Research on Price Strategy of Recycling Express Packaging Based on Game Theory

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Abstract

This paper aims to construct a secondary closed-loop supply chain model for the combined recycling of express packaging manufacturers and e-commerce logistics enterprises for the specific recycling objects of express packaging, and use the theory and method of game theory to make the optimal decision on the price of express packaging recycling. Considering the non-cooperative game and cooperative game under the condition of e-commerce logistics enterprises' self-reservation express packaging, calculate the selling price, wholesale price and recycling price of express packaging, and the profit of each participating entity. Finally, through numerical simulation,analyze the influence of each decision variable change on the profit function.

Keywords

Express packaging, game theory, recycling price.

1. Introduction

The rapid development of China's e-commerce has driven the booming development of the express delivery industry. As a result of the development of the express delivery industry in recent years, the problem of a large amount of express package wasted has attracted the attention of various industries. In 2017, the relevant state departments issued the "Guiding Opinions on Collaboratively Promoting Green Packaging in the Express Delivery Industry" to continue to promote the reform of the express packaging field. According to statistics, in 2018, the volume of China's express delivery business reached 50 billion pieces [1], but the recycling rate of express packaging was less than 20%. Therefore, it is imperative to recycle the available express packaging materials. Logistics companies and E-commerce companies under the B2C model, such as Jingdong, Vipshop, Suning, etc, provide self-operated logistics service enterprises, which will use a large amount of express packaging. In these two cases, express packaging can be recycled, and packaging cartons are used. The main recyclable packaging materials is express delivery packaging, and the recycling price is an important research content in recycling.

2. Literature References

The development of reverse packaging recycling in China lags behind the development of foreign countries. As early as the 1990s, packaging recycling in Europe and the United States has established a mature packaging recycling system. Germany [2] is the first country in the world to implement packaging recycling, and has adopted specific laws to establish specific standards for producers' actions; the implementation of the EU Directive [3] has also greatly improved the recycling level of packaging waste in European countries; According to the level of recycling rate of enterprise packaging, state governments appropriately exempt corporate-related taxes to increase the enthusiasm of enterprises for recycling packaging. Regarding the recycling of packaging waste, the current research mainly has the following aspects. Firstly, research on recycling models. Wu Yuping

[5] based on the extended producer responsibility(EPR) system, summed up the self-operated, alliance recycling and third-party recycling model and indirect responsibility trading system for the producer. Liu Guoqiu [6] integrate into the concept of cyclic symbiotic economy, proposed packaging users recycling model and joint recycling model and joint recycling organization can be organized by packaging manufacturers or packaging users, or jointly established by two industries. Hamed Jafari [7] based on sustainable development to establish a three-tier supply chain channel for collectors, a recycler and a manufacturer. Lu Fang, Luo Juan [8] pointed out that the express packaging recycling can rely on the express agent point and logistics network system for recycling. Secondly, research on recycling pricing research. In the closed-loop supply chain recycling of product remanufacturing, R. Canan Savaskan [9]proposed three recycling channels based on the Stanberg model to make pricing decisions to select the appropriate recycling channels. Guide [10] emphasizes the important impact of recycling management decisions such as recycling prices, recycling quantities and recycling product quality on remanufacturing earnings. Shu San Ga [11]consider time-dependent prices under two different schemes for product recycling including retailers, manufacturers and end customers. Wang Tingting, Nan Guofang [12] conducted game analysis in four states for price decision in reverse logistics recovery of retail products. Ding Yangke [13] conducted an in-depth discussion on the impact of factors such as economies of scale, government subsidies, and remanufacturing rates on the price decision of recycling process under the monopoly of remanufacturing reverse logistics and the mode of competitive recycling. Cheng Faxin [14] considered the closed-loop supply chain pricing decisions under government subsidy factors and uncertainty of Waste Product Quality. Hong Xianpei [15]proposed a price decision model for three recycling channels under a dual-channel closed-loop supply chain. Li Meiying [16] studied the optimal retail price, wholesale price and recovery rate under the dual-channel closed-loop supply chain model when retailers and manufacturers simultaneously recycling. Zhang Huayang [17] studied the recycling price of express carton mainly from the third-party recycling and the third-party and courier enterprise recycling jointly. Zhang Hui [18] studied the decision-making problem of producers adopting differentiated recycling price, and used the cooperation coefficient to discuss the efficiency of participating in main body profit and supply chain recovery rate under different cooperation levels.

In summary, the price decision model of e-commerce logistics enterprises as market leaders has its research value. Therefore, construct a secondary closed-loop supply chain model for the joint recycling of express packaging manufacturers and e-commerce logistics enterprises, analyze the impact of recycling rate and recycling scale on package price, wholesale price, recovery price and profit change of participating entities under the non-cooperation game and cooperative game, which will be used as reference for setting up the optimal price in express delivery packaging recycling for e-commerce logistics enterprises.

3. Modeling

3.1 Model description

Enterprises with e-commerce business set up a logistics system for their own business needs, and distribute products to consumers through distribution channels and distribution sites of self-built logistics. On the one hand, they can expand business areas, improve consumer satisfaction, and realize the control of the logistics service. On the other hand, e-commerce companies, as users of packaging, can use the packaging twice. Recycling directly from e-commerce-owned logistics or express delivery companies can improve recycling efficiency, reduce recycling costs in the supply chain, control the entire recycling process, and grasp the recycling information and avoid its uncertainty.

In the self-operated logistics recycling mode of e-commerce enterprises, e-commerce logistics enterprises are responsible for recycling and recycling, while express packaging manufacturers process and re-process. For the express packaging recovery that consumers actively participate in, they can give price concessions at the next consumption to increase their enthusiasm for participation.

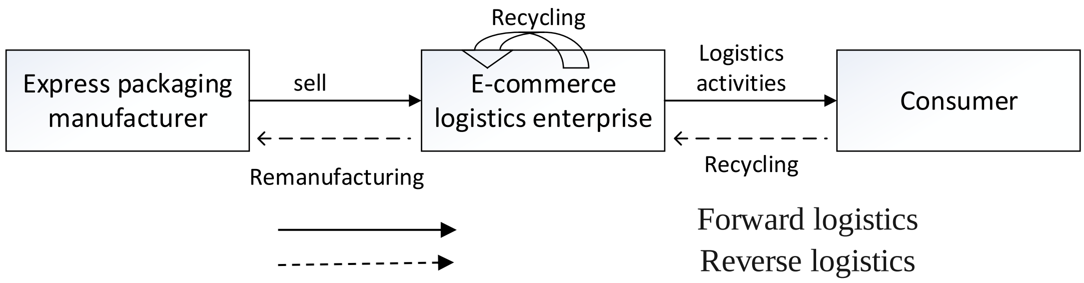

Fig.1 E-commerce enterprise self-operated logistics recycling model

As shown in Fig. 1, the solid line indicates the forward flow and the broken line indicates the reverse flow. Forward logistics activities: express packaging manufacturers produce cartons and provide them to e-commerce logistics companies at wholesale prices. E-commerce logistics companies determine the price of cartons and sell cartons and other product services to consumers.

Reverse logistics activities: Consumers will receive a discount for recycling the used express packing boxes through express delivery sites or self-contained recycling boxes.. The e-commerce express delivery enterprises will keep the used cartons for secondary recycling, and the express packaging manufacturer recycles other express packaging cartons for re-manufacturing at a recycling price, and re-enters the newly manufactured cartons into the market to form a closed-loop supply chain. Courier packaging manufacturers have a more cost advantage in the disposal of used packaging. Therefore, e-commerce or express delivery companies only provide recycling channels, and packaging manufacturers process raw materials and new carton manufacturing.

The recovery model has the following assumptions:

(1) A secondary supply chain recycling system consisting of one express packaging manufacturer and multiple e-commerce logistics enterprises;

(2) All participants are rational people, and pursue profit maximization when making independent decisions;

(3) Consider only the single cycle of express packaging and recycling, and carton is recycled as a single express packaging material

(4) Does not consider the inventory factor in the process of express packaging recycling;

(5) There is no difference between the re-manufactured and recycled courier boxes and the newly manufactured boxes, that is, the sales price is the same (recycling refers to courier packaging that can continue to be used; re-manufacturing refers to the manufacturer's use as raw materials);

(6) The unit cost of manufacturing waste paper boxes as raw materials is less than the unit cost of new material manufacturing;

(7) The express packaging recovery factor is directly proportional to the subsidized preferential price;

(8) The express carton is sold to consumers along with other services;

3.1.1 Model parameters and definitions

1. Parameters and definitions in the packaging recycling process of e-commerce or logistics enterprises

E-commerce or logistics enterprise set L = {1, 2, 3..., l }, where e-commerce or logistics enterprise $j \in$ L,

The number of consumer demand satisfies the linear demand function [20] :

$$Dj(Pj)=aj-bjPj \tag{1}$$

Where aj represents the potential market demand and bj represents the elasticity coefficient of the price and is greater than zero. From Dj$\geqq$0, we know that Pj$\leqq$aj/bj;

The recycling market scale is Bj, and the recovery rate is related to the stimulating investment [21], which is reflected in the price concession of the packaging recycler to the consumer, expressed as rj (rj>0), then the recovery rate of the e-commerce or logistics enterprise βj= K_j rj, where kj is the consumer's sensitivity to recycling subsidies.

It can be seen that the quantity recovered is:

$$G_{rj}(r_j)=\beta_j B_j=k_j r_j B_j \tag{2}$$

Therefore, the total amount of recycling market is:

$$G_j=D_j+G_{rj}=a_j-b_jP_j+k_jr_jB_j \tag{3}$$

The probability that the carton can be recycled by the manufacturer after recycling, Pm, 0<Pm<1

Cr: The other cost in the recycling process of e-commerce logistics enterprises;

2. Parameters and definitions of packaging manufacturers in the process of express packaging recycling

The packaging manufacturer M wholesales the carton to the packaging user at the wholesale price Wm, and recycles the used carton at the price rm. The unit processing cost is e, and the manufacturer's fixed input is Fm, then the cost of the manufacturer's re-manufacturing is:

$$C_m=F_m+\sum_{j=1}^{L}P_mG_{rj}(e+r_m) \tag{4}$$

The cost of packaging manufacturers to produce new cartons is:

$$C_p=\sum_{j=1}^{l}tD_j \tag{5}$$

Table1 Model parameters and definition table

Parameter	Definition	Parameter	Definition
Pj	Express packaging carton price	Cr	other costs in the recycling process
rj	Recycling price	Bj	Recycling size
Dqj	Consumer demand for cartons	βi	Recovery scale factor
Drj	Number of recycled courier cartons	e	Re-manufacturing unit cost
Drrj	Recycling express carton quantity	Fm	Fixed cost of the manufacturer
Dj	Total amount of recycling market	Cm	Total cost of re-manufacturing of used cartons
Pr	Probability of recycling by the E-commerce logistics enterprise	rm	Manufacturer recycling price
Pm	Probability of recycling by the manufacturer	t	The unit cost of using new materials，t>e
Wmi	Carton wholesale price	Cp	Total cost of producing new cartons

3.1.2 Participation in the main game model

E-commerce logistics enterprise profit function:

$$Max\ \prod_L(P_j, r_j)=(P_j-w_m)D_j+(P_j+r_m-r_j-w_m)G_{rj}P_m-C_r$$

$$=(P_j-w_m)(a_j-b_jP_j)+(P_j+r_m-r_j-w_m)(k_jr_jB_j)P_m-C_r \tag{6}$$

The profit of the e-commerce logistics enterprise is composed of two parts. The first part is the return of the enterprise to the logistics revenue, the enterprise purchases the carton from the production enterprise and sells the carton together with other services; the second part is the income generated by the enterprise reverse recycling carton, the enterprise The recycled carton is sold to the production enterprise with a probability of Pm, and the production enterprise recovers and reproduces at the recovery price r_m, and G_{rj} is a recoverable quantity.

Packaging manufacturer profit function:

$$Max \prod_M (w_m, r_m) = \sum^l (w_m - t) D_j + \sum^l P_m G_{rj} (w_m - r_m - e) - F_m$$
$$= \sum_j^l (w_m - t)(a_j - b_j P_j) + \sum^l P_m k_j r_j B_j (t - e - r_m) - F_m \quad (7)$$
$$\text{s.t. } P_j > w_m > 0,\ P_j \leqq \frac{a_j}{b_j},\ t > e,\ \beta_j > 0$$

The profit of the packaging manufacturer consists of two parts, one is the profit generated by the production of new packaging cartons. The difference between the total number of new packaging cartons and the amount of reverse recycling is the positive market demand, and the wholesale price of e-commerce logistics enterprises. The difference between the cost of using the new material is the profit of the new carton unit; the other part is the profit value of the manufacturer for the re-manufacturing of the carton, the unit profit is the difference between the wholesale price and the re-manufacturing cost price, and the manufacturer's recycling price for the carton user. .

It can be seen from equations (7) and (8) that the total supply chain profit of e-commerce logistics enterprises and packaging manufacturers is:

$$Max \prod_A = \sum_{j=1}^{L} (P_j - t)(a_j - b_j P_j) + \sum_{j=1}^{L} (P_j - r_j - e)(P_m k_j r_j B_j) - \sum_{j=1}^{L} C_r - F_m \quad (8)$$

3.2 Model solving

Consider a recovery game model between a packaging manufacturer and multiple recycling companies. When packaging manufacturers and e-commerce logistics companies have the same influence in the market, they are not market leaders, and both of them act at the same time. The two sides do not understand each other's decisions and use Nash game to solve the analysis. When the e-commerce logistics enterprise in the supply chain first enters the market to initiate the recycling behavior, the packaging manufacturer's decision-making information is fully understood, and the decision-making information is first made on the basis of this. The two-step sequential decision-making form uses the Stackelberg model. analysis. When the two sides reach cooperation, the goal of decision-making is to maximize the common interests. Quantitative analysis of recovery for different situations.

3.2.1 Nash Equilibrium Game

Packaging manufacturers and e-commerce logistics companies are completely static games, that is, both parties make decisions at the same time. At this time, the carton price p and the recycling preferential price rj are the decision variables of the e-commerce logistics enterprise, and the carton wholesale price w_m and the re-manufacturing recovery price rm are the decision variables of the manufacturer. Because the manufacturer's wholesale price w_m and the package price Pj satisfy $Pj > w_m$, assuming the minimum marginal revenue is the producer's marginal benefit [22], the relationship between the wholesale price and the selling price is as follows：

$$\text{By } P_j - w_m \geqq w_m - t \quad j \in L \quad \text{Know } w_m \leqq (P_j + t)/2$$

The wholesale price takes the boundary value and the optimal function is

$$w_m = (P_j + t)/2 \quad j \in \text{L} \quad (9)$$

The package recycling and resale income is not lower than the purchase cost saved by the manufacturer.

$$\text{By } r_m - r_j \geq t - e - r_m \quad \text{Know } r_m \geq (t - e + r_j)/2$$

That is, the packaging manufacturer’s optimal solution for the recycling price of the carton is

$$r_m = (t - e + r_j)/2 \quad j \in \text{L} \quad (10)$$

Equation (6) performs first-order derivation of rj and Pj, respectively:

By $\left(P_j + r_m - w_m\right)P_m k_j B_j - 2k_j r_j B_j P_m = 0$

$$\text{Know } rj = \frac{p_j + r_m - w_m}{2} \tag{11}$$

Substituting equation (13) into equation (8) and deriving Pj,

$$\frac{\partial \Pi_L}{\partial P_j} = a_j - 2b_j P_j + b_j w_m + k_j r_j B_j P_m \frac{(p_j + r_m - r_j)'}{2} = 0$$

$$P_j = \frac{2a_j + (2b_j - k_j B_j P_m)w_m + k_j B_j P_m r_m}{4b_j - k_j B_j P_m} \tag{12}$$

Find the second derivative of rj as -2$k_j B_j P_r$, Because $k_j B_j P_r$ it is greater than 0, then r_j'' <0, r_j the optimal value is obtained;

Find the second derivative of p_j as $\frac{k_j B_j P_m - 4b_j}{2}$, When $k_j B_j P_m - 4b_j$<0, p_j get the optimal value;

When $k_j B_j P_m - 4b_j \geqq 0$, $p_j = \frac{a_j}{b_j}$ ($k_j B_j P_m - 4b_j$ is expressed as δ)

Substituting equations (9) and (11) into (10) and obtaining

$$r_m = (p_j + 3t - 4e)/6 \tag{13}$$

Substituting equation (12) into equation (14) is solved:

$$P_j^* = \begin{cases} \dfrac{6a_j + 3b_j t - 2k_j B_j p_m e}{9b_j - 2k_j B_j p_m} & \delta < 0 \\ \dfrac{a_j}{b_j} & \delta \geqq 0 \end{cases} \tag{14}$$

$$r_j^* = \begin{cases} \dfrac{2a_j + b_j(t - 3e)}{9b_j - 2k_j B_j p_m} & \delta < 0 \\ \dfrac{1}{2}\left(\dfrac{a_j}{b_j} - e\right) & \delta \geqq 0 \end{cases} \tag{15}$$

$$w_m^* = \begin{cases} \dfrac{3a_j + (6b_j - k_j B_j p_m)t - k_j B_j p_m e}{9b_j - 2k_j B_j p_m} & \delta < 0 \\ \dfrac{1}{2}\left(\dfrac{a_j}{b_j} + t\right) & \delta \geqq 0 \end{cases} \tag{16}$$

$$r^*_m = \begin{cases} \dfrac{a_j + b_j(5t - 6e) - k_j B_j p_m (t - e)}{9b_j - 2k_j B_j p_m} & \delta < 0 \\ \dfrac{1}{6}\left(3t - 4e + \dfrac{a_j}{b_j}\right) & \delta \geqq 0 \end{cases} \tag{17}$$

3.2.2 Stackelberg game dominated by express packaging and recycling enterprises

In the non-cooperative decision-making model of packaging manufacturers and e-commerce logistics enterprises, the two parties participate in decision-making as rational independent stakeholders and pursue the best interests. In this decision-making model, the e-commerce logistics enterprise is the initiator of the recycling behavior, the price leader is the first action, and the express packaging production enterprise as the follower performs the Stackelberg game. It is a dynamic and sequential game with complete information, and the recycling subject The enterprise makes a decision under the response function of the express packaging manufacturing enterprise, and uses the inverse induction method to solve the problem, that is, firstly, the profit of the packaging manufacturer is maximized, and the wholesale price of the package and the optimal price for recycling the packaging from the e-commerce logistics enterprise are obtained, and then Substituting it into the profit function of the e-commerce logistics enterprise, and obtaining the packaging recycling price and the optimal recycling preferential price.

According to the (1) middle Nash equilibrium solution part, the wholesale price wm and the recovery price rm of the packaging manufacturer for the packaging manufacturer can be known, that is, the formulas (9) and (10). Bring the objective function of the e-commerce logistics enterprise (6) and guide the preferential price rj:

$$\frac{\partial \Pi_L}{\partial r_j} = k_j B_j P_{\mathrm{m}}(\frac{P_j - e}{2}) - k_j B_j P_{\mathrm{m}} r_j = 0$$

$$r_j = \frac{p_j - e}{2} \tag{18}$$

The second order of rj is derived as -kj Bj Pm<0, so rj obtains the optimal value.

Substituting equation (18) into equation (10): rm=(Pj+2t-3e)/4 (19)

Substituting equation (18) into (6) and deriving Pj:

By $\frac{\partial \Pi_L}{\partial P_j} = \frac{1}{2}(a_j - 2b_j P_j + b_j t) + k_j B_j P_{\mathrm{m}} \frac{P_j - e}{4} = 0$ we can know

$$\delta < 0 \quad P_j = -\frac{2a_j + 2b_j t - k_j B_j P_{\mathrm{m}} e}{\delta} \tag{20}$$

Continue to derive Pj, the second derivative is δ /4, when δ <0, Pj obtains the optimal value.

When $\delta \geqq 0$, the value of the objective function of the logistics e-commerce enterprise is maximized when Pj takes the boundary value $P_j = \frac{a_j}{b_j}$, and the equilibrium solution of other functions is obtained as follows:

$$P_j^{**} = \begin{cases} -\dfrac{2a_j + 2b_j t - k_j B_j p_m e}{\delta} & \delta < 0 \\ a_j / b_j & \delta \geqq 0 \end{cases} \tag{21}$$

$$r_j^{**} = \begin{cases} -\dfrac{a_j + b_j(t - 2e)}{\delta} & \delta < 0 \\ \dfrac{1}{2}(\dfrac{a_j}{b_j} - e) & \delta \geqq 0 \end{cases} \tag{22}$$

$$w_m^{**} = \begin{cases} -\dfrac{2a_j + 6b_j t - k_j B_j p_m(t + e)}{2\delta} & \delta < 0 \\ \dfrac{1}{2}(\dfrac{a_j}{b_j} + t) & \delta \geqq 0 \end{cases} \tag{23}$$

$$r^{**}{}_{m} = \begin{cases} -\dfrac{a_j + b_j(5t - 6e) + k_j B_j p_m(e - t)}{2\delta} & \delta < 0 \\ \dfrac{1}{4}(2t - 3e + \dfrac{a_j}{b_j}) & \delta \geqq 0 \end{cases} \tag{24}$$

3.2.3 Cooperative game between express delivery packaging enterprises and e-commerce logistics enterprises

Taking the formula (8) as the objective function, it can be seen that the common interests of the two are not related to the wholesale price of the e-commerce logistics enterprise w_m recovery price r_m, but only related to the package price Pj and the subsidized preferential price rj. Therefore, the objective function Derived separately:

$$\partial \Pi_A / \partial r_j = -2k_j B_j P_m r_j + k_j B_j P_m (P_j - e) = 0$$

$$r_j = \frac{p_j - e}{2} \tag{25}$$

The supply chain objective function (8) performs second-order derivation of rj to -2kj Bj Pm<0, so rj obtains the optimal value.

Substituting equation (24) into the objective function (8) and deriving Pj:

$$\frac{\partial \Pi_A}{\partial P_j} = \frac{\delta}{2} P_j + a_j + b_j t - \frac{k_j B_j p_m}{2} e = 0$$

$$P_j = -\frac{2a_j + 2b_j t - k_j B_j p_m e}{\delta} \tag{26}$$

When δ <0, the second order is derived as δ /2<0, and Pj obtains the optimal solution.

When $\delta \geqq 0$, the objective function obtains the maximum value Pj=aj/bj when Pj takes the boundary value, and the optimal solution in the cooperative game is known.

$$r_j^{***} = \begin{cases} -\frac{a_j + b_j(t - 2e)}{\delta} & \delta < 0 \\ \frac{1}{2}(\frac{a_j}{b_j} - e) & \delta \geqq 0 \end{cases} \tag{27}$$

$$P_j^{***} = \begin{cases} -\frac{2a_j + 2b_j t - k_j B_j p_m e}{\delta} & \delta < 0 \\ a_j / b_j & \delta \geqq 0 \end{cases} \tag{28}$$

It can be seen that the optimal solution of the cooperative game is the same as that of the e-commerce logistics enterprise. It can be seen that when the packaging user leads, the overall profit maximization can be achieved, which has nothing to do with the packaging manufacturer decision variables.

The analysis of non-cooperative game (Nash equilibrium, Stackelberg game) and cooperative game pricing under the self-operated logistics recycling mode of E-commerce logistics, the optimal pricing decision and maximum of the closed-loop supply chain and the whole closed-loop supply chain under the two modes income.

Table 2 Price optimal decision results

Variable	Non-cooperative game（δ <0）	Variable	Cooperative game (δ <0)
p_j	$\frac{6a_j + 3b_j t - 2k_j B_j p_m e}{9b_j - 2k_j B_j p_m}$	p_j	$-\frac{2a_j + 2b_j t - k_j B_j p_m e}{\delta}$
r_j	$\frac{2a_j + b_j(t - 3e)}{9b_j - 2k_j B_j p_m}$	r_j	$-\frac{a_j + b_j(t - 2e)}{\delta}$
r_m	$\frac{a_j + b_j(5t - 6e) - k_j B_j p_m (t - e)}{9b_j - 2k_j B_j p_m}$	r_m	$-\frac{a_j + b_j(5t - 6e) + k_j B_j p_m (e - t)}{2\delta}$
w_m	$\frac{3a_j + (6b_j - k_j B_j p_m) t - k_j B_j p_m e}{9b_j - 2k_j B_j p_m}$	w_m	$-\frac{2a_j + 6b_j t - k_j B_j p_m (t + e)}{2\delta}$

4. Numerical simulation

In order to verify the feasibility and practicability of the model proposed in this paper to determine the recovery pricing of reverse packaging logistics using the game model, the following numerical calculations are designed according to the actual situation and reference data to further research and analysis. The analysis results were obtained with MATLAB.R2016a as the operating platform. It can be seen from Table 2 that each result is affected by the three factors of variable parameters Pm, kj, and bj, and is analyzed by the control variable method.

4.1 Analysis of influence on Remanufacturing rate Pm

Taking the scope of a courier recycling market as the research object, under the circumstances given by other parameters, the packaging manufacturer will study the impact of the courier packaging carton on the two sides for remanufacturing with different probability Pm.

Take the following basic parameter values: aj=2000, bj=350, kj=0.01, Bj=5000, l=500 Other fixed values are e=1, t=3, Cr=10, Fm=30000, set remanufacturing rate In the interval of 0.1-0.9, the above numerical values are substituted into the equations of Table 2 and the functions (6)-(8), and the graph of Fig. 2 is obtained.

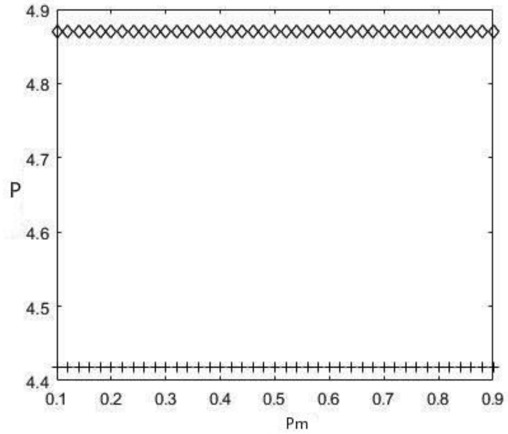

Fig. 2-1

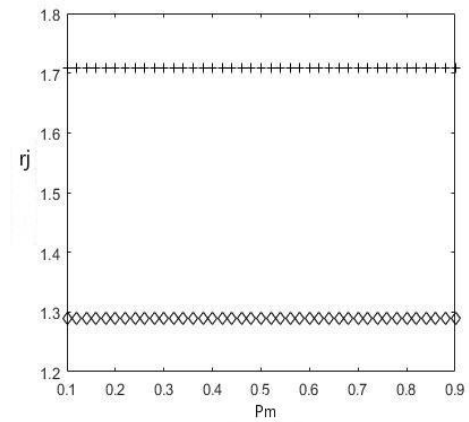

Fig. 2-2

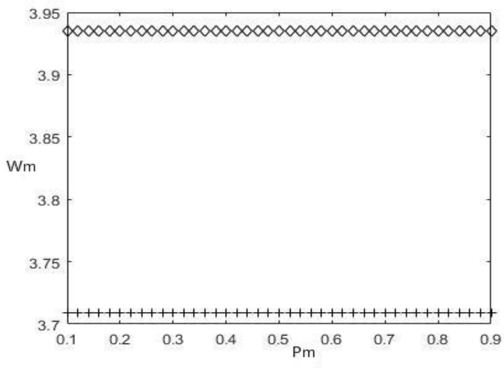

Fig.2-3

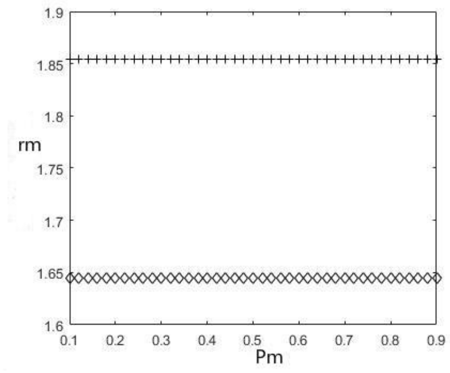

Fig. 2-4

□ Non-cooperative game
+ Cooperative game

According to the analysis of the results in Fig. 2, the remanufacturing rate Pm is changed under the condition that other parameters are unchanged, and the profit functions of the parameters Pj, rj, wm, rm and the participating entities (packaging manufacturer and e-commerce logistics enterprise) are performed. Numerical simulation, under the non-cooperative game and the cooperative game, there is a gap between the decision makers and the e-commerce logistics enterprises. From Figure 2-1 to

2-4, it can be found that in the case of Nash equilibrium, the price of the carton, the wholesale price is higher than the price under the cooperative game, the discounted price, and the producer's recycling price are lower than the price under the cooperative game. Under the non-cooperative game, each subject aims to maximize their own interests. For consumers, the price of cartons is lower under the cooperative game, and the recycling concessions are large, that is, when e-commerce logistics enterprises lead the recycling market, it is beneficial to consumers. For e-commerce logistics companies, lower wholesale prices and higher carton recycling prices are available.

It can be seen from Fig. 2-5 to 2-7 that as the remanufacturing rate Pm increases, the revenue of the e-commerce logistics company increases, the profit of the packaging production enterprise increases, and the overall revenue of the supply chain increases, that is, the remanufacturing rate of the carton is increased. Good for the entire system. From the two modes of Nash game and cooperative game, the cooperative game is the game initiated by the logistics e-commerce leader. For them, the benefit is relatively large, the interests of the participating subjects are greater than the profits under the Nash equilibrium, and the cooperative game Make the overall benefits of the supply chain bigger.

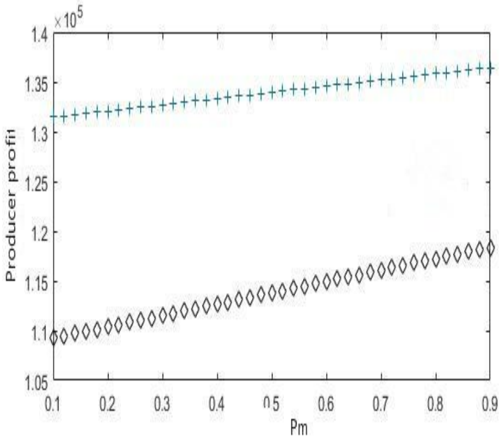

Fig.2-5

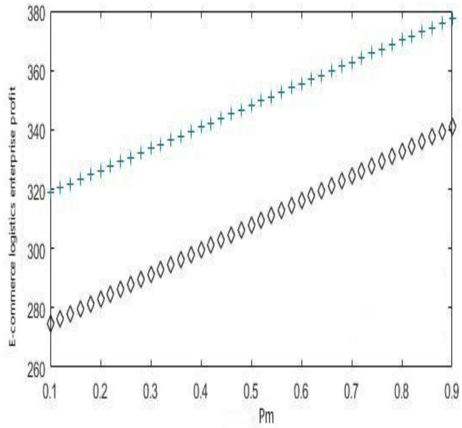

Fig. 2-6

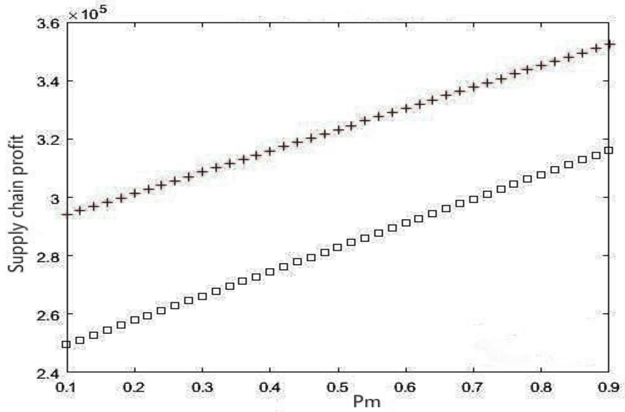

Fig. 2-7

4.2 Analysis of the sensitivity k of consumers to recycling subsidies Kj

Analyze the impact of consumer sensitivity on recycling subsidies kj on relevant parameters, take the following basic parameter values: aj=2000, bj=350, Pm =0.5, Bj=5000, l=500 other fixed values are e=1,t =3, Cr = 10, Fm = 30000. Under the constraint condition, the change of kj in the range of 0.01~0.1 is analyzed, and the group diagram of Fig. 3 is obtained.

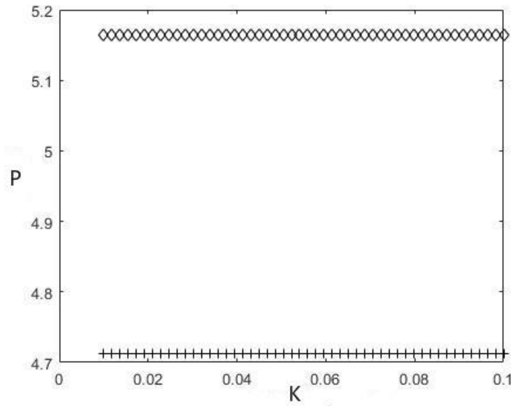

Fig.3-1

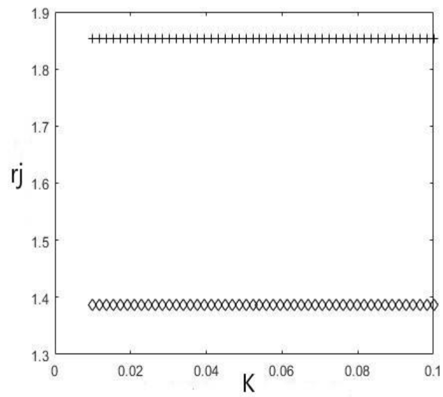

Fig.3-2

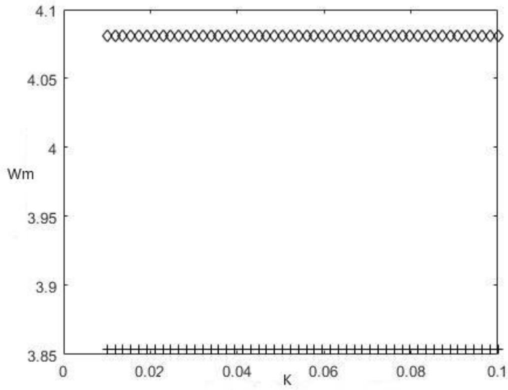

Fig.3-3

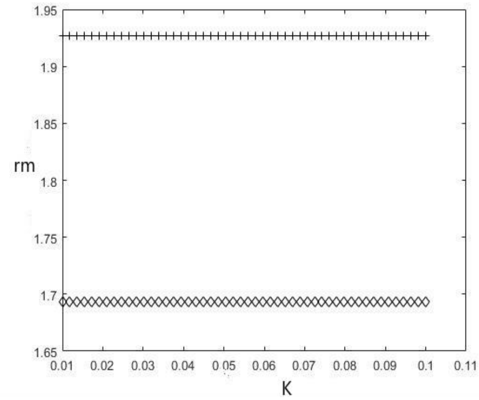

Fig.3-4

□	Non-cooperative game
+	Cooperative game

Comparing the corresponding graphs of the effects of the remanufacturing rate pm in Figures 3-1 to 3-4 and 2.1-2.4, it can be seen that the value of the decision variable under the range of kj varies, whether in the cooperative game or the non-cooperative game. It shows that consumers' sensitivity to recycling prices has a great impact on carton price, recycling price and recycling concessions. And the change of kj directly affects the recovery rate β. The increase in kj indicates that the recycling company is sensitive to the recycling subsidy given to consumers. The larger the k value, the higher the profit. According to Figures 3-6 to 3-7, when the e-commerce logistics enterprise is the leading enterprise, that is, when the two parties cooperate, the profits are higher than the profits of the enterprise under the Nash equilibrium.

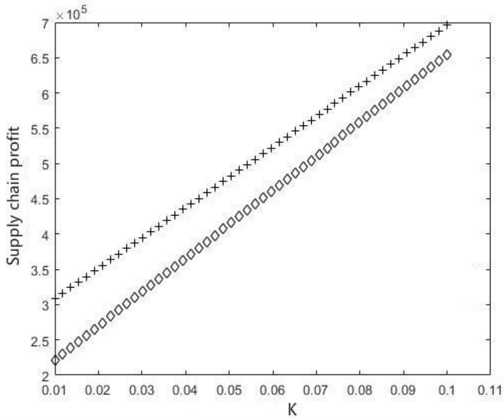

Fig.3-5

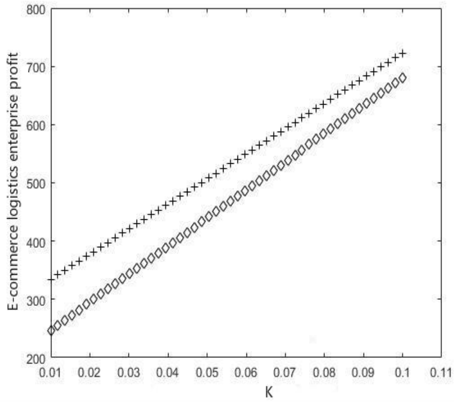

Fig.3-6

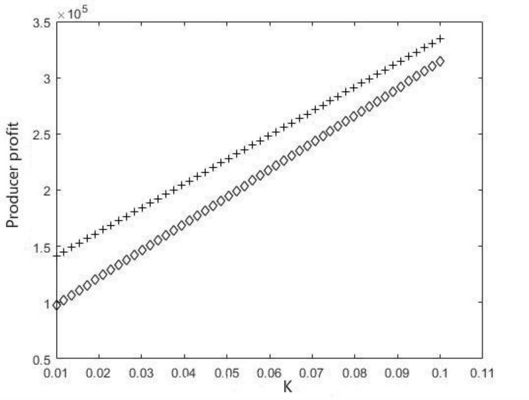

Fig.3-7

5. Conclusion

This paper studies a closed-loop supply chain system composed of a packaging manufacturer and a number of e-commerce logistics enterprises. In the two cases of non-cooperative game and cooperative game, the sales price and express delivery price set by the e-commerce logistics enterprise and the wholesale price and the secondary recovery price set by the production are the decision variables, respectively. And The game model with the optimal profit of e-commerce logistics enterprises and producers as the objective function uses the inverse induction method to solve the model. Finally, through numerical analysis, the results show that the profit of each enterprise and supply chain is greater when the cooperative game is adopted. Therefore, the packaging production enterprise and the e-commerce logistics enterprise should actively sign relevant contracts for express packaging and recycling, so that the participants in the recycling supply chain can be achieve win-win. E-commerce logistics enterprises should dominate the packaging of cartons in the market, packaging manufacturers should increase the remanufacturing rate, consumers should actively participate in express packaging recycling, try to avoid buying new packaging. For the government, the government's subsidies for recycling enterprises should be appropriately increased.

Since this paper only considers a closed-loop supply chain system consisting of one packaging manufacturer and multiple e-commerce logistics enterprises, it has certain limitations, and the real situation in real life is far more complicated. Therefore, further research can be carried out from the following aspects: reverse logistics recovery in the case of competition or monopoly; considering reverse logistics system by multiple packaging manufacturers and multiple recycling entities; and recycling of revenue in the case of multiple cycles Change, etc.

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