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Price strategy considering fairness concerns in closed-loop supply chain under asymmetric information

Li Xiang-Rong
School of Economics and Management, North University of China, Taiyuan 030051, (CHINA)
E-mail: yalixiangrong@163.com

ABSTRACT

Based on the theory of Nash bargaining fairness concerns, the model is built in this paper. We explore that retailer confess or lie about its recycling cost, which impact on the optimal pricing strategies of closed-loop supply chain members, their own profits and effectiveness as well as the total supply chain effectiveness, and verified with numerical analysis. Research shows that the retailers lying behavior acts on fairness concerns coefficient, which makes it have a certain impact on the optimal pricing of closed-loop supply chain members, as well as retailers' revenue, effectiveness and system total effectiveness.

KEYWORDS

Closed-loop supply chain; Nash bargaining; Fairness concerns; Asymmetric information; Pricing strategy.

INTRODUCTION

With the rapid development of economy and society, people's appeal of saving energy and sustainable development is increasing. As a research hotspot, closed-loop supply chain management plays an increasingly prominent role in sustainable development and environmental protection. People hope to be able to use resources efficiently and protect environment, as well as increase corporate earnings simultaneously. Recovery process adds to closed-loop supply chain, which makes the accurate pricing of recycled waste materials become an urgent problem to be solved by companies, and each node of closed-loop supply chain consisted of manufacturers, retailers and consumers could have an impact on other nodes, as a result, the rational pricing is a key factor for all interest subjects to maximize profits.

In recent years, many domestic and foreign scholars have devoted to the study of closed-loop supply chain and a lot of significant results have been achieved, although the study of remanufacturing closed-loop supply chain started relatively late. Savaskan et al. analyzed the optimal recovery model of closed-loop supply chain, i.e., the recovery model in retailers' charge under linear demand[1]. Gu et al.[2], Wang et al.[3] and Ge and Huang[4] all used supply chain system pricing strategy, which is the interaction of game theory with supply chain and reverse supply chain, to analyze. Zhang and Zhou studied the pricing strategy and designed the coordination mechanism of closed-loop supply chain under retailers' environment of competition[5]. By analyzing different recovery channels, Huang and Da discussed the recycled pricing strategy of closed-loop supply chain, but it ignored the impact from the price of recovery on waste products[6]. Yi considered the effects of different market power structure on rate of recovery, equilibrium price, equilibrium profits and total channel profits[7]. However, the above documents do not consider the behavior characteristics of decision makers, and ignore the fairness concerns of interest subjects as well.

Recent studies suggest that the behavioral tendencies of fairness concerns have a certain impact on the distribution of benefits between manufacturers and retailers. Cui et al. introduced fairness concerns into newsboy background, and studied its impact on supply chain contract[8]. Based on nonlinear demand, Ozgun took into account the supply chain coordination mechanism in situation that retailers have fairness concerns[9]. With double channel supply chain as a premise, Xing analyzed the impact from fair channel on the balanced strategy of manufacturers and retailers[10]. Tan and Li[11] and Ma[12] discussed the impact of the retailers with fairness concerns on the performance and the effect of typical coordination contracts, respectively.

These studies related to supply chain mentioned above are all on the basis of symmetry information, i.e., all the supply chain system members completely know the needs (cost information etc.) of each other clearly. However, in reality, the economic activities are complex, and in order to maximize their own interests, each enterprise often keeps the information confidential strictly, with a result that it is difficult for them to understand information of each other clearly. At present, researches related to asymmetric information have achieved great progress, Qiu and Huang[13] and Li and Qin[14] studied the problem of supply chain system revenue sharing coordination contracts under asymmetric information. Cheng and Zou[15] and Xu and Wu[16] established a model of supply chain buy-back under asymmetric cost information, while further studied the issue of supply chain coordination contracts. Zhang and Zhou analyzed the problem of price discrimination coordination in closed-loop supply chain under asymmetric information[17]. By adopting the method of game theory, Xiong and Zhang[18], Wang and Shen[19] and Li et al.[20] discussed the pricing strategy of closed-loop supply chain in the situation that decision makers lie about the cost, with a comparison with the optimal pricing under symmetric information, and finally they draw a conclusion that misreporting behavior has a certain impact on the profit of each member of the closed-loop supply chain system.

The literatures mentioned above provide new ideas for the further research on closed-loop supply chain, but the few studies which consider fairness concerns are mostly aimed at traditional open-loop supply chain, what's more, they ignore the fact that manufacturers and retailers have the behavioral characteristics of fairness concerns simultaneously. Zhang et al. considered that manufacturers and retailers have the behavioral characteristics of fairness concerns, but these researches were all discussed under symmetric information[21-23]. Different from existing studies, this paper comprehensively consider the reality of asymmetric information and the behavior preference of decision makers, based on the theory of Nash bargaining fairness concerns, comparatively analyze the impact of fairness concerns coefficient, resulted from retailers' act of confessing or lying about the recovery cost, on the optimal pricing of closed-loop supply chain members, their own profits and effectiveness as well as the total supply chain effectiveness. The results suggest that when the retailers have private cost recovery information, the retailers will exaggerate their recovery cost, in order to earn greater profits. But lying about the recovery cost can't increase retailers' effectiveness, furthermore, reduces the total closed-loop supply chain effectiveness.

ASSUMPTIONS OF THE PROBLEM AND DESCRIPTIONS OF PARAMETERS

In this paper, we investigate a two-stage closed-loop supply chain model consisted of a manufacturer and a retailer, with the model as research background, we assume that the manufacturer and retailer are both independent decision-makers in the process of game, who aim at maximizing their profits. In closed-loop supply chain, the manufacturer manufactures raw materials, and uses all the waste products recycled by the authorized retailer for remanufacturing. There is no difference between the new manufactured products and the remanufactured products in quality performance, which makes the manufacturer sells to the retailer at the same wholesale price, afterwards, the retailer would launch the old and new products on the market to sale at a certain price. The specific structure is shown in Figure 1.

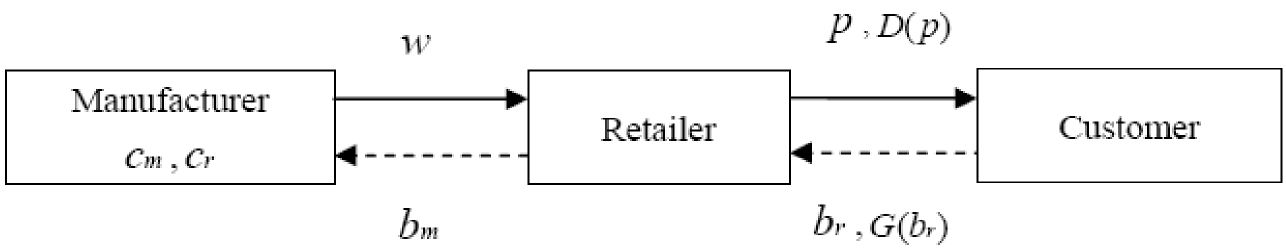

Figure 1 : The structure of the closed-loop supply chain system

According to the closed-loop supply chain model mentioned above, we give the description of the specific parameters.

p : Retail price of the retailer (at yuan per unit), which is the decision variable of the retail. With the assumption that new products and remanufactured products are replaceable completely, there is no difference in market sales.

w : Wholesale price of the manufacturer (at yuan per unit), which is the decision variable of the manufacturer.

c_m : Unit cost of the manufacturer's producing new products (at yuan per unit).

c_r : Unit cost of the manufacturer's remanufacturing end produces from recovery. In order to ensure the remanufacturing from recovery has significance for the manufacture, let $c_r < c_m$ represents that the manufacturer can save the cost by remanufacturing.

b_m : Transfer price of the manufacturer recycling.

b_r : The retailer's recycled price of waste products from customers. In order to ensure the manufacturer and the retailer not only have the driving force of recovery, but also could obtain profits, we assume $b_r < b_m < c_m - c_r$.

c_{rr} : Unit operating cost of the retailer recycling waste products. In order to ensure that the recovery make sense to the retailer, make $crr < b_r < b_m$.

$D(p)$: Demand for the products in the market (unit: piece), and we assume that the market demand is only related to the retail price, i.e., $D(p) = \alpha - \beta p$. More specifically, α represents the market size and β represents the sensitivity of consumers to the retail price, in addition, let $\alpha > 0, \beta > 0$.

$G(b_r)$: The amount of recycled waste products, which is feasible in condition that the recovery price is b_r in each unit. In reference to the model in Huang and Da[6], this paper assume $G(br) = \eta br^k$ $(\eta > 0, k > 1)$, where η represents the conversion constants and k represents the price elasticity.

π_m : Profits of the manufacturer.

π_r : Profits of the retailer.

π : Total profits of the supply chain system, i.e., $\pi = \pi m + \pi r$.

u_m : Effectiveness of the manufacturer's fairness concerns.

u_r : Effectiveness of the retailer's fairness concerns.

u : Total effectiveness of the supply chain system, i.e., $u = u_m + u_r$.

Based on the above problem descriptions and assumptions, the profits of the manufacturer and retailer can be represented respectively as follows:

$$\pi_r = (p - w)(\alpha - \beta p - \eta b_r{}^k) + (p - w)\eta b_r{}^k + (b_m - b_r - c_{rr})\eta b_r{}^k \quad \textbf{(1)}$$

$$\pi_m = (w - c_m)(\alpha - \beta p - \eta b_r{}^k) + (w - b_m - c_r)\eta b_r{}^k \quad \textbf{(2)}$$

PRICING STRATEGY CONSIDER DECISION MAKERS' FAIRNESS CONCERNS UNDER SYMMETRIC INFORMATION

Based on the assumption that the manufacturer and retailer both have fairness concerns, this paper conducts further research on the pricing strategy of closed-loop supply chain recovery. This paper refers to the fair reference solution in the theory of Nash bargaining fairness concerns and then we can get the effectiveness of decision makers with the relative fairness concerns, i.e., the effectiveness function of the retailer given by

$$u_r = \frac{(1 + \lambda_r)(\pi_r * (2 + \lambda_m) - \pi_m \lambda_r)}{2 + \lambda_m + \lambda_r} , \quad \textbf{(3)}$$

and the effectiveness function of the manufacturer is given by

$$u_m = \frac{(1+\lambda_m)(\pi_{m^*}(2+\lambda_r)-\pi_r\lambda_m)}{2+\lambda_m+\lambda_r}. \tag{4}$$

In according to the backward induction, with the simultaneous equations of $\frac{\partial u_r}{\partial p}=0$ and $\frac{\partial u_r}{\partial b_r}=0$, we can get the answer shown as follows:

$$\left.\begin{aligned} p &= \frac{2(\alpha+w\beta)+(\alpha+w\beta)\lambda_m+\beta(w-c_m)\lambda_r}{2\beta(2+\lambda_m)} \\ b_r &= \frac{k(-c_{rr}(2+\lambda_m)+(-c_m+c_r)\lambda_r+b_m(2+\lambda_m+\lambda_r)}{(1+k)(2+\lambda_m)} \end{aligned}\right\}. \tag{5}$$

Substituting Eq (5) into u_m, we can get the first derivatives of w and b_m respectively, furthermore, let them equal zero, we can get the answer shown as follows:

$$\left.\begin{aligned} w^* &= \frac{\alpha(2+\lambda_m)^2+\beta c_m(4*(1+\lambda_r)+\lambda_m(2+\lambda_r))}{\beta(4+\lambda_m)(2+\lambda_m+\lambda_r)} \\ b_m^* &= \frac{(c_{rr}(2+\lambda_m)^2+(c_m-c_r)(\lambda_m(2k+\lambda_r)+2(2k+(1+k)\lambda_r)))}{(2+2k+\lambda_m)(2+\lambda_m+\lambda_r)} \end{aligned}\right\} \tag{6}$$

Substituting Eq (6) into Eq (5) yields

$$\left.\begin{aligned} p^* &= \frac{\alpha(3+\lambda_m)+\beta c_m}{\beta(4+\lambda_m)} \\ b_r^* &= \frac{2k^2(c_m-c_r-c_{rr})}{(1+k)(2+2k+\lambda_m)} \end{aligned}\right\} \tag{7}$$

Furthermore, substituting Eq(6) and Eq(7) into u_m, u_r and u, we can get the optimal effectiveness of the manufacturer and retailer, as well as the supply chain system.

Proposition 1: If the retailer confesses the cost of recovery, in foundation of the Stackelberg equilibrium in closed-loop supply chain, the optimal pricing strategy of manufacturer and retailer p^*, b_r^*, w^* and b_m^* can be expressed respectively below:

$$\begin{aligned} p^* &= \frac{\alpha(3+\lambda_m)+\beta c_m}{\beta(4+\lambda_m)} \\ b_r^* &= \frac{2k^2(c_m-c_r-c_{rr})}{(1+k)(2+2k+\lambda_m)} \end{aligned},$$

And

$$\begin{aligned} w^* &= \frac{\alpha(2+\lambda_m)^2+\beta c_m(4*(1+\lambda_r)+\lambda_m(2+\lambda_r))}{\beta(4+\lambda_m)(2+\lambda_m+\lambda_r)} \\ b_m^* &= \frac{(c_{rr}(2+\lambda_m)^2+(c_m-c_r)(\lambda_m(2k+\lambda_r)+2(2k+(1+k)\lambda_r)))}{(2+2k+\lambda_m)(2+\lambda_m+\lambda_r)} \end{aligned}.$$

The superscript * in expressions represents the optimal solutions of the supply chain members under symmetry information.

PRICE STRATEGY CONSIDER DECISION MAKERS' FAIRNESS CONCERNS UNDER ASYMMETRIC INFORMATION

The equilibrium solutions above are built on the basis that the manufacturer and retailer are clear about the costs each other, nevertheless, the recovery of waste products has the complex property so that the manufacturer can not completely understand the real cost of the retailer recovery. For the sake of maximizing their own interests, companies always tend to keep their private information confidential, i.e., the retailer may lie about the recovery cost to benefit more. In general, the manufacturers are in large scale in the real closed-loop supply chain, and they seize the initiative, so this paper will not discuss the circumstance that the manufacturers lie about the cost. As a result, we assume that the retailer declare its recovery costs are $\bar{c}_{rr}$, but the true costs are c_{rr} , and we use the superscript s in expressions to represents the circumstance of asymmetry information, thus the overt profit function of the retailer can be given by

$$\pi_r = (p-w)(\alpha - \beta p - \eta b_r^{\,k}) + (p - w + b_m - b_r - \bar{c}_{rr})\eta b_r^{\,k} . \tag{8}$$

Substituting Eq (8) into the effectiveness function of the retailer, we can get

$$u_r = \frac{(1+\lambda_r)(\pi_r(2+\lambda_m) - \pi_m\lambda_r)}{2+\lambda_m+\lambda_r},$$

Therefore, we can get the effectiveness function of the retailer in the situation of lying. In according to the backward induction, with the simultaneous equations of $\frac{\partial u_r}{\partial p} = 0$ and $\frac{\partial u_r}{\partial b_r} = 0$, we can get

$$\left.\begin{aligned} p &= \frac{2(\alpha+\beta w)+(\alpha+\beta w)\lambda_m+\beta(w-c_m)\lambda_r}{2\beta(2+\lambda_m)} \\ b_r &= \frac{k(-\bar{c}_{rr}(2+\lambda_m)+(-c_m+c_r)\lambda_m+b_m(2+\lambda_m+\lambda_r)}{(1+k)(2+\lambda_m)} \end{aligned}\right\} \tag{9}$$

Substituting Eq (9) into u_m, we can get the first derivatives of w and b_m respectively, furthermore, let them equal zero, we can get the answer shown as follows:

$$\left.\begin{aligned} w^s &= \frac{\alpha(2+\lambda_m)^2+\beta c_m(4*(1+\lambda_r)+\lambda_m(2+\lambda_r))}{\beta(4+\lambda_m)(2+\lambda_m+\lambda_r)} \\ b_m{}^s &= \frac{(\bar{c}_{rr}(2+\lambda_m)^2+(c_m-c_r)(\lambda_m(2k+\lambda_r)+2(2k+(1+k)\lambda_r)))}{(2+2k+\lambda_m)(2+\lambda_m+\lambda_r)} \end{aligned}\right\} \tag{10}$$

Substituting Eq (10) into Eq(9), we can get the optimal retail price and recovery price in the situation of lying shown below:

$$\left.\begin{aligned} p^s &= \frac{\beta c_m+\alpha(3+\lambda_m)}{\beta(4+\lambda_m)} \\ b_r{}^s &= -\frac{2k^2(-c_m+c_r+\bar{c}_{rr})}{(1+k)(2+2k+\lambda_m)} \end{aligned}\right\}. \tag{11}$$

Substituting $w^s, b_m{}^s, p^s, b_r{}^s$ into the real effectiveness function of the retailer, and at this point the retail has to make an optimal lying decision in order to maximize the profits, therefore, by letting $\frac{\partial u_r}{\partial \bar{c}_{rr}} = 0$ we can get the optimal lying decision of the retail shown as follows:

$$\bar{c}_{rr}=\frac{(c_m-c_r)(2+\lambda_m)+kc_{rr}(2+2k+\lambda_m)}{2(1+k+k^2)+(1+k)\lambda_m}. \quad \textbf{(12)}$$

Because of $\bar{c}_{rr}-c_{rr}=\frac{(c_m-c_r-c_{rr})(2+\lambda_m)(2+\lambda_m)}{2(1+k+k^2)+(1+k)\lambda_m}>0$, we can draw the conclusions shown below:

Proposition 2: When the retailer holds the private cost information of recovery, exaggerating the recovery costs will help them earn greater profits, furthermore, the retailer's optimal lying cost can be shown as follows:

$$\bar{c}_{rr}=\frac{(c_m-c_r)(2+\lambda_m)+kc_{rr}(2+2k+\lambda_m)}{2(1+k+k^2)+(1+k)\lambda_m}.$$

Substituting Eq (12) into Eq(10) and Eq(11), we can get the Stackelberg game equilibrium solutions under asymmetric information, I.e., the proposition 3.

Proposition3: In the context of Stackelberg equilibrium under asymmetric information, the optimal pricing strategies of the manufacturer and retailer in closed-loop supply chain can be expressed respectively below:

$$\tilde{p}^s=\frac{\beta c_m+\alpha(3+\lambda_m)}{\beta(4+\lambda_m)}$$

$$\tilde{b}_r^{\,s}=\frac{2k^3(c_m-c_r-c_{rr})}{(1+k)(2*(1+k+k^2)+(1+k)\lambda_m)}$$

$$\tilde{w}^s=\frac{\alpha(2+\lambda_m)^2+\beta c_m(4(1+\lambda_r)+\lambda_m(2+\lambda_r))}{\beta(4+\lambda_m)(2+\lambda_m+\lambda_r)}$$

$$\tilde{b}_m^{\,s}=\frac{kc_{rr}(2+\lambda_m)^2+(c_m-c_r)(\lambda_m^2+\lambda_m(2(2+k^2)+(1+k)\lambda_r)+2(2(1+k^2)+(1+k+k^2)\lambda_r))}{(2(1+k+k^2)+(1+k)\lambda_m)(2+\lambda_m+\lambda_r)}$$

in which we use the superscript ~ to represent the optimal equilibrium solutions under asymmetry information.

Proposition 4: The retailer's lying cost of recovery increases along with the fair concern coefficient of the manufacturer when the manufacturer and retailer both have relatively fair concerns under asymmetry information, but it don't get any influence from the fair concern coefficient of itself.

The proof of proposition 4

Due to $\frac{\bar{c}_{rr}}{\lambda_m}=\frac{2k^3(c_m-c_r-c_{rr})}{(1+k)(2*(1+k+k^2)+(1+k)\lambda_m)}>0$, we can hold proposition 4.

Proposition 4 illustrates that the more fair concerns the manufacturer has, the more he reduces the recovery price, which aims at increasing his own profits, at the same time, the revenue of the retailer in the closed-loop supply chain will have a corresponding reduction to gain the maximal profits, in addition, in order to boost the profits, the retailer will lie about the recovery cost so that forcing the manufacturer to increase the recovery price of the wasted products, as a result, further increase their profits. However, no matter whether the retailer has fair concerns or not, it will not trigger the motivation to exaggerate the recovery cost.

Proposition 5: $w^*=\tilde{w}^s$, $p^*=\tilde{p}^s$ and $\tilde{b}_m^{\,s}>b_m^*$, $\tilde{b}_r^{\,s}<b_m^*$ and $\tilde{\pi}_r^{\,s}>\pi^*, \tilde{u}_r^{\,s}<u_r^*, \tilde{u}^s<u^*$.

The proof of proposition 5

Due to $\tilde{b}_m^{\,s}-b_m^*=\frac{(c_m-c_r-c_{rr})(2+\lambda_m)^3}{(4(1+2k+2k^2+k^3)+(4+6k+4k^2)\lambda_m+(1+k)\lambda_m^2)(2+\lambda_m+\lambda_r)}>0$

And

$\tilde{b}_r^{\,s}-b_r^*=-\frac{2k^2(c_m-c_r-c_{rr})(2+\lambda_m)}{(1+k)(2+2k+\lambda_m)(2(1+k+k^2)+(1+k)\lambda_m)}<0$, we can hold proposition 5.

Proposition 5 illustrates that there is not any influence from the retailer's lying cost on the manufacturer's wholesale price and the retailer's retail price, in addition, the retailer exaggerating the recovery cost results in that the manufacturer increases the recovery price under the circumstance that the manufacturer lies about the information, while the retailer reduces the recovery price of waste products so that increasing the retailer's short-term interests, however, the longstanding amount of recycling waste products will gradually decline, which leads to reducing the manufacturer's profits of remanufacture from recovery, furthermore, the retailer's revenue will also be affected, in the end, the effectiveness of the closed-loop supply chain system will be reduced. Under the circumstance of decision makers with fair concerns, aiming at maximizing the profits, decision makers can not obtain an optimal effectiveness by maximizing the profits of the manufacturer and retailer, consequently, the retailer lying about the recovery cost do not contribute to improve fairness effectiveness itself.

NUMERICAL STUDIES

In order to give a better explanation on the application of the model, this section below carried out an inspection on the effectiveness model of the fairness concerns aforementioned through a specific example, combined with numerical analysis, we studied that the retailer's recovery cost acts on the fairness concerns coefficient no matter under symmetric information or asymmetric information, which makes it have a certain impact on the optimal pricing of closed-loop supply chain members, as well as retailers' revenue and effectiveness.

In what follows, we gave the following assumptions: the market demand function is $D(p)=100-5p$, the function for recovery amount of the waste products is $G(b_r)=10b_r^2$, the function for the manufacturer's unit manufacturing cost of new products is $c_m=8$, the function for the manufacturer's remanufacturing cost of recycled waste products is $c_r=2$ and the function for the retailer's unit recovery cost of waste products is $c_{rr}=1$. According to the parameter assignments given above, we comparative analyzed the impacts from the fairness concerns coefficient retailers on the optimal pricing of closed-loop supply chain members, as well as retailers' revenue and effectiveness, in the circumstance that the retailer confess or lie about the recovery cost respectively. The numerical simulation conducted for verification is shown in Figure 2 and Figure 3.

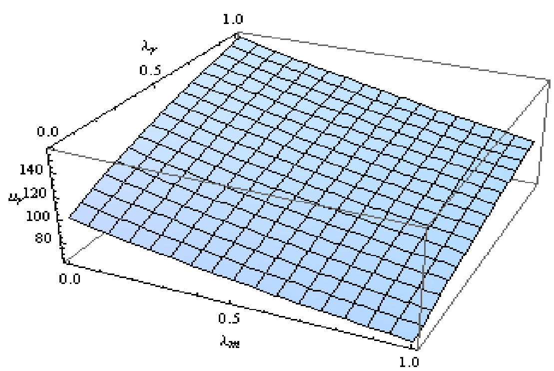

Figure 2 : The effect of fairness concerns on the retailer's utility under symmetric information

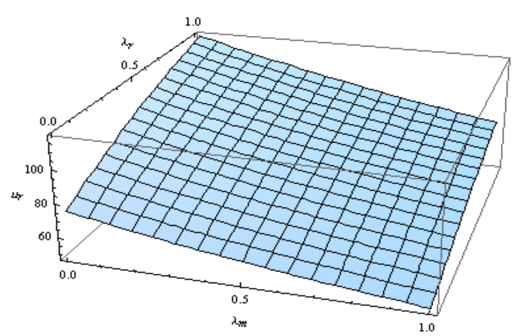

Figure 3 : The effect of fairness concerns on the retailer's utility under asymmetric information

As we can see from Figure 2 and Figure 3, in the case of symmetry information, the retailer's effectiveness decreases with the increase of the manufacturer's fairness concerns coefficient, and increases along with the fairness concerns coefficient. I.e., as a market leader, the more attention on fairness concerns he gives, the higher proportion of profits he gets in the closed-loop supply chain, at this time, the retailer's profit and effectiveness will have a corresponding decrease, as a result, the retailer will improve the effectiveness by increasing the retail price and reducing the recovery price of waste products, as well as increasing the revenue distribution proportion of the supply chain. There is a same conclusion under the corresponding case of asymmetric information, but compared with the changing in the range of 148~22 under symmetric information, the retailer's effectiveness changes in the range of 117~14 with the change of the fairness concerns coefficient, which shows that the retailer's effectiveness is decreased obviously under asymmetric information. Therefore, considering the circumstance of the decision-makers having fairness concerns, the retailer exaggerating the recovery price does not increase its fair effectiveness, nevertheless, makes the closed-loop supply chain system effectiveness decreased, as well as the system total efficiency.

CONCLUSIONS AND PROSPECTIONS

Based on the theory of Nash bargaining game, this paper constructed a supply chain effectiveness framework of fairness concerns, and we carried out an analysis on the pricing strategy of the closed-loop supply chain under asymmetric information, furthermore, we also discussed the retailer's misreporting behavior acts on the fairness concerns coefficient, which makes it have a certain impact on the optimal pricing of closed-loop supply chain members, as well as retailers' revenue, effectiveness and system total effectiveness. Compared with the circumstance of symmetry information, when the retailer has private recovery cost information, in order to obtain greater profits, he will exaggerate the recovery cost. however, the longstanding amount of recycling waste products will gradually decline, which leads to reducing the manufacturer's profits of remanufacture from recovery, furthermore, the retailer's revenue will also be affected, in the end, the effectiveness of the closed-loop supply chain system will be reduced. I.e., considering the fairness concerns of decision makers, with the fact that the decision makers aim at optimal effectiveness, the retailer exaggerating the recovery can not increase the fairness effectiveness, nevertheless, makes the closed-loop supply chain system effectiveness is decreased, as well as the system efficiency.

However, there are also some limitations in this paper. First, this paper is only discussed the simple secondary closed-loop supply chain system, we need to do further researches on the pricing strategy of the more complex closed-loop supply chain system composed of more members. Second, the pricing strategy of the closed-loop supply chain discussed in this paper only takes the asymmetric information and decision fairness preference into consideration, ignoring the coordination analysis which they act on the supply chain contracts. Therefore, the future research directions can be tried to discuss deeper so that makes it suitable for applying to more realities.

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