Pricing Decisions in Closed-Loop Supply Chains With Multiple Fairness-Concerned Collectors

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ABSTRACT In the same model, both distributional fairness concern and peer-induced fairness concern are considered, so are the absolute fairness concern and the relative fairness concern. When there are multiple recycling markets, collectors attach importance not only to the fairness distribution of profit with the manufacturer (distributional fairness concern), but also to the fairness distribution of profit with the peer collector (peer-induced fairness concern). On the basis of the perspective of the collectors, this article introduces distributional and peer-induced fairness concern into the closed-loop supply chain (CLSC). The impact of the collectors’ different fairness concerns on the CLSC pricing decisions is discussed under five models. The research shows that: (1) When the manufacturer considers the collectors’ fairness concern, the manufacturer’s profit and distributional fairness concern coefficient change inversely, and the collectors’ profit and distributional fairness concern coefficient move together, that is, the distributional fairness concern is of advantage to the collectors but not good for the manufacturer. On the contrary, the manufacturer’s profit and peer-induced fairness concern coefficient move in the same direction, while the profit of the collectors and peer-induced fairness concern coefficient change in opposite direction; (2) As long as the manufacturer considers the fairness of the collectors, the profit of the collector who pays attention to both fairness is always lower than that of the collector who only concerns distributional fairness, so peer-induced fairness concern is not a self-interest behavior. However, when the appeal of the two collectors for fairness distribution is not considered by the manufacturer, peer-induced fairness concern benefits himself; (3) The two-part Tariff contract has realized the coordination of the CLSC. Additionally, our findings provide some managerial insights on the pricing decision when the collectors consider multiple fairness concerns.

INDEX TERMS Closed-loop supply chain, distributional fairness concern, peer-induced fairness concern, absolute fairness concern, relative fairness concern, two-part Tariff contract.

I. INTRODUCTION

People’s longing for a better life is always subject to a worse and worse living environment, and the various walks of life have gradually realized the significance of the environment for sustainable development, which requires closed-loop supply chain (CLSC) managers to shift part of their energy from the original forward sales channel to the reverse channel responsible for the recycling of used products so as to perform the responsibility of recycling used products. The recycling activities of used products have mainly gone through two stages. The first is the passive recycling stage, where some major countries in the world have issued laws and regulations on the recycling of used products, requiring manufacturers to recycle a certain percentage of used products [1]–[5]. Secondly, in the active recycling stage, most enterprises have gradually realized the profitability of recycling activities, through which the enterprises not only gain more economic benefits, but also establish a good reputation, thus enhancing the competitiveness and providing conditions for
the sustainable development of the enterprise [6]–[8]. Given the pressure of laws and regulations and the profitability of recycling activities, collectors play an increasingly pivotal role in the CLSC, and their pricing decisions will inevitably cause changes in the equilibrium solution of the CLSC. Therefore, this article studies the pricing decision of the CLSC from the perspective of collectors.

In supply chain management, fairness concern is a factor that cannot be ignored by decision makers. For example, Scheer et al. [9] conducted in-depth investigations and visits to hundreds of car dealers in the United States and the Netherlands respectively, and found that when haggling with each other, the decision makers would pay attention to their own gains in trade activities. In 2010, many dealers found unfair product pricing in the cooperation, and terminated the cooperation with P&G. Additionally, LANSWE group had to terminate the cooperation in 2007 because its interests were not considered by WalMart. Many researchers have also demonstrated the existence of fairness concern and its influence on decision makers through experimental research [10]–[15].

In a one-to-many the CLSC system, on the one hand, decision makers will concern the fairness of distribution between their own profits and vertical decision makers, that is, distributional fairness. On the other hand, decision makers will also take account of the profit gap from horizontal peers, that is, peer-induced fairness. Ho and Su [16] proposed the concept of peer-induced fairness. By designing experimental schemes, it was found that the decisions of game participants are more affected by peer-induced fairness concern than by distributional fairness concern. Shi and Zhu [17] obtained the same conclusion as Ho and Su [16] through theoretical research under the premise that retailers had peer-induced fairness concern. Therefore, it is more theoretical and practical to carry out peer-induced fairness concern to the influence of decision-making of the CLSC.

At present, most research is related to the impact of fairness concerns on the supply chain operation acquiesce in that the manufacturer or the retailer is in the position of price leadership. When the return rate of the used products in the CLSC must reach the indicators stipulated by the relevant laws and regulations, the collectors who bear responsibility for the recycling activities play an important role in the CLSC, and the collectors also aspire to be treated fairly [18]. The collectors will not only pay attention to the fairness of the profit distribution with the manufacturer, but also to comparison of the profits with the peer collector [19].

For example, the original raw material (used paper) of Nine Dragons Paper (Holdings) Co., Ltd. founded in July 1998, mainly originated from overseas markets. With the sale of various types of paper produced in the domestic market, as well as the company’s development demand, Nine Dragons Paper has opened up two recycling markets at home and abroad. Certainly, there are many companies with multiple recycling markets like Nine Dragons Paper, which are not listed here. Based on the research needs of this article, assuming that the market information is symmetrical, the domestic market collector will pay attention to both the fairness of profit distribution with Nine Dragons Paper and the fairness of profit distribution with the collector from foreign counterparts. That is, the collector will pay attention to the fairness of profit distribution with the manufacturer, and will also concern the fairness of profit distribution with the peer collector. How collectors’ multiple fairness concerns affect the balanced solution of the CLSC is the core of this study.

To investigate the influence of fairness concern of collectors on decisions of the CLSC, this article concentrates on a CLSC composed of one manufacturer, one retailer and two collectors. Combining with observations from current practice and the extant literature, five models are considered: (1) the centralized decision-making model C; (2) the model TY in which collectors are fairness-concerned and the manufacturer considers (passive) the fairness concern of collectors; (3) the model TN in which collectors are fairness-concerned but the manufacturer doesn’t consider the fairness concern of collectors; (4) the model NN in which collectors are not fairness-concerned but the manufacturer doesn’t consider the fairness concern of collectors; (5) and the model NY in which collectors are not fairness-concerned but the manufacturer considers (active) the fairness concern of collectors.

First, the distributional fairness concern and peer-induced fairness concern are simultaneously introduced into the CLSC to fill the existing research gap. In addition, When the collectors do not have fairness concern, the manufacturer “actively” considers the collectors’ fairness concern, which is manifested by the manufacturer’s “active” concern for the collectors. Third, in the same model, both distributional fairness concern and peer-induced fairness concern are considered, so are the absolute fairness concern and the relative fairness concern. It is a supplement to the existing investigations. The last, when the game can be repeated, the decision of the players can be adjusted appropriately, so that the equilibrium solution of the system will change.

In a deeper sense, our work has enriched the research results that consider the factors of the decision makers’ behavior in the CLSC. The rest parts of the paper are organized as follows: the next part talks about the relative literature review. Question description and model hypothesis are proposed in the third part. The fourth part studies the equilibrium solution under the five models. The incentive contracts are given in the fifth part. The sixth part gives the evolution analysis of equilibrium strategies. The last part provides the numerical analyses and summarizes the conclusions.

II. LITERATURE REVIEW

The paper is mainly inspired by two aspects of literature, which will be reviewed separately below.

In the field of fairness concern, Yang et al. [20] believed that the retailer’s fairness concern brought disadvantages to him. Pu et al. [21] found that the retailer’s fairness concern could strongly influence the manufacturer’s decisions...
and negatively affect the expected profits. Zhang et al. [22] showed that government subsidies could mitigate the losses caused by the fairness concern of the retailer. Li et al. [23] proved that the fairness concern of the retailer was beneficial, and the impact of fairness concern on the retailer and the manufacturer was of disparity. Zhou et al. [24] argued that supply chain coordination had nothing to do with whether the retailer was fairness-concerned. Qin et al. [25] further studied the value of the retailer’s fairness concern to the supply chain under symmetrical and asymmetrical fairness concern information. The mutual profit decreased with the increase in fairness concern level, and the conclusion that the profit loss was bigger under information symmetry was obtained. These studies indicate that the retailer’s fairness concern can impact supply chain decisions. There are also some studies on the basis of the manufacturer’s fairness concern. For example, Li et al. [26] revealed that the impact of the manufacturer’s fairness concern on supply chain decisions was related to the market share of retailers. Li et al. [27] held that the size of the fairness concern of both parties would affect the effectiveness of the channel, while the fairness concern of the retailer would do more damage to the stability of the system. These studies present that whether it is the fairness concern of the retailer or the manufacturer will affect supply chain decisions. However, these studies all focus on absolute fairness concern, directly viewing the other party’s profits or multiples of profits as the fairness reference point, and not considering the strength and contribution of the players. Chen et al. [28] used the Nash bargaining solution as a fairness reference point and found that supply chain performance was positively related to fairness concern. Du et al. [29] drew the opposite conclusion on the newsboy problem. The fairness concern of both parties led to a reduction in the efficiency of the supply chain. Wei et al. [30] found that the impact of fairness concern on the manufacturer and the retailer depended upon the level of attention. This research work considered the strength and contribution of both parties, who considered relative fairness and were more reflective of reality. But these studies only considered the impact of distributional fairness concern on decision-making.

Ho and Su [16] first proposed the concept of peer-induced fairness, which validated through experiments that people cared more about comparisons with their peers. A new research direction has been opened up, and researchers in all walks of life have begun to discuss the impact of peer-induced fairness on the decision-making of game participants. Ho et al. [31], Shi and Zhu [17] found that considerable attention to peers was always harmful to the participants. Du et al. [32] promoted the research results of Ho et al. [31], Retailer 2 not only sympathized with the peers, but also had the heart of gloating. Studies have shown that the retailer’s profit and performance would be improved because of sympathy with peers, and losses would be incurred by gloating peers, which provides practical guidance for supply chain management. Nie and Du [33] thought that different members concerned with fairness had differential coordination conditions in terms of horizontal and vertical fairness. Zhang and Wang [34] also found that the impact of multiple fairness concern on decisions was inconsistent in the dual-channel supply chain. Shu et al. [19] considered peer-induced fairness concern in the CLSC and came to the identical conclusion as Ho et al. [31]. Peer-induced fairness concern placed the participants at a disadvantage.

This article differs from Li et al. [27] in that two different fairness concerns are considered in the same model. Meanwhile, both absolute fairness concern and relative fairness concern are taken into account.

In the field of supply chain coordination, that the players have different decision-making goals often contributes to the “double marginalization” and makes the supply chain inefficient, which makes the supply chain inefficient. So decision-makers are required to design a series of contracts to enhance the efficiency of the supply chain, such as Cachon [35], Giannoccaro and Pontrandolfo [36], Revenue sharing contract is a contract method commonly used by most researchers. For example, Govindan and Popiuc [37] designed revenue sharing contracts for the two-echelon and tertiary reverse supply chains, respectively, to improve channel performance. Zeng [38] portrayed consumers’ return behavior and achieved a win-win situation through a revenue sharing contract. There are other forms of contracts that can also achieve the purpose of improving the profits of various parties. For example, the quantity discount contract designed by Huang et al. [39] can address the problem of false returns. Walther et al. [40] made the recycling network meet the requirements of environmental protection regulations through a negotiation mechanism. Guan et al. [41] found that when the Nash bargaining game was launched between upstream manufacturers and downstream retailers, if the sharing rate was high, the revenue-cost sharing contract could raise channel efficiency. Shu et al. [19] realized the coordination of the CLSC through the Two-Part Tariff contract under the asymmetry information of fairness concern of collectors.

To sum up, the existing literature on the fairness concern of the members of the supply chain is all focusing on the case where one party considers the fairness concern, whether the other party considers this fairness. There is no literature yet when one side does not pay attention to the fairness of distribution, the other side actively considers that the other side is fairness-concerned. In order to fill this gap, supported by game theory methods, the impact of distributional fairness concern and peer-induced fairness concern on pricing decisions of the CSLS is explored under five models from the perspective of collectors.

### III. QUESTION DESCRIPTION AND MODEL HYPOTHESIS

#### A. QUESTION DESCRIPTION

The two collectors are located in different recycling markets. Since there are no benchmarks for collector $T_1$, who only focuses on the fairness of income distribution with the
manufacturer, and the strength and contribution of the collector and the manufacturer are not equal. Therefore, Nash bargaining solution is used as a reference point for fairness distribution, which can reflect the strength of both parties and their contribution to the alliance, is relative fairness. Collector $T_1$ as a reference standard collector $T_2$ who not only pay attention to the profit gap with the manufacturer (distributional fairness), but also pay attention to the gap in profit distribution with the peer collector $T_1$ (peer-induced fairness). For the convenience, it is assumed that the strength of the two collectors is equal, so the collector $T_1$ directly use the profits of the collector $T_1$ as a fair reference point, and absolute fairness is considered. This article will consider both relative fairness concern and absolute fairness concern in the same model, both distributional fairness concerns and peer-induced fairness concerns. See the appendix for all proofs.

B. MODEL ASSUMPTION

In order to facilitate the research, let’s first make the following statements.

The symbols $M$, $R$ and $T_i$ represent the manufacturer, the retailer, and the collectors, respectively, $i = 1, 2$. Subscript “sc” represents the supply chain decision, superscript “w” expresses the optimal solution, superscript “l” represents the model $l$, $l \in \{C, TY, TN, NY, NN\}$ and $C$ represents a centralized decision-making model; $TY$ represents a model in which the collectors are fairness-concerned and the manufacturer is “forced” to consider the collectors’ fairness concern; $TN$ represents a model in which the collectors are fairness-concerned, and the manufacturer does not consider the collectors’ fairness concern; $NY$ represents a model where the collectors are not fairness-concerned, the manufacturer “actively” considers the collectors’ fairness concern; $NN$ indicates a model where the collectors are not fairness-concerned and the manufacturer does not consider the collectors’ fairness concern. When $l \in \{TY, TN, NY, NN\}$, $\pi_{M}^l$, $\pi_{R}^l$ and $\pi_{T_i}^l$ represent the profits of the manufacturer, the retailer, and the collector under the model $l$, respectively, and when $l \in \{TY, TN\}$, $u_{T_i}^l$ represents the utility of the collector under the model $l$. Note that the fairness concern here refers to distributional fairness concern for collector $T_1$, but for collector $T_2$, which includes both distributional fairness concern and peer-induced fairness concern.

Hypothesis 1: The two recycling markets are independent, and the recycling quantity of the collector $T_i$ is determined by his recycling price, ie.

$$G_i = h_i + A_i \ (i = 1, 2).$$

(1)

Among them $h_i$ is the amount of used products obtained by collector $T_i$ without paying any recycling fees, reflecting consumers’ environmental awareness.

textbf{Hypothesis 2.} $D(p)$ is the demand function, which decreases with the retailer’s sales price, ie:

$$D(p) = a - bp.$$  \hspace{2cm} (2)

where $a$ represents the markets benchmark capacity, $b$ represents the price sensitivity coefficient, and $p$ represents the retail price which is the retailer’s decision variable.

Hypothesis 3: The cost of the manufacturer using raw materials to produce new products is $c$, the cost of remanufacturing with recycled products is $c_r$, the unit cost savings is $\Delta = c - c_r$ which represents the unit cost savings from the remanufacturing process of recycling used products, and the return rate of used products is $r_{sc}$, $r_{sc} = G/D$. $A_i$ represents the recycling price of collector $T_i$ and is the decision variable of collector $T_i$. $w$ is the wholesale price, $B$ is the transfer payment, both of which are the manufacturer’s decision variables. To ensure that all parties are profitable, it needs to meet $A_i < B < \Delta$.

Hypothesis 4: There will be no loss in the recycling and remanufacturing of used products, that is, the conversion rate of used products into new products is 1.

Hypothesis 5: Assuming that the new product and the remanufactured product are completely replaceable, the sales price in the market is the same, that is, the product produced using the new material and the remanufactured product are homogeneous products and are sold on the market at the same price.

Hypothesis 6: The Stackelberg game is conducted among members of the CLSC, with the manufacturer as a leader and the retailer and the collectors as followers. The manufacturer and the retailer are fairness-neutral, both of whom pursue profit maximization, and when paying fairness concern, the collectors pursue profit and utility maximization.

From the above assumptions and descriptions, the objective functions of the manufacturer $M$, the retailer $R$ and collector $T_i$ are as follows:

$$\begin{align*}
\max_{B, w} \pi_{M} &= (w - c)D + \sum_{i=1}^{2} (\Delta - B)G_i, \\
\max_{p} \pi_{R} &= (p - w)D, \\
\max_{A_i} \pi_{T_i} &= (B - A_i) G_i.
\end{align*}$$

IV. PRICING DECISIONS IN A CLSC WITH FAIRNESS CONCERN

As a single decision maker, the retailer does not consider the fairness of the alliance. This article only considers that the alliance members of the manufacturer and the two collectors. Two collectors are distributional fairness-concerned, collector $T_2$ has extra tendency to peer-induced fairness concern. Therefore, in this game, two rounds of games are played. It should be noted here that fairness concern of the collectors only pay attention to the profit of remanufacturing part by the manufacturer. According to the calculation method of Shu et al. [19], the utility under the fairness concern of the collectors can be obtained as follows:

$$u_{T_1}^{FY} = (1 + \lambda)(\frac{2}{2 + \lambda} \pi_{T_1}^{FY} - \frac{\lambda}{2 + \lambda} \pi_{MT_1}^{FY}).$$

(3)

$$u_{T_2}^{FY} = \frac{1 + \theta + \lambda}{2 + 2\theta + \lambda} [2(1 + \theta)\pi_{T_1}^{FY} - 2\theta \pi_{T_1}^{FY} - \lambda \pi_{MT_1}^{FY}].$$

(4)
A. THE MODEL C
Under the centralized decision model C, the manufacturer, the retailer and the collectors jointly determine the optimal decision of the system. And the wholesale price and transfer payment are endogenous variables, which will not cause the change of system profit. At this time, the profit of the CLSC system is:

$$\max_{p, A_j} \pi_{sc} = (p - c)D + \sum_{i=1}^{2} (\Delta - A_i)G_i.$$  

**Proposition 1:** Under model C, the optimal pricing decisions of the system are:

$$p_{C*} = \frac{a + bc}{2b}, \quad A_{j*} = \frac{\Delta - h_j}{2}.$$  

**Proof:** To improve the readability of the paper, see the Appendix for all proofs.

B. THE MODEL NN
Under the model NN, the collectors don’t consider the profit gap with the manufacturer, and the manufacturer doesn’t pay attention to the collectors’ income, each of whom pursues the maximization of change of system profit. At this time, the profit of the collector is:

Under the model NN, the optimal pricing decisions of the system are:

$$w_{NN*} = \frac{a + bc}{2b}, \quad p_{NN*} = \frac{\Delta - h_j}{2},$$  

$$A_{j*} = \frac{\Delta - 3h_j}{4}.$$  

**Corollary 1:** Under model NN, the optimal pricing decisions of the system are:

$$A_{j*} = \frac{\Delta - h_j}{2}.$$  

**Corollary 2:** Under the model NN, the optimal transfer payment and the optimal recycling price of the collector $T_1$ are:

$$B_{1*} = \frac{(1 + \lambda - h_1)}{2 + \lambda}, \quad A_{1*} = \frac{\Delta - 3h_1}{4}.$$  

**Corollary 3:** Under the model NN, the optimal recycling price of the collector $T_2$ is:

$$B_{2*} = \frac{(1 + \lambda + \theta - (1 + \theta)h_2}{2 + 2\theta + \lambda}, \quad A_{2*} = \frac{\Delta - 3h_2}{4}.$$  

C. THE MODEL TY
Regardless of whether it is the first round or the second round of the game, in the model TY, when the collectors have fairness concern, the manufacturer “passively” considers the collectors’ distributional fairness concern.

**Proposition 3:** Under model TY, (1) In the first round of the game, the optimal transfer payment $B_{1*}$ of the manufacturer and the optimal recycling price $A_{1*}$ of the collector $T_1$ are:

$$B_{1*} = \frac{(1 + \lambda - h_1)}{2 + \lambda}, \quad A_{1*} = \frac{\Delta - 3h_1}{4}.$$  

(2) In the first round of the game, the optimal transfer payment $B_{1*}$ of the manufacturer and the optimal recycling price $A_{1*}$ of the collector $T_1$ are:

$$B_{1*} = \frac{(1 + \lambda - h_1)}{2 + \lambda}, \quad A_{1*} = \frac{\Delta - 3h_1}{4}.$$  

Corollary 2: (1) \( \frac{\partial B_{1*}}{\partial \lambda} > 0, \frac{\partial B_{1*}}{\partial h_2} > 0, \)  

$$B_{1*} > B_{1*}^{NN*}, \quad \frac{\partial B_{1*}}{\partial \theta} < 0;$$  

Corollary 4: The profit of the CLSC remains unchanged with the collector’s fairness concern coefficient, i.e. $\pi_{sc*}^{NN*} = \pi_{sc*}^{TN*}$. It’s just that profit is redistributed between the manufacturer and the collectors.

D. THE MODEL TN
Under the model TN, the collectors’ appeal to fair distribution of profits can’t be responded by the manufacturer, which
causes two sides to have conflicts and making pricing decisions according to different models.

**Proposition 4:** Under model TN, (1) In the second round of the game, the optimal transfer payment \( B_{2TN}^* \) of the manufacturer and the optimal recycling price \( A_{2TN}^* \) of the collector \( T_2 \) are:

\[
B_{2TN}^* = \frac{\Delta - h_2}{2}, \\
A_{2TN}^* = \frac{(2 + 2\theta - \lambda)\Delta - (6 + 6\theta + \lambda)h_2}{8(1 + \theta)}.
\]

(2) In the first round of the game, the optimal transfer payment \( B_{1TN}^* \) of the manufacturer and the optimal recycling price \( A_{1TN}^* \) of the collector \( T_1 \) are:

\[
B_{1TN}^* = \frac{\Delta - h_1}{2}, \\
A_{1TN}^* = \frac{(2 - \lambda)\Delta - (6 + \lambda)h_1}{8}.
\]

**Corollary 5:** (1) \( \frac{dA_{1TN}^*}{d\lambda} < 0 \), \( \frac{dA_{2TN}^*}{d\theta} < 0 \), \( \frac{dA_{2TN}^*}{d\theta} > 0 \);

(2) When \( h_1 = h_2 = h \), \( A_{1TN}^* < A_{2TN}^* \);

(3) \( \frac{d\lambda_{sc}}{d\theta} < 0 \), \( \frac{d\lambda_{sc}}{d\theta} > 0 \).

Corollary 5 suggests that under the model TN, (1) the recycling price changes in the opposite direction of the distributional fairness coefficient, because the manufacturer does not consider the fairness concern of the collectors, and the collectors indirectly "punish" the manufacturer. In addition, the recycling price of the collector \( T_2 \) changes in the same direction with peer-induced fairness coefficient, that is, the more the collector \( T_2 \) pays attention to the peer, the more he worries about his own profit lower than that of the peer collector, so the collector \( T_2 \) raises the recycling price to increase the recycling volume to generate the income.

(2) If the two independent markets are identical, the recycling price of the collector \( T_2 \) is higher than that of the collector \( T_1 \), which makes the collector \( T_2 \) in a disadvantageous position. The reason is that collector \( T_2 \) doesn’t want his profit to be lower than that of the collector \( T_1 \).

(3) When the collectors’ fairness concern can’t be replied by the manufacturer, the more the collectors pay attention to the distribution fairness, the lower the return rate is. The collector \( T_2 \) would rather sacrifice some of the revenue, that is, increase the recycling price, thus promoting the return rate of the CLSC.

**Corollary 6:** (1) \( \frac{d\pi_{TN}^*}{d\lambda} < 0 \), \( \frac{d\pi_{TN}^*}{d\theta} > 0 \);

(2) \( \frac{d\lambda}{d\lambda_{T1}} < 0 \), \( \frac{d\lambda}{d\lambda_{T2}} < 0 \), \( \frac{d\lambda}{d\theta} > 0 \).

Corollary 6 shows that under the model TN, (1) because the collectors’ appeal to fair distribution is not considered by the manufacturer, the collectors indirectly "punish" the manufacturer by reducing the recycling price, so the manufacturer’s profit changes in the opposite direction with the distributional fairness concern coefficient, but that the collector \( T_2 \) has peer-induced fairness concern benefit the manufacturer instead.

(2) With the increase in the distributional fairness concern coefficient, the collectors lower the recycling price, resulting in a reduction in the recycling amount and consequently a decrease in profits. In the meantime, with the increase in the peer-induced fairness concern coefficient, the more the collector \( T_2 \) worries that the revenue is lower than the first collector’s, so the collector \( T_2 \) raises the recycling price, thus making the amount of recycling and the profit increases.

**E. THE MODEL NY**

Under the model NY, the collectors do not care about how much the manufacturer gets, and collector \( T_2 \) is unconcerned about the profitability of the collector \( T_1 \), but the manufacturer will still “actively” care about the collectors, thinking that collectors pay attention to the fairness of revenue distribution. What needs to be pointed out here is that the manufacturer thinks that collector \( T_2 \) pays attention to both distributional fairness and peer-induced fairness.

**Proposition 5:** Under the model NY, the optimal pricing decisions of the system are:

\[
B_{1NY}^* = \frac{(1 + \lambda)\Delta - h_1}{2}, \\
A_{1NY}^* = \frac{(1 + \lambda)\Delta - (3 + \lambda)h_1}{2(2 + \lambda)}, \\
A_{2NY}^* = \frac{(1 + \theta + \lambda)\Delta - (1 + \theta)h_2}{2(2 + \theta + \lambda)},
\]

(2) \( A_{1NY}^* > A_{1TY}^* \); \( i = 1, 2 \);

(3) \( \frac{d\lambda_{sc}}{d\theta} > 0 \), \( r_{NY} > r_{TY} \).

Corollary 7 shows that (1) Although the collectors are not concerned about the fairness of the profit distribution with the manufacturer, the latter “actively” increases the transfer payment. After receiving an “unexpected” surprise, the collectors also increase the recycling price to indirectly “reward” the manufacturer, but the manufacturer considers that the collector \( T_2 \) also pays attention to the peer-induced fairness, so the transfer payment offered by the manufacturer to the collector \( T_2 \) will be reduced, and the collector \( T_2 \) will also reduce the recycling price.

(2) Since the collectors have received the “accidental” concern from the manufacturer, they will be more active than in the model TY.

(3) The recycling price of the collectors increases, leading to an increase in the return rate of the CLSC, which has a positive impact on the sustainable development of enterprises.

**Corollary 8:** (1) \( \frac{\partial \pi_{NY}^*}{\partial \theta} < 0 \), \( \frac{\partial \pi_{NY}^*}{\partial \theta} > 0 \);

(2) \( \frac{\partial \lambda_{MT}}{\partial \theta} < 0 \), \( \frac{\partial \lambda_{MT}}{\partial \theta} > 0 \).

Corollary 8 shows that under the model NY, (1) the impact of distributional fairness concern on the manufacturer’s profit
is greater than peer-induced fairness concern, that is, the manufacturer cares more about distributional fairness concern.

(2) The manufacturer pays attention to the distributional fairness of the collectors, which will reduce his profit, but because collector $T_2$ pays attention to peer-induced fairness, which always make himself in a passive position, the profit of the remanufactured part of the manufacturer increases with the increase of the peer-induced fairness concern coefficient.

\[ \frac{d\pi_{TY}^*}{dT_2} > 0, \quad \frac{d\pi_{TY}^*}{T_2} > 0, \quad \frac{d\pi_{TY}^*}{\theta} < 0; \]

\[ M\pi_{TY}^* > M\pi_{TY}^{*-T_2}, \quad M\pi_{TY}^{*-T_2} < M\pi_{TY}^*; \]

Corollary 9 presents that (1) If the manufacturer devotes more attention to the distributional fairness, the profit of the collectors will become higher. But if he pays more attention to the peer-induced fairness, the collector $T_2$ becomes smaller.

(2) After being actively cared about by the manufacturer, the collectors will show a more positive attitude, whose marginal impact is greater than that in model TY, which is the same with the peer-induced fairness concern, but after the peer-induced fairness concern makes the recycling price increase, the profit of the collector $T_2$ drops.

\[ \frac{d\pi_{TY}^*}{dT_2} > 0, \quad \frac{d\pi_{TY}^*}{T_2} > 0, \quad \frac{d\pi_{TY}^*}{\theta} < 0. \]

Corollary 10 makes it clear that the manufacturer knows that concerning the fairness of the collectors will cause his own profit to be lost, but because of his “active” attention, the collectors are more positive, and greatly increases the recycling price, which makes the increased profit by the collectors larger than the lost profit by the manufacturer, so the supply chain profit has increased, but the collector $T_2$ will reduce the recycling price due to the peer-induced fairness concern, so the supply chain profit will change in the opposite direction with the peer-induced fairness concern coefficient.

**Corollary 11:** Whether it is in the model TY, model TN, or model NY, the peer-induced fairness concern leaves the pricing decisions of collector $T_2$ in a passive position.

**F. COMPARATIVE ANALYSES OF EQUILIBRIUM SOLUTIONS**

**Corollary 12:**

1. $A_i^{TY} < A_i^{NY} < A_i^{TY*} < A_i^{CS}, \quad i = 1, 2$;

2. $B_i^{TY} < B_i^{NY} < B_i^{TY*} = B_i^{TY}, \quad i = 1, 2$;

3. $r_{sc}^{TY} < r_{sc}^{CS} = r_{sc}^{NY} = r_{sc}^{TY*} < r_{sc}^{NY}$.

Corollary 12 shows that (1) Under the model C, double-marginalization disappears, and the recycling price is the largest. Moreover, after receiving the active attention of the manufacturer, the collectors more actively participate in the recycling activities, and the recycling price is greater than when their own fairness concern is considered by the manufacturer. Eventually, when the collectors’ fairness concern is not accepted by the manufacturer, they also passively carry out the recycling activity, thus the recycling price is the lowest.

(2) As a leader of the channel who has the initiative to set prices, the manufacturer must either consider the fairness concern of the collectors or not. Obviously, when considering the fairness concern of the collectors, the manufacturer will increase the transfer payment to shift part of the profit to the collectors. Therefore, the transfer payment when considering collectors’ fairness concern is greater than that when not considering.

(3) After acquiring the manufacturer’s “unexpected” care, the collectors show an active recycling strategy, which leads to an increase in the recycling amount, so the return rate is the largest, but the fairness concern of the collectors is not responded by the manufacturer, the recycling price is the smallest, so the return rate is the lowest.

**V. COORDINATION CONTRACT UNDER THE MODEL TY**

In order to achieve Pareto improvement of the CLSC, the two-part Tariff contract are proposed here. Since this article considers retailers as independent decision makers, the retailer’s decisions in the incentive contract will not change.

Assuming that the contract provided by the manufacturer to the collector $T_i$ is $(F_i, B_i^r)$, $F_i$ represents the franchise fee paid by the collector $T_i$ to the manufacturer, in order to obtain the right to provide recycling services specifically for the manufacturer. $B_i^r$ stands for transfer payment under the incentive contract. And with the superscript “‘r” to indicate the decision under the incentive contract, the decision model of the manufacturer and the collectors is:

**Proposition 6:** Under the incentive contract provided by the manufacturer, the CLSC system equilibrium solutions are:

\[ F_i^r = \Delta, \quad A_i^r = \Delta - h_i \]

\[ F_2^r = \frac{3(1 + \theta)(2 + \lambda)(\Delta + h_2)^2 - \lambda \theta(\Delta + h_2)^2}{8(2 + \lambda + 2 \theta + \lambda)}. \]

**Corollary 13:** $r_{sc}^{TY} < r_{sc}^{CS} = r_{sc}^{NY} < r_{sc}^{TY*} < r_{sc}^{NY}$. Corollary 13 manifests that the proposed two-part Tariff contract are effective, under which the profit of the manufacturer and the collectors are promoted, so is the return rate, which is conducive to environmental protection and sustainable development of enterprises.

**VI. NUMERICAL SIMULATION**

In the previous section, the two-part Tariff contract was proposed to improve the efficiency of the CLSC. In this section, numerical examples will be employed to verify the effectiveness of the two-part Tariff contract, and the impact of two fairness concerns on decisions of the CLSC will be studied. In this example, the basic parameter values are set as $a = 1000$, $b = 1$, $h_1 = h_2 = 10$, $c = 120$, $c_r = 40$, $\Delta = 80$.

**A. THE IMPACT OF DISTRIBUTIONAL FAIRNESS CONCERN ON THE SUPPLY CHAIN**

When the peer-induced fairness concern coefficient remains unchanged ($\theta = 0.4$), under the model TN, the collectors’ appeal to fair distribution cannot be considered by the manufacturer, so the manufacturer’s transfer payment remains
unchanged (as shown in Figure 1-2). After receiving the manufacturer’s unchanged transfer payment, the collectors know their fairness concern is not taken into account, and a decision to significantly reduce the recycling price will be made to indirectly “punish” the manufacturer (as shown in Figure 3-4), and the return rate will decrease (as shown in Figure 5). Used products cannot be recycled effectively, causing harm to the environment.

On the contrary, under the model NY, the collectors are not fairness-concerned, but have received “accidental” attention from the manufacturer (as shown in Figure 1-2). In order to “reward” the manufacturer, the collectors raise the recycling price to form a “reciprocity” situation. The performance of the collectors is more positive than their fairness concern to be recognized by the manufacturer (as shown in Figure 3-4).

Regardless of whether the manufacturer “actively” considers the distributional fairness of the collectors’ (model NY) or passively (model TY), the profit of the manufacturer will be lost. Distributional fairness concern is a profit-making behavior of the manufacturer, which is a more profitable method for the collectors, but compared with the “passive” consideration, the “active” consideration is less loss, which is also an “indirect” profit method for the manufacturer (see Figure 6). Under model NY and model TY, the profit of the collectors changes in the same direction as the distributional fairness concern coefficient (see Figure 7-8). Under the model NY, since the collectors take a more active part in the recycling activity, the increased profit is greater than the
manufacturer’s loss, so the gross profit of the CLSC increases (see Figure 9). Under the two-part Tariff contract, the profit of the manufacturer and the collectors has reached Pareto improvement.

Under model TY and model TN, the utility of collectors changes in different directions with the distributional fairness coefficient (see Figure 10-11). When the fairness concern of collectors is considered by the manufacturer, the utility increases, otherwise the utility decreases.

**B. THE IMPACT OF PEER-INDUCED FAIRNESS CONCERN ON THE SUPPLY CHAIN**

In order to analyze the impact of peer-induced fairness concern on decisions of the CLSC, it is assumed that the collectors’ distributional fairness concern coefficient remains...
unchanged (let $\lambda = 0.2$). Since only under the model TY and model NY, the manufacturer considers the collectors’ peer-induced fairness concern, and the transfer payment and the peer-induced fairness concern coefficient change in the opposite direction. Obviously, the collector’s peer-induced fairness concern makes the manufacturer reduce the transfer payment (see Figure 12). Under the model TY, the collector $T_2$ receives a lower transfer payment than the collector $T_2$, and the collector $T_2$ lowers the recycling price and indirectly “retaliates” the manufacturer. Therefore, when the manufacturer considers the peer-induced fairness concern of the collectors, it is not good for the collector $T_2$.

However, under the model TN, because the fairness concern of the collectors is not considered by the manufacturer, and the recycling price is already very low, the collector $T_2$ increases the recycling price to gain the profit which is not less than the collector $T_1$ (Figure 13). The recycling amount of the CLSC is determined by the recycling price, so the direction change of the return rate is consistent with the recycling price (Figure 14).

Under the model TN, the collectors’ fairness concern has not been considered by the manufacturer, however, the collector $T_2$ will raise the recycling price so as to make the profit not less than the collector $T_1$, and the manufacturer will indirectly obtain profit. In other models, the collector’s peer-induced fairness concern always puts him in a disadvantaged position, so the manufacturer’s profit and peer-induced fairness concern of the collector $T_2$ change in the same direction (see Figure 15).

In the model TY and model NY, although peer-induced fairness concern of the collector $T_2$ is considered by the manufacturer, but the manufacturer’s transfer payment to the collector $T_2$ and the peer-induced fairness concern coefficient change in the opposite direction, so the profit of collector $T_2$ peer-induced fairness concern coefficient changes in the opposite direction, but under the model TN, the fairness concern of the collectors has not been considered by the manufacturer. In order to compare with the collector $T_1$, the collector $T_2$ raises the recycling price to collect more used products, so the profit of the collector $T_2$ and peer-induced fairness concern coefficient change in the same direction (see Figure 16).

**C. COMPARISON OF PROFIT OF THE COLLECTORS UNDER DIFFERENT MODELS**

Under the model NY, the rate of decline in the profit of the collectors is higher than the rate of increase in the profit of the manufacturer, so the profit of the CLSC decreases.
FIGURE 16. The impact of peer-induced fairness concern on the collector $T_2$’s profit.

FIGURE 17. The impact of peer-induced fairness concern on profit of the CLSC.

FIGURE 18. Comparison of profit of the collectors under the model TY.

FIGURE 19. Comparison of profit of the collectors under the model TN.

FIGURE 20. Comparison of profit of the collectors under the model NY.

Under the model TN, the profit of both the collectors and the manufacturer is increased because of the peer-induced fairness concern, so the profit of the CLSC increases (see Figure 17).

Whether it is in model TY or model NY, as long as the collectors’ fairness concern is considered by the manufacturer, the collector $T_2$ can only concern the peer collector $T_1$. At this time, in order to make the profit not less than the collector $T_1$, the collector $T_2$ appropriately increases the recycling price, so the profit of the collector $T_2$ is higher than the collector $T_1$ (see Figure 19).

VII. CONCLUSION

In the context of the two existing recycling markets, this article discusses both the distributional fairness concern and the peer-induced fairness concern of the collectors in the same model, where both absolute fairness concern and relative fairness concern are considered. Through backward induction, the system equilibrium solution under five models is obtained. Eventually, two-part Tariff contract is constructed under the model TY.

Studies have shown that under the model TY, the manufacturer is “pressed” to increase transfer payment so that the collectors also increase recycling prices to indirectly “reciprocate” the manufacturer. At this time, the distributional fairness concern of the collectors helps improve their profit but hurts manufacturer. Under the model NY, the manufacturer “actively” care about the collectors so that they are even more “active” than their fairness concern to be considered by the manufacturer, so the profit is the largest.
However, under the model TN, because the collectors’ fairness concern cannot be considered by the manufacturer, the collectors lower the recycling price and indirectly “punish” the manufacturer, resulting in a lose-lose situation. In a certain situation where distributational fairness concern coefficient remains unchanged, the collector $T_2$ who pays attention to distributional fairness and peer-induced fairness raises the recycling price in order to make profits not less than the profits of the collector $T_1$, so the profit of the manufacturer and the collector $T_2$ changes in the same direction as the peer-induced fairness coefficient. Under the models TY and NY, the transfer payment received by the collector $T_2$ is always lower than that of the collector $T_1$, which puts the former in a relatively disadvantaged position.

The collectors’ distributional fairness concern has improved their own profits but has “hurt” the manufacturer. Therefore, the manufacturer is more eager to establish effective contracts to increase his profit. This article proposes the two-part Tariff contract for a manufacturer to consider the fairness concern of the collectors. Theoretical and numerical studies show that the profit of the manufacturer and the collectors have reached the level of centralized decision-making model C under the proposed contract.

In conclusion, this article studies the interactive effects of collectors’ two fairness concerns on pricing decisions of the CLSC and finds that as a leader of the manufacturer, “active” consideration of collectors’ fairness concern is always better than “passive” one.

In a deeper sense, this article contributes to our understanding about the interaction between distributional and peer-induced fairness concerns, and our findings provide some managerial insights on the pricing decision of the CLSC. When followers have fairness concern, the leader’s optimal decision is to consider the followers’ fairness concern, otherwise, he will not consider it. When there are multiple peers in the market, one should not care too much about the income of the peers, otherwise he will be at a disadvantage.

However, all the research concentrates on the reverse channel in this article, and the fairness concern of collectors has no impact on retailers. When the manufacturer considers the Corporate Social Responsibility (CSR) of the channel and the sustainable development of the enterprise, he will increase the advertising investment, green product promotion and so on to change the reputation of the CLSC. At this time, the reputation of the CLSC will change with the CSR level of the manufacturer, which will definitely have a certain effect on the forward channel. Therefore, when the manufacturer invests in CSR, how the equilibrium solution of the CLSC changes with the peer-induced fairness concerns merits the future research.

APPENDIX

PROOF OF PROPOSITION 1

Since the manufacturer, the retailer, and the collectors are all fairness-neutral, $p$ and $A_i$ are decision variables. Therefore, the Hessian matrix of the CLSC about $p$ and $A_i$ is:

$$H = \begin{pmatrix} -2b & 0 \\ 0 & -2 \end{pmatrix}.$$

From the above equation, it can be seen that the Hessian matrix is negative definite, that is, $\pi^2_{NN}$ is a strictly concave function of $p$ and $A_i$. With first-order condition, the optimal pricing decisions of the CLSC in model C can be obtained.

**PROOF OF PROPOSITION 2**

Stackelberg game between the manufacturer, the retailer and the collectors. The manufacturer is a leader, the retailer and the collectors, followers. Solved by the backward induction, we can get:

$$A_i = \frac{B_i - h_i}{2}.$$

And because the Hessian matrix of $\pi^2_{NN}$ with respect to $w$ and $B_i$ is:

$$H = \begin{pmatrix} -b & 0 \\ 0 & -1 \end{pmatrix}.$$

From the above equation, it can be seen that the Hessian matrix is negative definite, that is, $\pi^2_{NN}$ is a strictly concave function of $w$ and $B_i$. With first-order condition, the optimal pricing decisions of the CLSC in model C can be obtained.

**PROOF OF COROLLARY 1**

$$p^C - p^{NN} = \frac{-a + bc}{4b} < 0,$$

$$A^C - A^{NN} = \frac{\Delta - h_i}{4} > 0,$$

$$r^C - r^{NN} = 0,$$

$$\pi^C - \pi^{NN} = \frac{(a - bc)^2}{16b} + \frac{(\Delta + h_i)^2}{16} + \frac{(\Delta + h_i)^2}{16} > 0.$$
The optimal transfer payment $B_2^{TY*}$ can be obtained from the first-order condition, and then $A_2^{TY*}$ is obtained, and the expressions of $B_1^{TY*}$ and $A_1^{TY*}$ are obtained in the same way.

**PROOF OF COROLLARY 2**

(1) \[ \frac{dB_1^{TY*}}{d\lambda} = \frac{\Delta + h_1}{(2 + \theta)^2} > 0, \]
(2) \[ \frac{\partial B_2^{TY*}}{\partial \lambda} = \frac{(1 + \theta)(\Delta + h_2)}{(2 + 2\theta + \lambda)^2} > 0, \]
\[ B_1^{TY*} - B_2^{NY*} = \frac{\lambda(\Delta + h_1)}{2(2 + \lambda)} > 0, \]
\[ B_1^{TY*} - B_2^{TY*} = \frac{\lambda(\Delta + h_1)}{2(2 + \lambda)} < 0, \]
\[ \frac{\partial B_2^{TY*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{(2 + 2\theta + \lambda)^2} < 0; \]

(2) When $h_1 = h_2 = \frac{h}{2}$, then
\[ B_2^{TY*} - B_2^{TY*} = \frac{-\lambda\theta(2\Delta + h)}{2(2 + \lambda)(2 + 2\theta + \lambda)} < 0. \]

**PROOF OF COROLLARY 3**

(1) \[ \frac{\partial \pi^{TY*}_M}{\partial \lambda} = \frac{(\Delta + h_1)^2}{4(2 + \lambda)^2} - \frac{(1 + \theta)(\Delta + h_2)^2}{4(2 + 2\theta + \lambda)^2} < 0, \]
\[ \frac{\partial \pi^{TY*}_M}{\partial \theta} = \frac{\lambda(\Delta + h_2)^2}{4(2 + 2\theta + \lambda)^2} > 0; \]
\[ d\pi^{TY*}_M \] \[ \frac{d\pi^{TY*}_M}{d\lambda} = \frac{(\Delta + h_1)^2}{4(2 + \lambda)^2} > 0, \]
\[ \frac{d\pi^{TY*}_M}{d\lambda} = \frac{(1 + \theta)(\Delta + h_2)^2}{4(2 + 2\theta + \lambda)^2} > 0, \]
\[ d\pi^{TY*}_M \] \[ \frac{d\pi^{TY*}_M}{d\theta} = -\frac{\lambda(\Delta + h_2)^2}{4(2 + 2\theta + \lambda)^2} < 0. \]

**PROOF OF COROLLARY 5**

(1) \[ \frac{dA_1^{TN*}}{d\lambda} = -\frac{\Delta + h_1}{8} < 0, \]
\[ \frac{dA_1^{TN*}}{\partial \lambda} = -\frac{\Delta + h_2}{8(1 + \theta)} < 0, \]
\[ \frac{dA_2^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_2)}{8(1 + \theta)^2} > 0; \]

(2) When $h_1 = h_2 = \frac{h}{2}$, then
\[ A_2^{TN*} - A_1^{TN*} = \frac{\theta(2\Delta + h)}{16(1 + \theta)} > 0; \]
\[ \frac{dA_1^{TN*}}{d\lambda} = -\frac{2(\Delta + h) + \theta(\Delta + h_1)}{2(1 + \theta)(a - bc)} < 0, \]
\[ \frac{dA_1^{TN*}}{d\theta} = \frac{\lambda(\Delta + h_2)}{2(1 + \theta)^2(a - bc)} > 0. \]

**PROOF OF COROLLARY 7**

(1) \[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\Delta + h_1}{2(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{(1 + \theta)(\Delta + h_2)}{2(2 + \theta + \lambda)^2} < 0, \]
\[ \frac{\partial A_2^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{2(2 + \theta + \lambda)^2} < 0; \]
\[ A_1^{TN*} - A_2^{TN*} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)} > 0, \]
\[ A_2^{TN*} - A_1^{TN*} = \frac{\lambda(\Delta + h_2)}{4(2 + \lambda)} > 0; \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = \frac{\lambda(\Delta + h_1)}{4(2 + \lambda)^2} > 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \lambda} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
\[ \frac{\partial A_1^{TN*}}{\partial \theta} = -\frac{\lambda(\Delta + h_2)}{4(2 + \lambda)^2(a - bc)} < 0, \]
**PROOF OF COROLLARY 8**

\[
\frac{\partial \pi_{MT}^{NY*}}{\partial \theta} \quad \frac{\partial \pi_{MT}^{NY*}}{\partial \lambda} = -\frac{\lambda}{2} (\Delta + h_1)^2 \quad + \frac{\lambda}{2} (\Delta + h_1)^2 < 0;
\]

\[
\frac{\partial \pi_{MT}^{NY*}}{\partial \lambda} = -\frac{\lambda}{2} (\Delta + h_1)^2 \quad \frac{\lambda}{2} (\Delta + h_1)^2 < 0,
\]

\[
\frac{\partial \pi_{MT}^{NY*}}{\partial \theta} = -\frac{\lambda}{2} (\Delta + h_1)^2 \quad \frac{\lambda}{2} (\Delta + h_1)^2 < 0.
\]

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