Influence of Government Financial Regulation on Remanufacturing under Dual Source Supply

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Abstract: *A closed-loop supply chain system consisting of the manufacturer, the new components supplier and the recovered components supplier is designed based on the reality that the new components supplier and the recovered components supplier supply to the manufacturer in the product remanufacturing process.By introducing government financial intervention as an exogenous variable in the system, the influence effect of the situation in which the government imposes disposal tax on new products and makes subsidies for recovered components is analyzed by Stackelberg game. The results show that with the increase of tax and subsidy, the profits of manufacturers and recyclable components suppliers will always increase under the higher consumer recognition.Under low and medium consumer recognition, the supplier of recycled components will still make profits, but the manufacturer may face the loss of profits.For new suppliers, losses are inevitable in either case.*
Key words: *closed loop supply chain; Remanufacturing; Government financial intervention; Stackelberg game*

I.   INTRODUCTION

According to the comprehensive utilization of waste electric and electronic products recycling in China and a white paper industry 2018 ", the actual capacity of our 2018 waste electrical and electronics products of about 79 million units, the theory of scrap 150 million units, the actual processing capacity of 170 million units, a large amount of waste electrical and electronics products are caused great environmental pollution and resource waste[1].Remanufacturing can not only reduce the environmental pollution of waste electronic products but also reduce the production cost of products.Take Fuji Xerox for example. In the 1990s, Xerox began to recycle and remanufacture used copiers. Through the reprocessing of core components and the replacement of discarded components, each remanufactured product can save 30-70% of the cost for Xerox [2].In consideration of the technical and financial requirements of remanufacturing, more enterprises are encouraged to participate in the remanufacturing process. In 2009, the Chinese government issued a series of reward and punishment mechanisms and management regulations centering on the "Management Regulations on Recycling and Disposal of Discarded Electronic Products" [3].

Many scholars at home and abroad actively discuss the role of government financial regulation in closed-loop supply chain remanufacturing.Wang Yuyan et al.analyzed altruistic concern decision-making in the closed-loop supply chain under the government incentive mechanism, and the research showed that the incentive mechanism would take effect only when the government incentive meets a certain threshold [4].Huihui Liu analyzed the impact of government subsidies on recycling channels, and the results showed that when the quality of waste products was high but the government subsidies were limited, informal recycling channels always had more advantages[5]. Wei-min Maet al. studied government subsidies to consumers, showing that manufacturers, suppliers and consumers can benefit from government consumption subsidies to different degrees[6].XiongZhongkai et al.analyzed three situations in which the manufacturer is responsible for recycling, the retailer is responsible for recycling and the supplier is responsible for recycling under the government incentives[7]. The results show that the government incentives can always reduce the product price and improve the recovery rate of waste products.

Most of the above scholars started their research from the aspect of government subsidies, and many also considered the effects of government subsidies and taxes at the same time.Wang Wenbin and Da Qingli studied the decision-making of closed-loop supply chain under centralized and decentralized conditions, and analyzed and compared the decision-making problems under the reward and punishment mechanism based on recovery rate and recovery rate[8]. In addition, Wang Wenbin et al. also considered the situation of the government punishing manufacturers and the amount of subsidy recycling, and the results showed that the subsidy recyclers could effectively increase the amount of waste products recycling, but the lack of punishment caused a decline in the amount of waste products recycling[9].Li Xinran et al. considered the recycling of waste products by government rewards and punishments retailers, and discussed the impact of government rewards

and punishments and the lowest recovery rate on the optimal decision-making of different power structures in the supply chain [10].Wang Wenbin et al. designed a two-cycle closed-loop supply chain game model and studied the impact of government reward and punishment mechanism on the pricing, recovery and profit of supply chain members [11].

Most of the literatures mentioned above only involve manufacturers, retailers and other downstream enterprises in the supply chain, but there is little research on suppliers who provide components in the supply chain. Huang et al. analyzed the value of information sharing among retailers and found that information sharing was beneficial to both manufacturers and suppliers, but would harm the interests of retailers[12].Xiao-min Zhao etc. constructed a "manufacturer - supplier" two levels of closed-loop supply chain system, analysis of supply even members of the profit performance under different power structure, found that the remanufacturing strategy always help manufacturers gain more interests, suppliers can get more benefit when strong, may be aggrieved when weak [13].He et al. constructed a closed-loop supply chain consisting of manufacturers, new components suppliers and recovered components suppliers [14]. However, in the study, the game between manufacturers and recyclers was mainly analyzed.Ni Ming et al., in the context of uncertain market demand and differences in consumers' willingness to pay, constructed three recovery processing models under government subsidies respectively, and analyzed the impact of different willingness to pay and government subsidies on product recovery rate and pricing decisions[15].

Based on previous studies, this paper considers the supply and availability of new components suppliers and recycled components suppliers, and focuses on the analysis of the incentive effect of the government's financial intervention measures on the closed-loop supply chain remanufacturing, so as to provide theoretical reference for the government to promote the development of electronic product components recovery and remanufacturing.

II. NOTATIONS DESCRIPTION AND RESEARCHASSUMPTIONS

In this paper, a closed-loop supply chain system composed of manufacturer, new components supplier and recovered components supplier is studied.FIG. 1 is a schematic diagram of a closed-loop supply chain system in which a manufacturer acquires new components and remanufactured components to provide new products and remanufactured products.Among them, new components suppliers provide new components, manufacturers use new components to produce new products;Recycled components suppliers provide recycled components and manufacturers use recycled components to produce remanufactured products.Manufacturers sell products to consumers, and suppliers recycle used new products, and provide recycled components for manufacturers to produce remanufactured products after decomposition, forming a new cycle.
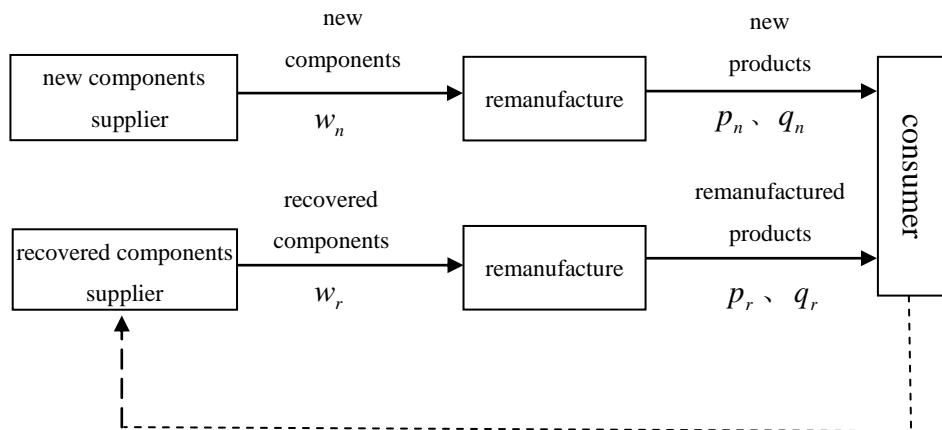

FIG. 1 Closed-loop supply chain system under dual-source supply

2.1NotationsDescription

p_n : Sales price of the new product;

p_r : The sales price of the unit remanufactured product;

q_n : Sales of new products;

q_r : Sales volume of remanufactured products;

w_n : Price of new components per unit;

w_r : Unit recovery components price;

c_n : production cost of new product per unit;

c_r : Production cost of unit remanufactured product;

c_{sn} : Production cost of new components per unit;

c_{sr} : Production cost of recovered components per unit;

s : The government subsidy received by units for recycled components;

f_n : The amount of tax a manufacturer must pay per unit of new product;

δ : Consumer acceptance of remanufactured products;

2.3 Research Assumption

Assumption 1. Although the remanufactured product has reached the same quality standard as the new product in terms of performance, consumers' recognition of the remanufactured product is lower than that of the new product due to the difference in value perception, namely;

Assumption 2. Compared with the new product, the remanufactured product requires less energy and materials, so the manufacturing cost of the remanufactured product is lower than the manufacturing cost of the new product, i.e.

Assumption 3. According to the fund treatment policy, the government gives subsidies to the recyclers and collects a disposal tax on the new products from the manufacturers. The subsidy amount of the recovered components per unit and the tax amount of the new products per unit is;

Assumption 4. The market demand of the product depends on the different recognition degree of consumers for the two types of products. According to the research of Ferguson and Toktay[16], the demand function of the new product and the remanufactured product is:

$$\begin{cases} q_n = 1 - \dfrac{p_n - p_r}{1 - \delta} \\ q_r = \dfrac{\delta p_n - p_r}{\delta(1 - \delta)} \end{cases} \quad (1)$$

III. MODEL

3.1 Profit function

According to the above assumptions, new component supplier decide the price of new component, recovered component suppliers decide the price of recovered component, and manufacturer decide the price of new product and remanufactured product.The profit function of each party is as follows:

The production cost of new componentis c_{sn}, and the wholesale price is w_n .Therefore, the profit function of the new component supplier is:

$$\pi_{sn} = (w_n - c_{sn})q_n \quad (2)$$

The production cost of recoveredcomponent is c_{sr}, the wholesale price is w_r ,the sale subsidy is s. Therefore, the profit function of the recovered component supplier is:

$$\pi_{sr} = (w_r - c_{sr} + s)q_r \quad (3)$$

The selling price of the new product is p_n, the selling price of the remanufactured product is p_r, and the profit function of the manufacturer is:

$$\pi_m = (p_n - w_n - c_n)q_n + (p_r - w_r - c_r)q_r - f_n q_n \quad (4)$$

3.2 Optimal Decisions

The order of the decision-making process is as follows :(1) suppliers determine the wholesale prices of components;(2) The manufacturer determines the selling price of new products and remanufactured products based on the wholesale price.According to the backward induction method:

Firstly, the relationship between the price of new product and the remanufactured product and the price of components under the circumstance of profit maximization is obtained. Formula (1) is substituted into Formula (4). By $\dfrac{\partial \pi_m}{\partial p_n} = 0$, $\dfrac{\partial \pi_m}{\partial p_r} = 0$ we can obtain:

$$\begin{cases} p_n = \dfrac{w_n + c_n + f_n + 1}{2} \\ p_r = \dfrac{w_r + c_r + \delta}{2} \end{cases} \quad (5)$$

Formula (1) and (5) are substituted into formula (2) and (3) respectively , by $\dfrac{\partial \pi_{sn}}{\partial w_n} = 0$, $\dfrac{\partial \pi_{sr}}{\partial w_r} = 0$, optimal

wholesale price of new components and recovered components:

$$\begin{cases} w_n = \dfrac{(\delta - 2)(c_n + f_n) + c_r + 2c_{sn} + c_{sr} + f_r - s + 2(1 - \delta)}{4 - \delta} \\ w_r = \dfrac{c_n \delta + (\delta - 2)(c_r + f_r) + c_{sn}\delta + 2c_{sr} + f_n\delta - 2s + \delta(1 - \delta)}{4 - \delta} \end{cases} \quad (6)$$

Proposition 1: The price of new product decreases with the increase of government tax on new product, and decreases with the increase of government subsidy on remanufactured product. The price of recycled components increases with the increase of government tax on new products and decreases with the government subsidy on remanufactured products.

Proof: $\dfrac{\partial w_n}{\partial f_n} = \dfrac{\delta - 2}{4 - \delta} < 0$, $\dfrac{\partial w_n}{\partial s} = \dfrac{-1}{2(4 - \delta)(1 - \delta)} < 0$, $\dfrac{\partial w_r}{\partial f_n} = \dfrac{\delta}{4 - \delta} > 0$, $\dfrac{\partial w_r}{\partial s} = \dfrac{-2}{4 - \delta} < 0$.

Formula (6) is substituted into formula (5) to obtain the optimal price of the new product and remanufactured product:

$$\begin{cases} q_n = \dfrac{(\delta - 2)(c_n + f_n + c_{sn}) + c_r + c_{sr} + f_r - s + 2(1 - \delta)}{2(1 - \delta)(4 - \delta)} \\ q_r = \dfrac{c_n \delta + (\delta - 2)(c_r + c_{sr} + f_r) + c_{sn}\delta + f_n\delta + 2s + \delta(1 - \delta)}{2\delta(1 - \delta)(4 - \delta)} \end{cases} \quad (7)$$

Proposition 2: The sales of new products decrease with the increase of government tax on new products and the increase of government subsidy on remanufactured products;The sales of remanufactured goods increase with government taxes on new products and with government subsidies for remanufactured goods.

Proof：$\dfrac{\partial q_n}{\partial f_n} = \dfrac{\delta - 2}{2(1 - \delta)(4 - \delta)} < 0$, $\dfrac{\partial q_n}{\partial s} = \dfrac{-1}{2(1 - \delta)(4 - \delta)} < 0$, $\dfrac{\partial q_r}{\partial f_n} = \dfrac{\delta}{2\delta(1 - \delta)(4 - \delta)} > 0$,

$\dfrac{\partial q_r}{\partial s} = \dfrac{1}{\delta(1 - \delta)(4 - \delta)} > 0$.

By substituting formula (7) into formula (1), the optimal price of the new product and the remanufactured product can be obtained:

$$\begin{cases} p_n = \dfrac{2c_n + c_r + 2c_{sn} + c_{sr} + 2f_n + f_r - s - 3\delta + 6}{2(4 - \delta)} \\ p_r = \dfrac{c_n \delta + 2c_r + c_{sn}\delta + 2c_{sr} + f_n\delta + 2f_r - 2s + 5\delta - 2\delta^2}{2(4 - \delta)} \end{cases} \quad (8)$$

Proposition 3: The price of new product increases with the increase of government's tax on new product and decreases with the increase of government's subsidy on remanufactured product.The price of remanufactured products increases with the increase of government tax on new products and decreases with the increase of government subsidy on remanufactured products.

Prove: $\dfrac{\partial p_n}{\partial f_n} = \dfrac{1}{4 - \delta} > 0$, $\dfrac{\partial p_n}{\partial s} = \dfrac{-1}{2(4 - \delta)} < 0$, $\dfrac{\partial p_r}{\partial f_n} = \dfrac{\delta}{2(4 - \delta)} > 0$, $\dfrac{\partial p_r}{\partial s} = \dfrac{-1}{4 - \delta} < 0$.

IV. NUMERICAL ILLUSTRATION

In order to further explore the impact of government tax and subsidy policies under different levels of consumer approval, numerical examples are used for analysis in this section.The basic parameters are set as follows, $c_n = 0.5$, $c_r = 0.5$, $c_{sn} = 0.3$, $c_{sr} = 0.15$;Consumer recognition is considered in three ways: $\delta = 0.3$ (low), $\delta = 0.5$(medium), $\delta = 0.8$(high).

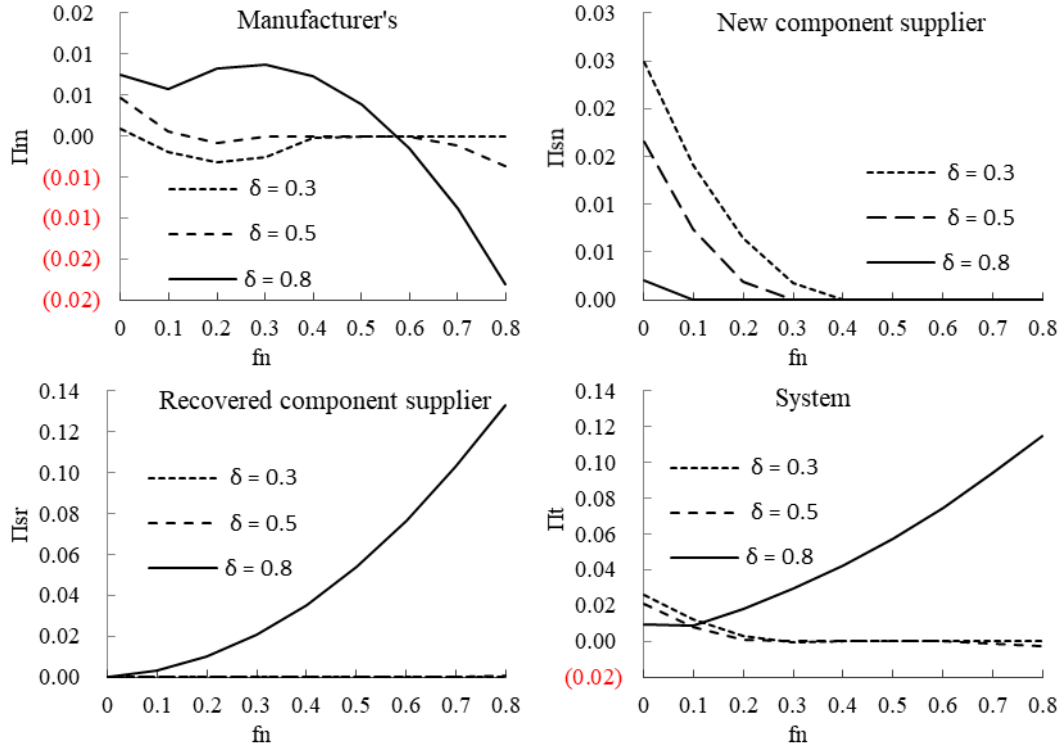**4.1 The government imposes a disposal tax on new products**

Fig. 2. The impact of government tax on profits

Figure 2 shows the profits of member enterprises and the system as a whole under the circumstance that the government imposes taxes on new products. It can be seen that :(1) the profits of new components suppliers decrease with the increase of taxes. Especially, when consumers have a high recognition of remanufactured products, the profits of new components suppliers suffer serious losses.(2) For suppliers of recycled components, whether they can make profits depends on consumers' recognition of remanufactured products. Under low or medium recognition, suppliers of recycled components are not profitable, so they have no incentive to carry out the business of recycled components. Even the increase of tax can't change this situation.However, under high recognition, it is possible for recovered components suppliers to make profits, and with the increase of tax revenue, the profit of recovered components suppliers increases significantly. At this time, tax policy plays a positive incentive role on recovered components suppliers.(3) For manufacturers, their profits show a complex change of "first falling, then rising, then falling" with the increase of tax. It is particularly noteworthy that when consumers have a high recognition of remanufactured products, moderate tax is beneficial, such as when $0.1 < f_n < 0.3$, the measure of levy disposal tax on new products can promote the increase of manufacturers' profits. The reason is that moderate taxation will promote manufacturers to use recycled components to produce remanufactured products and benefit from the sales of remanufactured products.In addition, no matter whether the recognition is low or high, excessive tax will have a large negative impact, resulting in manufacturers unable to make profits and forced out of the market, so the formulation of tax policies should pay attention to the principle of moderation.(4) from the point of profit system as a whole, when the consumers of remanufacturing products is low recognition, system total profits along with the increase of tax revenue decline, when consumers of remanufacturing products are highly recognized, rising with the increase of the tax system total profit, so from the system as a whole, the tax policy only in high recognition situation can play a positive role.

Conclusion 1: in supplier leadership of closed-loop supply chain structure, tax policy play a positive role in high recognition situation, only the system's overall profit increase, but apparent conflicts of interest

between the members of the business, new suppliers are facing loss of profit will be hard to avoid, and manufacturers and recycling suppliers will be moderate to the tax policy incentives.
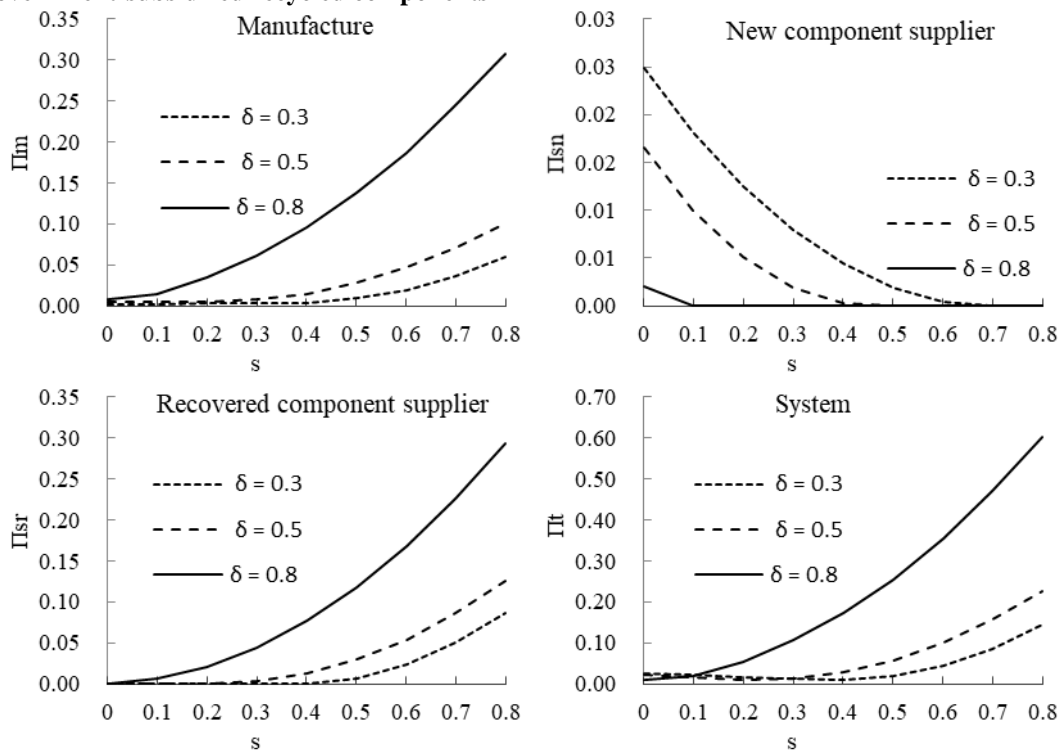
4.2 Government-subsidized recycled components

Fig.3. The impact of government subsidies on profits

Fig. 3.Shows the members under the leadership of the enterprise for the suppliers as well as the profit of the system as a whole, it can be seen that: (1) the new supplier of profit under the effect of subsidies and tax under the action of effect similar to that of its profits as the government suffered losses, subsidies for recycling has increased in the consumer recognition of remanufacturing products is higher when the situation is more serious.(2) For suppliers of recycled components, government subsidies can significantly improve their profits, and the level of profits is also affected by consumers' recognition of remanufactured products. The higher the recognition level is, the more significant the increase in profits will be.Therefore, the suppliers of recycled components are profitable with government subsidies and have the incentive to participate in recycling and remanufacturing.The subsidy has a positive effect on the suppliers of recycled components.(3) Subsidies also play a positive role in promoting manufacturers' profits. Under the effect of subsidies, manufacturers' profits also show an upward trend. Influenced by consumers' recognition of remanufactured products, the higher the recognition degree is, the stronger the promotion effect is for manufacturers' profits.(4) From the perspective of the overall profit of the system, the profit is on the rise in the low, medium and high three recognition degrees, which indicates that the policy can effectively improve the overall profit of the system.

Conclusion 2: In the supplier-led closed-loop supply chain structure, the government subsidy policy for the recovered components supplier can improve the profit level of the manufacturer and the recovered components supplier under both high and low recognition degree, and the overall profit level of the system can also be improved, and the higher the recognition degree is, the more significant the improvement effect will be.Under the influence of subsidy policy, the profit of new components supplier is in a declining trend, and it needs to make some sacrifices.Therefore, in the supplier-led closed-loop supply chain structure, subsidy policy can play an incentive role for manufacturers and recovered components suppliers to participate in remanufacturing.

V. CONCLUSION

In this paper, a Stackelberg game is employed to compare the price and sales volume of new and recovered components, the profit of manufacturer, new part supplier and recovered part supplier and the total profit of the system under two different power structures, so as to provide theoretical and practical Suggestions for government incentive remanufacturing.

It can be seen from the example analysis that :(1) under the leadership of suppliers, when consumers

have low recognition of remanufactured products, the government tax will be increased, and the member enterprises of the supply chain will not make any profit;When the recognition is high, raising the tax can increase the overall profit of the recovered components supplier and the system, but the manufacturer can only make profits under certain conditions.Therefore, remanufacturing through tax incentives needs to be through moderate tax policy incentives.(2) Under the leadership of suppliers, increasing government subsidies will increase the profits of manufacturers and suppliers of recycled components and encourage them to participate in remanufacturing.(5) It can be seen that in several cases of incentive remanufacturing development, the level of consumer recognition directly affects the profits of member enterprises.In particular, under the leadership of manufacturers, the government has the influence of tax. Only under the high recognition, manufacturers are interested in participating in remanufacturing. Therefore, the government should make some efforts to improve the recognition of consumers.(6) In addition, in the process of encouraging the development of the remanufacturing industry, new components suppliers are always in a disadvantaged position and their profits are severely damaged.As the total profit of the system is increasing, the internal interests of the system can be considered to coordinate and maintain the profits of new components suppliers.New components suppliers should also actively consider the transformation to become an integrated supplier of new components supply and recovered components supply.

It should be pointed out that the profit of new components supplier in this paper has been seriously damaged under various circumstances.How to coordinate the profits of manufacturers, new components suppliers and recovered components suppliers to make new components suppliers profitable and the sustainable development of closed-loop supply chain remains to be considered.In addition, this paper takes the government's financial intervention as an exogenous variable and does not discuss the cost of government's financial subsidy, which can be considered in future studies.

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