Study on revenue sharing contract coordination of manufacturer-led CLSC considering sales effort

Bin Li[1, a], Ziyun Zhao[2, b], Siqi Tong[1, c]

[1]School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing 400065, China;

[2]School of Economics, Southwest University of Political Science & Law, Chongqing 400031, China;

[a] 819247603@qq.com, [b] 714292991@qq.com, [c] tongsiqixxzx@qq.com

Abstract

In order to study the coordinating effect of manufacturer-led closed-loop supply chain pricing decisions and revenue sharing contracts when sales efforts affect market demand, this paper constructs a manufacturer-led closed-loop supply chain composed of a single retailer and a single manufacturer. Firstly, Stackelberg game model is used to study the pricing decision of closed-loop supply chain in two modes: centralized decision making and decentralized decision making· profit decline of closed-loop supply chain; Then, this paper also found the relationship between the overall profit of the supply chain and various parameters. The overall profit of the supply chain is in direct proportion to the maximum market demand and sales effort effect, and is in direct proportion to consumers' environmental awareness, and inversely proportional to the recovery price sensitivity coefficient. Finally, this paper solves the profit distribution problem of manufacturers and retailers by revenue sharing contract, and analyzes the value range of revenue sharing ratio coefficient by numerical simulation, so as to weaken the double marginal effect and improve the overall profit of the closed-loop supply chain in the closed-loop supply chain.

Keywords

Closed-loop supply chain, revenue-sharing contract, manufacturer-led, sales effort.

1. Introduction

With the increase of consumers' disposable income year by year, consumers' consumption concept changes. In addition, the development of manufacturing industry also reduces the price of products. Consumers have the conditions to improve the quality of life. If the electronic manufacturing industry recycles and reuses the discarded products, it can not only protect the environment and save resources, but also obtain the same market price as the newly mined precious metal products when using recycled materials to produce new products, but the recycling and remanufacturing cost is far lower than the mining and manufacturing cost. In addition, consumers pay more attention to products and services, such as extended warranty service, shopping guide service and other sales efforts are more attractive than no sales efforts. In practice, manufacturers and retailers make contracts to make their supply chains work better. Therefore, considering sales efforts, it is of great significance to study manufacturers' leading closed-loop supply chain pricing decisions and revenue sharing contracts for guiding the operation and management of closed-loop supply chain.

For the closed-loop supply chain, there have been more mature research results at home and abroad. Wu Z D et al.[1] studied the influence of different leading modes on the performance of closed-loop supply chain, and found that the leading mode had an important influence on the pricing decision, profit distribution, performance level and coordination mechanism. Giri[2] studied the pricing and recycling decision of dual-channel closed-loop supply chain and found that the performance of the manufacturer leading the whole supply chain is the best. Gao[3] simulated the risk-averse closed-loop supply chain's optimal order quantity decision, optimal wholesale price model and CVaR

decision by using CVaR model, optimal order quantity model and optimal wholesale price model. You et al.[4] studied the b-transform model of the bullwhip effect on the closed-loop supply chain and found that it was the best decision to collect all returned products, and the length of time before production and delayed recovery affected the bullwhip effect. The above studies have improved and developed related theories of closed-loop supply chain management, but more and more detailed classification studies are not mature yet. For example, considering the pricing decision and coordination of closed-loop supply chain with sales efforts, there are few research results in this direction.

Yao F M et al.[5] found that whether manufacturers or retailers are responsible for sales efforts, CSR(corporate social responsibility) can improve the overall supply chain performance and social welfare, but retailers are responsible for sales efforts more than manufacturers are responsible for sale sell effort better; When retailers are responsible for sales efforts, it is better for retailers to take CSR than manufacturers. Wu[6] product demand is studied by the length of the warranty period and sales efforts affect to the size of the closed loop supply chain, established by the manufacturers and retailers to provide warranty service affect the model of sales efforts, and put forward the manufacturers and retailers and warranty costs and cost of sales efforts, share the benefits of coordination modes. Wang[7] to study the affected by the price and sales efforts to news of the supply chain coordination problem in ordinary channel coordination mechanism under the condition of not coordinate, "volume discount" plan is put forward, make any income distribution manufacturers according to their wishes, and leaves retailers survive, only to coordinate this Class supply chain. The above research made more contributions to the direction of supply chain sales effort, but did not consider the role of sales effort in the closed-loop supply chain.

At home and abroad, there have been some research results on the coordination effect of revenue sharing contract on traditional supply chain. Ji X J [8] under the condition of considering the double channel conflict, the introduction of revenue sharing contract mechanism, and found that the mechanism can improve supply chain performance, and can coordinate the decentralized decision making behavior. Liu Juan [9] structure in the comparative studies of closed-loop supply chain contracts to coordinate a retailer recycling model of closed-loop supply chain model, compared the pricing contract and revenue sharing contract, found that can both contract coordination model of closed-loop supply chain coordination effect, the two are different in terms of transfer payment. Sun [10] revenue sharing contract is studied, the lateral transfer influence on supply chain, based on Stackelberg game, found the reprint can coordinate inventory levels, revenue sharing contract can coordinate the supply chain profit distribution, a combination of these are beneficial to improve supply chain performance. Wang [11] studied the demand for change with time, the retail price and the initial freshness of fresh product supply chain inventory coordination problems, under a revenue sharing contract, freshness, and retail prices had a great influence on performance. By the above research status can be seen for the research of supply chain revenue sharing contract is already relatively mature, but emerging the closed-loop supply chain, which has a great development prospect, also has the problem of secondary markup of the supply chain.

The existing results provide reference and ideas for further study of closed-loop supply chain pricing decisions and coordination contracts considering sales efforts. However, few studies have been conducted on closed-loop supply chain under the guidance of manufacturers to formulate corresponding coordination contracts to solve the retailer's consideration of the impact of sales efforts on demand and pricing. Therefore, this article to guide manufacturers dominate the closed-loop supply chain operation as a starting point, in-depth analysis of market demand, product sales efforts degrees wholesale price, retail price, and how about the price of recycling decisions, how to set up a revenue sharing ratio so as to coordinate the supply chain to profit distribution of the relationship between supply chain members, to study the effect of revenue-sharing contract on supply chain performance improvement.

2. Problem description and parameter description

The double benefit of the closed - loop supply chain is in line with the requirement of sustainable development mode. However, all participants in the supply chain participate in economic activities with the goal of maximizing their own profits, which will lead to double marginal benefits, thus reducing the performance level including the overall profit of the supply chain. In order to solve this problem, this paper proposes a revenue-sharing contract, in which the retailer provides a portion of the revenue to subsidize the loss borne by the manufacturer due to the reduction of the wholesale price. This paper will study the effect of the contract on weakening the double marginal effect and improving the overall performance level of the supply chain.

The symbols used in this article are illustrated as follows:

a is the maximum market demand without sales effort effect, $a > 0$;

b is the sensitivity coefficient of consumers to retail price, $b > 0$;

c is the cost coefficient of sales effort. For each additional unit of sales effort, the cost of sales increases by $\frac{1}{2}cy^2$;

h is the sensitivity coefficient of consumers to the recycling price of waste products, $h > 0$. For each additional unit of recycling price, the recycling quantity increases by hq;

k is the amount of waste products voluntarily returned by consumers when the market recycling price is 0. It can be regarded as the degree of consumers' social environmental protection awareness, $k > 0$;

l refers to sales effort effect, which represents the degree to which retailers' sales effort influences demand, $l > 0$;

m is the unit manufacturing cost of the manufacturer using new raw materials;

r refers to the unit manufacturing cost of recycling products for remanufacturing. Considering the difference in quality and recycling process of recycled products, r is the average value, and $m > r$, the manufacturer has the power of recycling and remanufacturing, namely $q \le m - r$;

p is the unit selling price of products sold by retailers;

q is the average unit price of recyclable products. Due to uneven quality of recyclable products, q is the average unit recycling price;

w is the unit wholesale price provided by the manufacturer to the retailer;

y is the sales effort of the retailer, assuming that the cost of the retailer's sales effort (such as store layout, advertising, etc.) is the increase of y function, and it has the properties of a convex function, $\frac{1}{2}cy^2$.

Assuming that the initial market demand is a, that is, the market demand when the market price p is 0, and the market demand D is affected by the price p and the sales effort y, then the market demand function is:

$$D(p, y) = a - bp + ly \tag{1}$$

The voluntary amount returned by consumers is k, and the supply quantity of recycled waste products is a linear increasing function of recovery price q, that is:

$$G(q) = k + hq \tag{2}$$

The manufacturer's profit is to deduct the production cost of using new materials from the income from selling products made with new materials to retailers, plus the income from recycling and remanufacturing of waste products to retailers to deduct the remanufacturing cost of waste products and recycling cost of waste products, that is, the profit function of the manufacturer is:

$$\begin{aligned}\pi_m &= (w-m)(D-G)+(w-q-r)G \\ &= (w-m)(a-bp+ly-k-hq)+(w-q-r)(k+hq)\end{aligned} \tag{3}$$

The profit of the retailer is sales income minus wholesale cost and sales effort cost, that is, the profit function of the retailer is:

$$\pi_r = (p-w)D-\frac{1}{2}cy^2 = (p-w)(a-bp+ly)-\frac{1}{2}cy^2 \tag{4}$$

The profit of the whole supply chain is manufacturer's profit plus retailer's profit, that is, the profit function of the whole supply chain is:

$$\pi=\pi_m+\pi_r = (p-m)(a-bp+ly)+(m-q-r)(k+hq)-\frac{1}{2}cy^2 \tag{5}$$

The next step is to explore the optimal solution w^*, q^*, p^*, y^* for the decision variables w and q for the manufacturer, p and y for the retailer at the maximum of their respective utility functions, as well as the element π^*, π_m^*, π_r^* when taking the optimal solution in this case. Suppose the superscript of centralized decision is c, and the superscript of decentralized decision is d.

3. The manufacturer leads the optimal decision of the closed-loop supply chain.

3.1 Optimal decision under centralized decision.

Centralized decision-making means that the upstream and downstream members of the supply chain are regarded as a whole, and manufacturers and retailers are regarded as a community of interests, and the recovery price q, retail price p and sales effort y are determined with the goal of maximizing the overall profit of the supply chain, i.e., maximization formula (5). When $\frac{\partial\pi^c}{\partial q}=0, \frac{\partial\pi^c}{\partial p}=0, \frac{\partial\pi^c}{\partial y}=0$, we can get:

$$q^{c*} = \frac{h(m-r)-k}{2h} \tag{6}$$

$$p^{c*} = \frac{c(a-bm)-l^2m}{2bc-l^2} \tag{7}$$

$$y^{c*} = \frac{l(a-bm)}{2bc-l^2} \tag{8}$$

Substitute equation (6), (7) and (8) into equation (5), and get:

$$\pi^{c*} = \frac{2a^2ch-4abchm+2b^2chm^2+2bc(k+hm-hr)^2-l^2(k+hm-hr)^2}{8bch-4hl^2} \tag{9}$$

To ensure that the equilibrium results are all positive, the parameters need to be satisfied:

$$h(m-r)\geq k, 2bc-l^2>0, a-bm>0$$

3.2 Optimal decision under decentralized decision.

When making decentralized decisions, each party of the decision aims to maximize its own profit. The manufacturer, as the leader of Stackelberg game, makes a decision on unit wholesale price w and recovery price q in the first stage of the game. After observing the retailer's decision, the manufacturer decides the optimal retail price p and the optimal sales effort y. The reverse induction method is adopted to solve the problem as follows:

Retailers make decisions with their own profit maximization as the target, and seek the derivatives of p and y in equation (3) respectively, and then make simultaneous decisions. When $\frac{\partial\pi_r^d}{\partial p}=0, \frac{\partial\pi_r^d}{\partial y}=0$, we can get:

$$p^d = \frac{ac + bcw - l^2 w}{2bc - l^2} \tag{10}$$

$$y^d = \frac{l(a - bw)}{2bc - l^2} \tag{11}$$

Substitute equations (10) and (11) into the manufacturer's profit function (3), we can get:

$$\pi_m^d = \frac{(2bc - l^2)(k + hq)(m - q - r) + bc(a - bw)(w - m)}{2bc - l^2} \tag{12}$$

Take the derivative of w, q and when $\frac{\partial \pi_m^d}{\partial w}=0, \frac{\partial \pi_m^d}{\partial q}=0$ to equation (12), we can get:

$$w^{d*} = \frac{a + bm}{2b} \tag{13}$$

$$q^{d*} = \frac{h(m - r) - k}{2h} \tag{14}$$

By substituting equations (13) into formula (12) of manufacturer's profit function, it can be obtained that the maximum profit of manufacturer under decentralized decision-making is:

$$\pi_m^{d*} = \frac{a^2 ch - 2abchm + b^2 chm^2 + 2bc(k + hm - hr)^2 - l^2(k + hm - hr)^2}{8bch - 4hl^2} \tag{15}$$

Substitute equations (13) and (14) into equations (10) and (11) to get:

$$p^{d*} = \frac{3abc - al^2 + b^2 cm - bl^2 m}{4b^2 c - 2bl^2} \tag{16}$$

$$y^{d*} = \frac{l(a - bm)}{4bc - 2l^2} \tag{17}$$

Put equation (13), (16) and (17) into equation (4) of retailer's profit function to obtain the maximum profit of retailer under decentralized decision:

$$\pi_r^{d*} = \frac{c(a - bm)^2}{16bc - 8l^2} \tag{18}$$

The total profit of the supply chain is:

$$\pi^{d*} = \frac{3a^2 ch - 6abchm + 3b^2 chm^2 + 4bc(k + hm - hr)^2 - 2l^2(k + hm - hr)^2}{8h(2bc - l^2)} \tag{19}$$

4. Analysis of equilibrium results

Conclusion 1: The pricing decision under centralized decision is better than that under decentralized decision. The retail price of centralized decision-making is lower, the sales effort is greater, the recycling price of centralized decision-making is the same as that of decentralized decision-making, and the overall profit of the supply chain under centralized decision-making is larger.

Conclusion proof:

$$p^{c*} - p^{d*} = -\frac{-ac - bcm + l^2 m}{2bc - l^2} - \frac{3abc - al^2 + b^2 cm - bl^2 m}{4b^2 c - 2bl^2} = \frac{(bc - l^2)(-a + bm)}{2b(2bc - l^2)} < 0$$

$$y^{c*} - y^{d*} = -\frac{l(-a + bm)}{2bc - l^2} - \frac{l(a - bm)}{4bc - 2l^2} = \frac{l(a - bm)}{4bc - 2l^2} > 0$$

$$q^{c*} - q^{d*} = -\frac{k - hm + hr}{2h} - \frac{-k + hm - hr}{2h} = 0$$

$$\pi^{c*} - \pi^{d*} = \frac{c\ (a-bm)^2}{16bc-8l^2} > 0$$

Conclusion analysis: By simulation of Stackelberg game model, a closed-loop supply chain composed of manufacturer and retailer can produce a double marginal effect when making decentralized decisions, making the retailer's optimal order quantity not the manufacturer's optimal production volume. Therefore, all participants in the supply chain should strengthen information sharing and communication, and make supply chain coordination contract.

Conclusion 2: The higher the maximum market demand, the higher the profit of supply chain. The overall profit of the supply chain is in line with the maximum market demand.

Conclusion proof: $\frac{\partial \pi^{d*}}{\partial a} = \frac{3c(a-bm)}{8bc-4l^2} > 0, \frac{\partial \pi^{c*}}{\partial a} = \frac{c(a-bm)}{2bc-l^2} > 0$

The partial derivative of the total profit of decentralized decision making and centralized decision making to the maximum demand of the market is greater than 0, that is, the overall profit of the supply chain is proportional to the maximum demand of the market.

Conclusion analysis: Market demand largest said people very strong demand for such products, manufacturers of such products are in line with market demand, market demand, the greater the biggest price factor, retailers will sell more goods, manufacturers received the order, the more fierce embellish to increase the supply chain. Therefore, supply chain should produce products that meet the market demand and meet the maximum market demand.

Conclusion 3: The higher the cost coefficient of sales effort, the smaller the profit of supply chain. Supply chain overall profit and sales effort cost coefficient inverse ratio.

Conclusion proof: $\frac{\partial \pi^{d*}}{\partial c} = -\frac{3l^2(a-bm)^2}{8\left(-2bc+l^2\right)^2} < 0, \frac{\partial \pi^{c*}}{\partial c} = -\frac{l^2(a-bm)^2}{2\left(-2bc+l^2\right)^2} < 0$

The total profit of decentralized decision making and centralized decision making is less than 0 to the partial derivative of the cost coefficient of sales effort, that is, the overall profit of the supply chain is inversely proportional to the cost coefficient of sales effort.

Conclusion analysis: It can be known from the cost of sales effort that, the larger the cost coefficient of sales effort is, the larger the cost of labor cost is for each unit of sales effort paid, and the larger the total cost is and the smaller the total profit is. Therefore, supply chain should choose the means of sales effort with lower cost coefficient.

Conclusion 4: The stronger consumers' environmental awareness (the number of recyclable products voluntarily returned by consumers), the bigger the closed-loop supply chain will be, and the overall profit of the supply chain is directly proportional to consumers' environmental awareness.

Conclusion prove: $\frac{\partial \pi^{d*}}{\partial k} = \frac{k+hm-hr}{2h} > 0, \frac{\partial \pi^{c*}}{\partial k} = \frac{k+hm-hr}{2h} > 0$

The total profit of decentralized decision making and centralized decision making is less than 0 to consumers' environmental awareness, that is, the overall profit of the supply chain and consumers' environmental awareness increases in direct proportion.

Conclusion analysis: Made from recycled product supply function available, the stronger the consumer's environmental protection consciousness, is a manufacturer not give consumers recycling compensation, consumers to voluntarily return the recycled products, the more the recycling of consumer product supply, the greater the manufacturers use recycled products remanufacturing compared to using new materials to save the manufacturing cost, the greater the profits, manufacturers, the greater the supply chain as a whole, the greater the profits. Therefore, economically developed regions are more conducive to the operation of closed-loop supply chain. According to the above research background, consumers' environmental awareness increases with the development of

economy. If enterprises intend to try closed-loop supply chain management, they may start from developed regions.

Conclusion 5: The more sensitive consumers are to recycling price, the greater the total profit of supply chain is. The total profit of supply chain is proportional to the recovery price sensitivity coefficient.

Conclusion proof: $\frac{\partial \pi^{d*}}{\partial h}=\frac{1}{4}\left(-\frac{k^2}{h^2}+(m-r)^2\right)>0, \frac{\partial \pi^{c*}}{\partial h}=\frac{1}{4}\left(-\frac{k^2}{h^2}+(m-r)^2\right)>0$

The partial derivative of the total profit of decentralized decision making and centralized decision making to the recovery price sensitive coefficient is less than 0, that is, the overall profit of the supply chain is proportional to the recovery price sensitive coefficient.

Conclusion analysis: Made from recycled product supply function available, the recycling price sensitive coefficient, the greater the means manufacturers recycling each additional unit prices, consumers are willing to provide the greater the amount of recycled products, the recycled product supply, the greater the manufacturers use recycled products remanufacturing compared to using new materials to save the manufacturing cost, the greater the profits, manufacturers, the greater the supply chain as a whole, the greater the profits. Therefore, the recycling of consumer groups with high price sensitivity coefficient is more conducive to the operation of the closed-loop supply chain studied in this paper.

Conclusion 6: The greater the effect of sales effort, the greater the total profit of supply chain. The total profit of supply chain is proportional to the effect of sales effort.

Conclusion proof: $\frac{\partial \pi^{d*}}{\partial l}=\frac{3cl(a-bm)^2}{4\left(-2bc+l^2\right)^2}>0, \frac{\partial \pi^{c*}}{\partial l}=\frac{cl(a-bm)^2}{\left(-2bc+l^2\right)^2}>0$

The total profit of decentralized decision making and centralized decision making is less than 0, that is, the overall profit of supply chain is proportional to the sales effort effect.

Conclusion analysis: According to the market demand function, the larger the sales effort effect 1 is, the greater the market demand increased by each unit of sales effort, the more goods the retailer will sell, and the more orders the manufacturer receives, the higher the profit of the retailer and the manufacturer, and the higher the profit of the supply chain. Therefore, for products with large sales effort effect, the supply chain can invest more sales efforts.

5. Manufacturer -led closed-loop supply chain coordination mechanism

This paper assumes that before sales, the manufacturer provides products to the retailer at a lower wholesale price. After sales, the retailer returns $(1-t)$ proportion of earnings to the manufacturer to make up for the cost loss of the manufacturer, and retains part of the sales revenue of t. The so-called manufacturer dominance means that the manufacturer determines the revenue sharing proportion. The two parties participating in the same contract are subject to Stackelberg master-subordinate game, in which the leader is the supplier and the follower is the retailer. The superscript of the revenue sharing contract model is z.

At this point, the profit function of the manufacturer is:

$$\begin{aligned}\pi_m^z &= (w-m)(D-G)+(w-q-r)G+(1-t)pD= \\ &(w-m)(a-bp+ly-k-hq)+(w-q-r)(k+hq)+(1-t)p(a-bp+ly)\end{aligned} \tag{20}$$

The Retailer's profit function is:

$$\pi_r^z = tpD-wD-\frac{1}{2}cy^2=(tp-w)(a-bp+ly)-\frac{1}{2}cy^2 \tag{21}$$

The derivatives of p and y are calculated respectively for equation (21), and when $\frac{\partial \pi_r^z}{\partial p}=0, \frac{\partial \pi_r^z}{\partial y}=0$, we can get:

$$p^z=\frac{act+bcw-l^2tw}{2bct-l^2t^2} \tag{22}$$

$$y^z=\frac{l(at-bw)}{2bc-l^2t} \tag{23}$$

Substitute equation (22) and (23) into equation (20) to get, the profit function of the manufacturer is:

$$\pi_m^z=\frac{\begin{array}{c}a^2bc^2(1-t)\ t^2+t^2(k+hq)(m-q-r)\left(2bc-l^2t\right)^2+b^2cwmt\left(2bc-l^2t\right)- \\ b^2c\left(-l^2t+bc(1+t)\right)w^2+abct^2\left(l^2(mt-w)+2bc(w-m)\right)\end{array}}{t^2\left(2bc-l^2t\right)^2} \tag{24}$$

The derivative of w and q is obtained by solving equation (24). In parallel, when $\frac{\partial \pi_m^z}{\partial w}=0, \frac{\partial \pi_m^z}{\partial q}=0$,we can get:

$$w^{z^*}=\frac{t\left(2b^2cm+\left(a\left(2bc-l^2\right)-bl^2m\right)t\right)}{2b\left(bc(1+t)-l^2t\right)} \tag{25}$$

$$q^{z^*}=\frac{k+h(m-r)}{2h} \tag{26}$$

Substitute equation (25) and (26) into equation (24) to get:

$$\pi_m^{z^*}=\frac{1}{4}\left(\frac{(k+h(m-r))^2}{h}+\frac{c(a-bm)^2}{bc(1+t)-l^2t}\right) \tag{27}$$

Substitute equations (25) and (26) into equations (22) and (23) to get:

$$p^{z^*}=\frac{bc(a+bm)+\left(2abc-al^2-bl^2m\right)t}{2b\left(bc(1+t)-l^2t\right)} \tag{28}$$

$$y^{z^*}=\frac{l(a-bm)t}{2\left(bc(1+t)-l^2t\right)} \tag{29}$$

Substitute equation (25), (28) and (29) into equation (21) of retailer's profit, and get:

$$\pi_r^{z^*}=\frac{ct(a-bm)^2\left(2bc-l^2t\right)}{8\left(bc(1+t)-l^2t\right)^2} \tag{30}$$

The total profit of the supply chain is:

$$\pi^{z^*}=\frac{1}{8}\left(\frac{\left(c(a-bm)^2t\left(2bc-l^2t\right)\right)}{\left(bc(1+t)-l^2t\right)^2}+2\left(\frac{\left(k+h\ (m-r)\right)^2}{h}+\frac{c(a-bm)^2}{bc(1+t)-l^2t}\right)\right) \tag{31}$$

In order to embody the function of revenue sharing contract, the optimal retail price and centralized decision-making of revenue sharing contract should be made, i.e. $p^{z^*}=p^{c^*}$, $y^{z^*}=y^{c^*}$, and the profits of manufacturers and retailers under the revenue sharing is greater than the centralized decision making profits, $\pi_m^{z^*}>\pi_m^{d^*}$, $\pi_r^{z^*}>\pi_r^{d^*}$.

6. Numerical simulation analysis

Examples are used to compare the pricing, recovery price, sales effort decision and profit acquisition of manufacture-led closed-loop supply chain under different decision-making situations, and further analyze the impact of revenue sharing coefficient on relevant parameters, so as to provide guidance for the formulation of coordination contract of closed-loop supply chain. The values of relevant parameters of the closed-loop supply chain refer to the values set by Xiong Z K[12], a=400, b=4, c=300, h=18, k=100, l=30, m=50, r=30.

Under centralized decision-making, pricing decisions of retailers and manufacturers are shown in table 1.

Table 1. Pricing decisions under centralized numerical simulation decisions

p^{c*}	y^{c*}	q^{c*}	π^{c*}
90	4	7.22	6938.89

Under decentralized decision-making, pricing decisions of retailers and manufacturers are shown in table 2.

Table 2. Pricing decisions under decentralized decisions of numerical simulation

p^{d*}	y^{d*}	w^{d*}	q^{d*}	π^{d*}
95	2	75	7.22	5938.89

Through numerical simulation, the comparison between centralized decision making and decentralized decision making shows that centralized decision making is indeed superior to decentralized decision making.

In order to coordinate the supply chain, the optimal retail price of revenue sharing contract should be equal to the optimal retail price of centralized decision-making, and the optimal sales effort of revenue sharing contract should be equal to the optimal sales effort of centralized decision-making, i.e., $p^{z*} = p^{c*}$, $y^{z*} = y^{c*}$. In addition, the profit of manufacturers and retailers under revenue sharing is greater than that of centralized decision-making, i.e., $\pi_m^{z*} > \pi_m^{d*}$, $\pi_r^{z*} > \pi_r^{d*}$, so the value range of revenue sharing coefficient t under revenue sharing contract model is [0.71, 0.83]. With the change of revenue sharing ratio coefficient, pricing decision also changes, and the change rule is as follows.

1) the optimal retail price is proportional to the revenue sharing proportional coefficient t, as shown in figure 1.

$$\text{Proof: } \frac{\partial p^{z*}}{\partial t} = \frac{bc^2(a-bm)}{2(l^2t - bc(1+t))^2} > 0$$

The optimal retail price is determined by the partial king 0 of the revenue sharing proportional coefficient, that is, the optimal retail price and revenue sharing proportional coefficient t· proportional. Under decentralized decision-making, retailers make decisions based on their own profit maximization. The higher the revenue sharing ratio coefficient is, the greater the sales revenue saved by the retailer, and the higher the retail price, the higher the profit of the retailer.

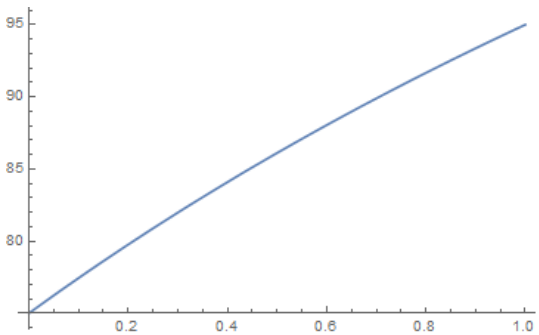

Figure 1. The optimal retail price changes with the change of revenue sharing ratio coefficient

2) the optimal sales effort is proportional to the revenue sharing proportional coefficient t, as shown in figure 2.

$$\text{Proof: } \frac{\partial y^{z^*}}{\partial t} = \frac{bcl(a-bm)}{2(l^2 t - bc(1+t))^2} > 0$$

The optimal sales effort to revenue sharing proportional coefficient partial derivative is too 0, that is, the optimal sales effort and revenue sharing proportional system. The number t is proportional. Under decentralized decision-making, retailers make decisions based on their own profit maximization. The greater the revenue sharing ratio coefficient is, the greater the sales revenue saved by the retailer. At this time, the greater the sales effort is, the greater the market demand is, and the more products the retailer sells, the greater the retailer's profit is.

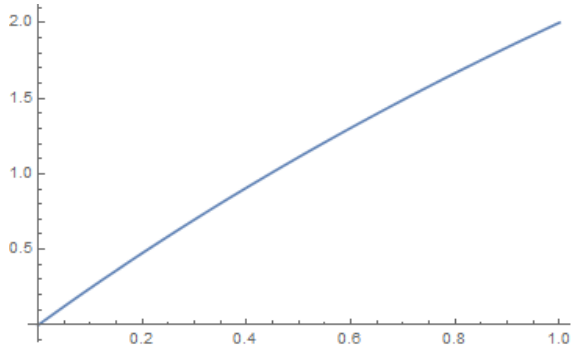

Figure 2. The optimal sales effort varies with the revenue sharing proportional coefficient

3) the optimal wholesale price is proportional to the revenue sharing proportional coefficient t, as shown in figure 3.

Under decentralized decision-making, manufacturers make decisions based on their own profit maximization. The larger the ratio coefficient of revenue sharing is, that is, the larger the sales revenue saved by the retailer, the smaller the profit of the manufacturer. In this case, the higher the wholesale price is, the higher the manufacturer's cost is.

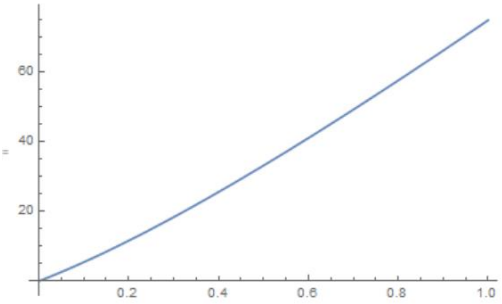

Figure 3. The optimal wholesale price changes with the income sharing ratio coefficient

4) the optimal recovery price is independent of the revenue sharing proportional coefficient t, as shown in figure 4.

$$\text{Proof: } q^{z^*} = \frac{h(m-r)-k}{2h}$$

No matter how t changes, the recycling price remains the same.

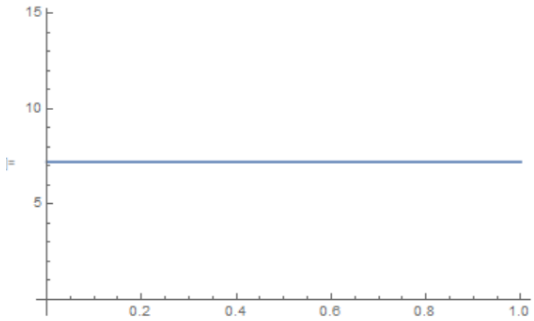

Figure 4. The optimal recovery grid remains unchanged with the change of the revenue sharing proportional coefficient

5) within the desirable range of t [0.71,0.83], the proportional coefficient t of optimal total profit and revenue sharing in the supply chain is inversely proportional, as shown in fig. 5 shown below. Therefore, it is suggested in this paper to select $t = 0.71$ as the optimal revenue-sharing proportional coefficient, and the pricing decision of $t = 0.71$ is shown in table 4.

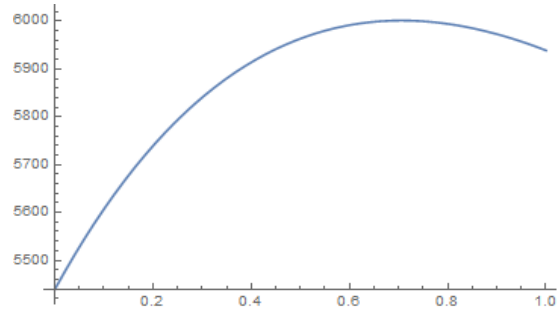

Figure 5 the total profit of the optimal supply chain changes with the change of revenue sharing ratio coefficient

Table 3 Pricing decisions under decentralized decisions of numerical simulation

p^{d*}	y^{d*}	w^{d*}	q^{d*}	π^{d*}
90	1.50	48.03	7.22	6001.36

Although this scheme cannot reach the ideal state of centralized decision-making, it has reached the pareto optimal state compared with the total profit of the supply chain under the decentralized decision-making state.

7. Conclusion.

This paper studies a manufacturer-led closed-loop supply chain consisting of a single manufacturer and a single retailer, before considering the sale of nu... Under the circumstance of market demand being influenced by force, the decision of supply chain members in E model is studied by game theory, price, discarded product prices and sales efforts, demand maximum comparative analysis of the market and sales efforts, recycling price sensitive coefficient effect of closed-loop supply chain profit and sales efforts, was investigated on the basis of the revenue sharing contract effect to the promotion of closed-loop supply chain profit, to provide the reference for the closed-loop supply chain members, finally has carried on the numerical analysis.

The results show that: (1) the same as the traditional supply chain, the closed-loop supply chain in the decentralized decision-making situation, there will be a second markup phenomenon, resulting in a double marginal effect, the overall profit of the supply chain relative to the centralized decision. Therefore, information sharing among closed-loop supply chain members should be increased, and appropriate contracts should be established to coordinate the closed-loop supply chain, so as to increase the overall profit and share the profit and cost fairly. (2) expanding market demand is one of

the efforts of members in the closed-loop supply chain. In this paper, the maximum market demand, retail price, price sensitivity coefficient, sales effort and sales effort effect all affect the market demand. According to the above proof, the overall profit of the supply chain is directly proportional to the maximum market demand and sales effort effect. Therefore, members of the supply chain should choose products with a wide market and increase the maximum demand of the market. And to investigate the sales effort effect of each market, select the market with relatively large sales effort effect, and increase the market demand with each increase of one unit of sales effort;"(3) increasing the quantity of recyclable products is the key of closed-loop supply chain to save manufacturing cost for traditional supply chain. Set in this paper, the supply of recycled products function and consumers' environmental protection consciousness, the recycling price sensitive coefficient and recycling prices are concerned, the stronger the consumer's environmental protection consciousness, the recycling price sensitive coefficient is larger, can make the recycled product number, so that the number of new products by recycling remanufacturing production increase, will save more production cost. Therefore, members of the closed-loop supply chain should apply the closed-loop supply chain management mode in the market where consumers have strong environmental awareness and recovery price sensitivity coefficient is large. (4) the revenue-sharing contract proposed in this paper can weaken the double marginal effect of decentralized decision-making, thus coordinating the closed-loop supply chain. The condition of implementing the revenue sharing contract is that the pricing decision of the revenue sharing contract of each member of the closed-loop supply chain is better than the decentralized decision of no sharing, so the range of the revenue sharing proportional coefficient is obtained. When the revenue sharing proportional coefficient changes in the range, the pricing decision of the supply chain will also change. In this paper, the revenue proportional coefficient that maximizes the overall profit of the closed-loop supply chain is selected as the optimal decision.

Based on the existing results, this paper studies the decision-making of closed-loop supply chain members when sales efforts affect market demand in the manufacture-led closed-loop supply chain, and discusses the coordination effect of revenue sharing contract on the closed-loop supply chain. Still can be in many ways, this paper further deepen, if consider more participants, including distributors, third-party recycler, manufacturer of objects, such as the third party logistics compensation cost of retailers' sales efforts, consider online sales and recycling channels, etc., all of these are worth to expand the direction of the research, we will be completed in the subsequent work.

References

[1] Wu Z D, Huang M. Performance and Coordination of Closed-loop Supply Chain with retailer Collecting under Different Dominant Mode [J]. Science and Technology Management Research, 2018, 38(20):235-242.

[2] Giri B C, Chakraborty A, Maiti T. Pricing and return product collection decisions in a closed-loop supply chain with dual-channel in both forward and reverse logistics [J]. Journal of Manufacturing Systems, 2017, 42:104-123.

[3] Gao W J, Ju H C. Research on decisions of closed-loop supply chain optimization and coordination based on CvaR [J]. Control and Decision, 2011, 4:104-123.

[4] You J X, Sui M G, Huo J Z. Bullwhip Effect in Closed-Loop Supply Chain [J]. Systems Engineering-Theory & Practice, 2007, 27(12):111-116.

[5] Yao F M, Wang Y, Teng C X. Sales Effort and Pricing Decisions for Closed-loop Supply Chain with Corporate Social Responsibility [J]. Computer Integrated Manufacturing Systems, 2017, 37(12):1-20.

[6] Wu Z X, Zhi L Y, Mathematics S O. Supply Chain Model with Joint Decision of Sales Efforts and Quality Assurance Services[J]. College Mathematics, 2015, 37(12):1-20.

[7] Wang Y Y, Wang J C. Coordinating a supply chain for a newsvendor-type product with sales effort effects[C] IEEE International Conference on Industrial Engineering & Engineering Management. 2014, 27(12):111-116.

[8] Research on Supply Chain Contract Coordination Based on Promotion Efforts [D]. Taiyuan University of Technology, 2017, 30(05):140-144.
[9] Liu Juan. Comparative Research on Contract Coordination of Closed-loop Supply Chain [J]. Journal of Gansu Sciences, 2018, 30 (5):137-141.
[10] Rui S, Wei L. Supply chain coordination with revenue sharing contract and lateral transshipment[C] International Conference on Industrial Technology & Management. 2017, 22(9):116-123.
[11] Wang D P, Lu W, Zhang B Q. Coordination model of inventory system for deteriorating items with time-varying demand based on revenue-sharing contract [C] IEEE International Conference on Information & Automation. 2015, 2(9):16-23.
[12] Xiong Z K, Wang K, Xiong Y. Research on the closed-loop supply chain that the distributor engages in re-manufacturing [J]. Journal of Management Sciences in China, 2011, 14(11):1-9.