xi_1}$$

$$\frac{\partial q_n^N}{\partial \xi_2} = \frac{\partial (\theta c_n-c_r-p)\zeta_2}{\partial \xi_2}$$

Because: $(1-c_n)(1-\theta) > \theta c_n - c_r - p$, obviously,

$$\frac{\partial q_n^N}{\partial \xi_1} < 0, \frac{\partial q_n^N}{\partial \xi_2} > 0; \frac{\partial q_n^N}{\partial \xi_1}, \frac{\partial q_n^N}{\partial \xi_2}$$

Obviously: $\frac{\partial q_n^N}{\partial \xi_1} < 0, \frac{\partial q_n^N}{\partial \xi_2} < 0; \frac{\partial q_n^N}{\partial \xi_1}, \frac{\partial q_n^N}{\partial \xi_2}$. Proposition 3 is proved.

Proposition 3 indicates that: When the manufacturer and the remanufacturer do not consider the retailer’s fairness concerns, the demand of new products decrease with vertical one fairness concern and increase with vertical two fairness concerns, vertical one fairness concern has a higher impact on the demand of new products than vertical two fairness concern, therefore, the retailer’s bidirectional fairness concerns reduces the demand of new products. The demand of remanufactured products decrease with vertical one and vertical two fairness concerns, vertical one fairness concern has a higher impact on the demand of remanufactured products than vertical two fairness concerns, therefore, the retailer’s bidirectional fairness concerns reduces the demand of remanufactured products.

**Proposition 4.** When the manufacturer and the remanufacturer do not consider the retailer’s fairness:

(1) $\frac{\partial M_1^N}{\partial \xi_1} < 0, \lim_{\xi_1 \to 0} \frac{\partial M_1^N}{\partial \xi_2} < 0, \lim_{\xi_1 \to 1} \frac{\partial M_1^N}{\partial \xi_2} > 0; \frac{\partial M_1^N}{\partial \xi_1}, \frac{\partial M_1^N}{\partial \xi_2}$

(2) $\frac{\partial M_1^N}{\partial \xi_1} < 0, \lim_{\xi_1 \to 0} \frac{\partial M_1^N}{\partial \xi_2} < 0, \lim_{\xi_1 \to 1} \frac{\partial M_1^N}{\partial \xi_2} > 0; \frac{\partial M_1^N}{\partial \xi_1}, \frac{\partial M_1^N}{\partial \xi_2}$

(3) $\frac{\partial M_1^N}{\partial \xi_1} < 0, \lim_{\xi_1 \to 0} \frac{\partial M_1^N}{\partial \xi_2} < 0, \lim_{\xi_1 \to 1} \frac{\partial M_1^N}{\partial \xi_2} > 0; \frac{\partial M_1^N}{\partial \xi_1}, \frac{\partial M_1^N}{\partial \xi_2}$

(4) $\frac{\partial M_1^N}{\partial \xi_1} < 0, \lim_{\xi_1 \to 0} \frac{\partial M_1^N}{\partial \xi_2} < 0, \lim_{\xi_1 \to 1} \frac{\partial M_1^N}{\partial \xi_2} > 0; \frac{\partial M_1^N}{\partial \xi_1}, \frac{\partial M_1^N}{\partial \xi_2}$

**Proof:** Find the partial derivative of the profit of each members and system with respect to the factor of fairness concerns $\xi_1$ and $\xi_2$ respectively. Take the manufacturer as an example.

$$\frac{\partial M_1^N}{\partial \xi_1} = (w_n - c_n)\frac{\partial q_n^N}{\partial \xi_1} + f \frac{\partial q_n^N}{\partial \xi_2}$$

$$\frac{\partial M_1^N}{\partial \xi_2} = \frac{\theta (1-c_n)N-c_r-p\zeta_2}{16\theta (1-\theta)(1+\zeta_1+\zeta_2)^2}$$

where: $M = (\theta c_n-c_r-p)(1+\zeta_1+2\zeta_2(1+c_r+p-\theta-c_n)N = (\theta c_n-c_r-p)(1-\zeta_1)$. Based on proposition 3, obviously,

$$\frac{\partial M_1^N}{\partial \xi_1} < 0, \lim_{\xi_1 \to 0} \frac{\partial M_1^N}{\partial \xi_2} < 0, \lim_{\xi_1 \to 1} \frac{\partial M_1^N}{\partial \xi_2} > 0; \frac{\partial M_1^N}{\partial \xi_1}, \frac{\partial M_1^N}{\partial \xi_2}$$

The certification of other members and system is the same as the manufacturer. The proposition 4 is proved.

Proposition 4 indicates that: When the manufacturer and the remanufacturer do not consider the retailer’s fairness concerns, the remanufacturer’s profits decrease with vertical one and vertical two fairness concerns. The manufacturer’s, the retailer’s and the system’s
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profits decrease with vertical one fairness concerns; the effect of the vertical two fairness concerns on the manufacturer’s, the retailer’s and the system’s profits is affected by vertical one fairness concerns: When the degree of vertical one fairness concerns is towards 0, the manufacturer’s, the retailer’s and the system’s profits decrease with vertical two fairness concerns, on the contrary, the manufacturer’s, the retailer’s and the system’s profits increase with vertical two fairness concerns. Vertical one fairness concerns has a higher impact on the profits of each members and system than vertical two fairness concerns. The retailer’s bidirectional fairness concerns reduces the profits of each members and system.

4.3. Comparative analysis

Proposition 5. Comparing the profits of each members and system in three situations, including: unfairness concerns, the manufacturer and the remanufacturer consider the retailer’s fairness concerns, the manufacturer and the remanufacturer not consider the retailer’s fairness concerns.

(1) \( \Pi_M^D > \Pi_M^F > \Pi_M^N \);
(2) \( \Pi_R^D > \Pi_R^F > \Pi_R^N \);
(3) \( \Pi_R^F > \Pi_R^D > \Pi_R^N \);
(4) \( \Pi_c^D = \Pi_c^F > \Pi_c^N \);

Proof: take the manufacturer as an example.

\[
\Pi_M^D - \Pi_M^F = \frac{(bc_n - c_r - p)^2 + 2(1-\theta)(1-\theta)(1-c_n)^2}{16(1-\theta)(1+2\zeta_1+\zeta_2)}.;
\]

\[
\Pi_M^F - \Pi_M^N = \frac{(bc_n - c_r - p)^2 (3\zeta_1^2 + 3\zeta_1^2\zeta_2 + \zeta_1^2 + \zeta_2^2 + \zeta_1 + \zeta_2 + 2\zeta_1^2\zeta_2 + \zeta_1 + \zeta_2)^2}{16(1-\theta)(1+2\zeta_1+\zeta_2)(1+\zeta_1+\zeta_2)}.;
\]

Obviously, \( \Pi_M^D - \Pi_M^F > 0, \Pi_M^F - \Pi_M^N > 0 \). The certification of other members and system is the same as manufacturer. The proposition 5 is proofed.

Proposition 4 indicates that: When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, the profits of each members and system are greater than the profits when the retailer’s fairness concerns is not considered. Compared with the profits under unfairness concerns, the retailer’s fairness concerns reduces the profits of the manufacturer and the remanufacturer, increases its own profits, and keeps the total profit of the system unchanged.

6. Conclusion

This paper builds a closed-loop supply chain consists of the manufacturer, the remanufacturer and the retailer, background in which the manufacturer patent licensing the remanufacturing activity to the remanufacturer, to study the impact of the retailer’s bidirectional fairness concerns on closed-loop supply chains. Get the following conclusion.

(1)When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, the demand of new and remanufactured products are not affected by the retailer’s fairness concerns. When the manufacturer and the remanufacturer not consider the retailer’s fairness concerns, the retailer’s bidirectional fairness concerns reduces the demand of new and remanufactured products, where, vertical one fairness concerns has a higher impact on the demand of new and remanufactured products than vertical two fairness concerns.
(2)When the manufacturer and the remanufacturer consider the retailer’s fairness concerns, the retailer’s bidirectional fairness concerns increases its own profit but decreases the profit
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of the manufacturer and the remanufacturer, where, vertical one fairness concerns has a
greater impact on the profit of the manufacturer and the retailer than vertical two fairness
concerns, vertical two fairness concerns has a greater impact on the profit of the
remanufacturer than vertical one fairness concerns. When the manufacturer and the
remanufacturer not consider the retailer’s fairness concerns, the retailer’s bidirectional
fairness concerns decreases the profit of each members and system, where, vertical one
fairness concerns has a greater impact on the profit of each members and system than
vertical two fairness concerns.

Through the above conclusions, we can get the following related management
lessons:
The retailer’s fairness concerns from the manufacturer has a much greater impact on the
demand of products (especially the demand of remanufactured products) and the profit of
system than its fairness concerns from the remanufacturer. Therefore, focusing on
managing the retailer’s fairness concerns from the manufacturer can effectively reduce the
losses to closed-loop supply chains caused by fairness concerns.

The research in this paper is based on the single-cycle closed-loop supply chain model,
and the conclusions obtained are limited. Further research can extend the period of the
model to multiple cycles, so that the conclusions of the study can be better applied to the
actual situation.

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