The Establishment and Decision-Making about Recycling Model of Waste Electronic Products under Government's Incentive

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***Abstract*— Electronic waste can cause major environmental harm. Obviously, a possible solution to this problem is to increase the volume of collected waste that can be recycled. This paper shows that it is possible to use a government funded incentive function to boost waste collection by manufactures as well as third party vendors. Using numerical analysis, the results show that a governmental incentive can (a) have a positive effect on waste recovery rate, and (b) further increase the reuse of the recycled material in the manufacturing process.**

***Keywords*—** Government incentives, Waste electronic products, Recycling and treatment, Closed-loop Supply Chain

1. Introduction

With the progress of technology, the rapid growth of electronic products simultaneously brought the dramatically increasing of waste electronic products, provided that they are not treated scientific and effectively, they will bring severe negative impact on the ecological environment and humanity health.

Currently, fairly a few papers have studied the recycling and remanufacturing case of waste electronic products. This paper can be divided into two aspects:

(1) From the macro level, some papers take the effect of government policy into account on recycling behavior of waste electronic products. Ref.[1] refers that, the driving factors of recycling the waste electronic products in China's electronic industry through some cases and point out that the policy of state subsidy can effectively stimulate the electronic product manufacturers to implement the recycling of waste electronic products. The authors in [2] makes a detailed analysis to the present situation of the recycling and disposal of waste electronics in developing countries. He found that the government played a decisive role in effective recovery and ecological treatment of waste electronic products. Ref. [3] refers that governments should impel and supervise the electronic products manufacturers and designs appropriate punishment for electronic products manufacturers so that avoids ratcheting effect. In [4] the authors establish the game model of closed-loop supply chain of waste electronic products and advise the government to impose a minimum operating tax on new electronic products, which can further stimulate effective recovery of waste electronic products. Finally a numerical example is given to verify the validity of the model. Ref.[5] refers that E-waste (discarded computers and electronic goods) has become a major environmental issue. It can be minimized by increasing recovery from the waste stream through reverse supply chains. Factor such as government legislation, incentive and customer demand are found to be the major drivers. Through the establishment of game model, the authors in [6] discuss several decision-making situations about the presence or absence under government subsidies. The research results illustrate that the recovery yield of Reverse Supply Chain will be improved through subsidies policy implemented by government. The authors in [7] analyzes the effects of governmental financial intervention on green supply chain competition using a three--stage game-theoretic model. Numerical results reveal that under equilibrium conditions, social welfare and chain-based profits improve by 27.8% and 306.6%, respectively, compared with the case without financial intervention.

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(2) From the internal supply chain side, the analysis and research of recycling and remanufacturing of waste products are introduced in other papers. The author in [8] makes a research on the optimal channel structure of closed-loop supply chain based on remanufacturing. The result suggests that in the linear demand the channel structure of the retailer responsible for recycling is better than the manufacturers or the third party responsible for recycling; The authors in [9] makes research on the closed-loop supply chain of manufacturers responsible for recycling. The research analyzes and compares the efficiency of manufacturers and retailer under different market positions. Ref. [10] refers that the retail collection model analytically outperforms when the third-party firm is a non-profit organization for recycling and disposal. The authors in [11] discusses supply chain coordination as a manufacturer-retailer partnership based on profit sharing.

Therefore, based on the previous research, and combined the government's macro regulation and supply chain internal system , this paper build closed-loop supply chain model dominated by manufacturer and the third party respectively. Suppose the government respectively sets a minimum rate of recycling to manufacturer and the third party, and takes incentive to recycle behavior of manufacturers and the third party. Design the incentive function between the government, the manufacturers and the third party, and respectively discussing the optimal strategy under the three cases: the case manufacturers didn't recycle, the case with incentive and without incentive. The effectiveness of incentive measures by government and influence of convert parameter on the recovery rate and the profits of chain members in supply chains are also analyzed.

2. Problem description and model establishment

The authors in [12] divided the recycling channels of waste products in closed-loop supply chain into three forms ： Retailer Owned Collection； Manufacturer Owned Collection； Third Party Owned Collection. In [13],[14] the authors takes specific classification to closed loop supply chain under the electronic market environment, and the recovery form is specific to five forms, they are MRCRM(retailer selling and retailer recycling), MRCTM(retailer selling and the third party recycling), MRCM(retailer selling and manufacturing recycling), MCTM(manufacturing selling and the third party recycling), MCM(manufacturing selling and manufacturing recycling).

Based on the theory of closed-loop supply chain, this paper mainly discusses the channel type by the third party responsible for recycling.

MRCTM: in the forward logistics, manufacturers wholesale the products to retailer, then the retailer sells them to consumers; in reverse logistics, the third party is responsible for recycling electronic products from consumers, then provide them to manufacturers. The process is shown in Fig 1.1.

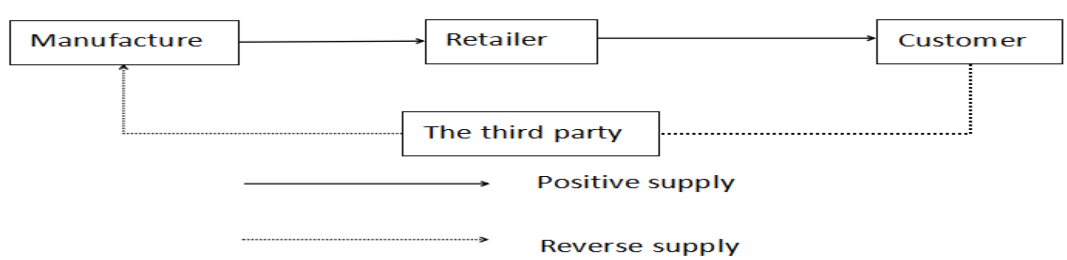

Fig1.1 Model framework of closed-loop supply chain

2.1 Model assumptions and symbolic description

(1) Suppose that new product can be manufactured by raw materials or part of waste electronic products, and the manufactured products are homogeneous.

(2) Suppose that unit cost is c_1 when manufacturer use raw materials to manufacture, the cost is c_2 when manufacture use recycled scrap electronic products to manufacture ,and , $c_1 > c_2$, $\theta = c_1 - c_2$ express the cost savings by using recycled products, the remanufacture rate of

recycled products is r, $0 \le r \le 1$.

(3)Suppose that the wholesale price of the product is w, retail price is p, consumer's demand function for the product is $d(p) = \alpha - \beta p + \varepsilon$,α is the biggest market demand, β is the sensitivity coefficient of consumer demand to price, ε is a random factor in the market, $\varepsilon \sim N(0, \delta^2)$ is normal distribution.

(4)Suppose that the unit costs of recycling waste electronic products, which the third party recycles from consumers, is c_3 ; the price of recycling waste electronic products, which the manufacture recycle from the third party, is b, and $c_3 \le b \le c_1 - c_2$.

(5)Suppose that the fixed input cost of recycling waste electronic products is I(including the construction of recycling network, advertising and other costs), the recovery rate is T, and there is a relationship between I and T, adopting the Thierry express method, set up $I = kt^2$, k indicates the difficulty coefficient of recycling; the amount of recovery can be expressed as td(p) [15].

(6) When the manufacturer is responsible for recycling waste electronic products, manufacturer's expected profit is π, and retailer's expected profit is π_r.

(7)When the third party is responsible for the recovery of waste electronic products, manufacturer's expected profit is π_m, retailer's expected profit is π_r, the third party's expected profit is π_t.

According to the above assumptions, it can be concluded that when the third party is responsible for the recovery of waste electronic products, the expected profit function of the manufacture, retailer and third party's is

$$\pi_m = E\left[(w - c_1)d(p) + (c_1 - c_2)td(p)r - btd(p)\right] = (\alpha - \beta p)(w - c_1 + \theta tr - bt)$$

$$\pi_r = E\left[(p - w)d(p)\right] = (p - w)(\alpha - \beta p)$$

$$\pi_t = E\left[(b - c_3)td(p) - I\right] = (\alpha - \beta p)t(b - c_3) - kt^2$$

Therein w, b is the manufacturer's decision variable, p is retailer's decision variable; t is the third party's decision variable.

2.2 Decision-making of no-recycling waste products

When there is no enterprise recycling waste products, manufacturers can only use raw materials to manufacture, so, the manufacturer sets the wholesale price based on their own best interests, and the retailer sets the sales price based on the wholesale price to maximize their interests. So the specific decision model of maximum profit of manufacturers and retailer is as follows,

$$\max \pi_m = (w - c_1)(\alpha - \beta p) \quad (1\text{-}1)$$

$$\max \pi_r = (w - p)(\alpha - \beta p) \quad (1\text{-}2)$$

Let the first derivative of the P in Eq.(1-2) is 0, get

$$p = \frac{\alpha}{2\beta} + \frac{w}{2} \quad (1\text{-}3)$$

Bring Eq.(1-3) into Eq.(1-2), solved first-order partial derivative to W , get;

$$w = \frac{\alpha}{2\beta} + \frac{1}{2}c_1 \quad (1\text{-}4)$$

Thus, the profits of manufacturers and retailers are

$$\pi_m = \frac{(\alpha - \beta c_1)^2}{8\beta} \quad (1\text{-}5)$$

$$\pi_r = \frac{(\alpha - \beta c_1)^2}{16\beta} \quad (1\text{-}6)$$

2.3 Decision-making of recycling waste electronic products

In MRCTM closed loop supply chain system, the supply chain members make decision analysis based on their own maximize profits. In the decentralized closed-loop supply chain, suppose that the manufacturer is leader, the retailer and the third party are followers, composing a Stackelberg game： a leader and more follower. In this game, in order to maximize their own profits, the manufacturer sets the wholesale price and recycling price of the waste electronic products, also in order to maximize profits, the retailer and the third party set their own sales price and recovery rate according to the given wholesale price and the recycling price. According to the expected profit function of the three parties in 2.1, these three party's principal and subordinate game decision-making model is expressed as follows:

$$\max_{w,b} \pi_m = (\alpha - \beta p)(w - c_1 + \theta tr - bt) \quad (1\text{-}7)$$

$$\max_r \pi_r = (p - w)(\alpha - \beta p) \quad (1\text{-}8)$$

$$\max_t \pi_t = (\alpha - \beta p)\, t(b - c_3) - kt^2 \quad (1\text{-}9)$$

Using the backward induction method, the maximum benefit of the supply chain members is

Optimal wholesale price：

$$w^* = \frac{8k(\alpha + \beta c_1) - (r\theta - c_2)^2 \alpha\beta}{16k\beta - (r\theta - c_3)^2 \beta^2} \quad (1\text{-}10)$$

Optimal recovery price:

$$b^* = \frac{r\theta + c_3}{2} \quad (1\text{-}11)$$

Optimal sale price:

$$p^* = \frac{\alpha}{2\beta} + \frac{8k(a + \beta c_2) - (r\theta - c_3)^2 \alpha\beta}{32k\beta - 2(r\theta - c_3)^2 \beta^2} \quad (1\text{-}12)$$

Optimal recovery rate:

$$t^* = \frac{(\alpha - \beta c_1)(r\theta - c_3)}{16k - (r\theta - c_3)^2 \beta^2} \quad (1\text{-}13)$$

Let(1-10),(1-11),(1-12),(1-13)into(1-7),(1-8),(1-9) get the profits of supply chain members

Manufacturer profits:

$$\pi_m^* = \frac{k(\alpha - c_1\beta)^2}{8k\beta - \frac{1}{2}\beta^2 (r\theta - c_3)^2} \quad (1\text{-}14)$$

Retailer profits:

$$\pi_r^* = \frac{k^2 (\alpha - c_1\beta)^2}{\beta\left[4k - \frac{1}{4}\beta(r\theta - c_3)^2\right]^2} \quad (1\text{-}15)$$

The third party's profits

$$\pi_r^* = \frac{k(r\theta - c_3)^2 (\alpha - c_1\beta)^2}{\left[16k - (r\theta - c_3)^2 \beta\right]^2} \quad (1\text{-}16)$$

3. Model improvement and strategy analysis

3.1 Model improvement

In order to realize the coordination of closed loop supply chain in China, through learning overseas successful experience, government should set a minimum recovery rate to manufacturers to constrain the recycling behavior of manufacturers. According to the manufacturer's performance of recycling wastes, the government will take incentive. When the recovery rate of the manufacturer is more than the recovery rate of the government regulation, the excess part will be rewarded, When the recovery rate of the manufacturer is lower than the recovery rate of the government regulation, the incomplete part will be punished. Assume that the government provides the incentive function: $L = v(t - m)d(p)$, t is the actual recovery rate of the manufacturer, m is the incentive factor. When $t \geq m$, L expresses government's unit reward, when $t < m$,L expresses government's unit of punishment.

3.2 Analysis on the implementation of incentive policies for manufacturers

Considering the government's restrictions, in order to avoid the punishment or get the reward from government, the manufacturers will affect the retailer and the third party's decision through adjusting the wholesale and recycling price of waste electronic products, thus achieving the better coordination of the supply chain. When the government take incentive to the manufacturer, manufacture's expected profit function can be expressed as

$$\pi_m = E\left[(w - c_1 + tr\theta - bt)d(p) + v(t - m)d(p)\right] = (w - c_1 + tr\theta - bt)(\alpha - \beta p) + v(t - m)(\alpha - \beta p)$$

The Leader-follower game decision model of manufacturer, retailer and the third party is as follows

$$\max \pi_m = (w - c_1 + tr\theta - bt)(\alpha - \beta p) + v(t - m)(\alpha - \beta p) \quad (1\text{-}17)$$

$$\begin{cases} \max \pi_r = (p-w)(\alpha-\beta p) \\ \max \pi_t = (\alpha-\beta p)t(b-c_3)-kt^2 \end{cases} \quad (1\text{-}18)$$

Using backward induction method, the solving method is the same as 2.3, get

$$p^{**} = \frac{\alpha}{2\beta} + \frac{w}{2} \quad (1\text{-}19)$$

$$t^{**} = \frac{b-c_3}{4k}(\alpha-\beta w) \quad (1\text{-}20)$$

Let (1-19),(1-20)into(1-17),and respectively solve partial derivation

to w and b

$$w^{**} = \frac{2k(\alpha+c_1\beta+vm\beta)+\alpha\beta(b-c_1)(b-r\theta-v)}{4k\beta+\beta^2(b-c_3)(b-r\theta-v)} \quad (1\text{-}21)$$

$$b^{**} = \frac{1}{2}(r\theta+c_3+v) \quad (1\text{-}22)$$

Let (1-21),(1-22)into(1-20)get

$$t^{**} = \frac{(\alpha-c_1\beta-vm\beta)(r\theta+v-c_3)}{16k-(r\theta+v-c_3)^2\beta} \quad (1\text{-}23)$$

Let(1-19),(1-21),(1-22),(1-23)into (1-17),(1-18),get

$$\pi_m^{**} = \frac{k(\alpha-c_1\beta-vm\beta)^2}{8k\beta-\frac{1}{2}\beta^2(r\theta+v-c_3)^2} \quad (1\text{-}24)$$

$$\pi_r^{**} = \frac{k^2(\alpha-c_1\beta-vm\beta)^2}{\beta\left[4k-\frac{1}{4}\beta(r\theta+v-c_3)^2\right]^2} \quad (1\text{-}25)$$

$$\pi_t^{**} = \frac{k(r\theta+v-c_3)^2(\alpha-c_1\beta-vm\beta)^2}{\left[16k-(r\theta+v-c_3)^2\beta\right]^2} \quad (1\text{-}26)$$

Compared the optimal decision of the above three cases . get:

Conclusion 3.1 (1) $t^{**} > t^*$

(2) $\pi_m^{**} > \pi_m^* > \pi_m$; $\pi_r^{**} > \pi_r^* > \pi_r$; $\pi_t^{**} > \pi_t^*$

It can be seen from the conclusion (1) that when the government restrains to the manufacturer, the manufacturer's recycling rate will increase. Manufacturers, retailer, and the third party in the closed loop supply chain can get more profits than those without government restraint.

Conclusion3.2 the supply chain, which is the government constrain to the manufacturer, shows there is a increasing relationship between the recovery rate T and $(r\theta+v-c_3)$. It means that if the cost of callback manufactured products can save more cost, the recovery will be higher. When the recycling price is lower, the government's incentive strategy can play a role; besides, the greater the unit incentive of the government, the higher the optimal recovery rate and it will more able to motivate the manufacturer to recycle.

Conclusion 3.3 there is an increasing relationship between the income of the supply chain members and $(r\theta+v-c_3)$, which indicates that the higher the cost saving of recycling and remanufacturing rate, the greater the government's incentive, and the higher the profit of the supply chain members.

3.3 Analysis on the implementation of incentive policies for the third party

Considering the government's restrictions, in order to avoid the punishment or get the reward from government, the third party will affect the retailer and manufacture's decision through adjusting the wholesale and recycling price of waste electronic products, thus achieving the better coordination of the supply chain. When the government take incentive to the third party, the third party's expected profit function can be expressed as

$$\pi_t = E\left[(b-c_3)td(p)-kt^2+v(t-m)d(p)\right] = t(\alpha-\beta p)(b-c_3)-kt^2+v(t-m)(\alpha-\beta p)$$

The Leader-follower game decision model of manufacturer, retailer and third party is as follows

$$\max_{w,b} \pi_m = (\alpha-\beta p)(w-c_1+\theta tr-bt) \quad (1\text{-}27)$$

$$\max_r \pi_r = (p-w)(a-\beta p) \quad (1\text{-}28)$$

$$\max_t \pi_t = (\alpha-\beta p)t(b-c_3)-kt^2+v(t-m)(\alpha-\beta p) \quad (1\text{-}29)$$

The solving method is the same as 2.3, get

$$t^{**} = \frac{(r\theta-c_3+v)(\alpha-\beta c_1)}{16k-(r\theta-c_3+v)^2\beta} \quad (1\text{-}30)$$

$$p^{**} = \frac{\alpha}{2\beta} + \frac{8k\left(\alpha+\beta c_1\right) - \alpha\beta(r\theta - c_3 + v)^2}{32k\beta - 2(r\theta - c_3 + v)^2\beta^2} \quad (1\text{-}31)$$

$$b^{**} = \frac{r\theta + c_3 - v}{2} \quad (1\text{-}32)$$

$$w^{**} = \frac{8k\left(\alpha+\beta c_1\right) - \alpha\beta(r\theta - c_1 + v)^2}{16k\beta - (r\theta - c_3 + v)^2\beta^2} \quad (1\text{-}33)$$

Let (1-33),(1-32),(1-31),(1-30) respectively into (1-27),(1-28),(1-29),get the profits of supply chain members：

$$\pi_m^{**} = \frac{2k(\alpha - c_1\beta)^2}{16k\beta - \beta^2(r\theta - c_3 + v)^2} \quad (1\text{-}34)$$

$$\pi_r^{**} = \frac{16k^2(\alpha - c_1\beta)^2}{\beta\left[16k - \beta(r\theta - c_3 + v)^2\right]^2} \quad (1\text{-}35)$$

$$\pi_t^{**} = \frac{k(\alpha - c_1\beta)\left[(r\theta - c_3 + v)^2(\alpha - c_1\beta + 4\beta vm) - 64vmk\right]}{\left[16k - (r\theta - c_3 + v)^2\beta^2\right]^2} \quad (1\text{-}36)$$

Compared Eq. (1-13), (1-30) can be seen, when $(r\theta - c_3) > 0$, $t^{**} > t^*$.The following conclusions can be drawn:

Conclusion 3.4 the optimal recovery of waste products increase with the increase of cost saving, and increases with the improvement of the remanufacturing rate.

Conclusion 3.5 when the cost saving of waste products is greater than zero, the recycling rate of waste products under the incentive policy is greater than there is no incentive. namely $t^{**} > t^*$.

Conclusion 3.6 the optimal recovery rate of waste electronic products increases with the increase of the government's unit incentive factor V. The greater the government's incentive , it will be more able to motivate the third party's recovery behavior .

3.4 Comparison of decision making in supply chain members under three cases

(1)There are two cases: no recycling of waste products and recycling of waste electronic products without incentive,

It can be seen from Eq. (1-5),(1-14) ,

when $r\theta - c_3 = 0$, $\pi_m = \pi_m^*$;

When $(r\theta - c_3) > 0$, $\pi_m < \pi_m^{**}$

It can be seen from Eq. (1-6),(1-15),

when $r\theta - c_3 = 0$, $\pi_r = \pi_r^*$;

when $(r\theta - c_3) > 0$, $\pi_r < \pi_r^{**}$

It can be seen from Eq.(1-16),

when $r\theta - c_3 = 0$, $\pi_t^* = 0$

Conclusion3.7 when there is no incentive, only cost savings of recycling is greater than zero, namely $(r\theta - c_3) > 0$, the manufacturer will recycle the waste electronic products; when the cost saving is zero, the recovery rate is zero. Therefore, it is necessary for the government to set incentives to the behavior of recycling.

(2)There are two cases of recycling waste electronic products: one is that government has incentive policy and the other is not.

It can be known from the Eq.(1-16), (1-36):

$$\pi_t^{**} - \pi_t^* > \frac{k(\alpha - \beta c_1)\{(\alpha - \beta c_1)[v^2 + 2v(r\theta - c_3)] - 4vm[16k - \beta(r\theta - c_3 + v)^2]\}}{[16 - \beta(r\theta - c_3 + v)^2]^2}$$

If $\pi_t^{**} - \pi_t^* > 0$, then:

$$(\alpha - \beta c_1)\left[v^2 + 2v(r\theta - c_3)\right] > 4vm\left[16k - \beta(r\theta - c_3 + v)^2\right] \quad (1\text{-}37)$$

It can be known $t^{**} < 1$,

$$16k - \beta(r\theta - c_3 + v)^2 > (r\theta - c_3 + v)(\alpha - \beta c_1) \quad (1\text{-}38)$$

From Eq. (1-30) ,get,

$$v + 2(r\theta - c_3) > 4m(r\theta - c_3 + v) \quad (1\text{-}39)$$

Compared Eq. (1-14), (1-34) and Eq. (1-15), (1-35) can be known

$$\pi_m^{**} > \pi_m^* \;\; \pi_r^{**} > \pi_r^*$$

Conclusion 3.8 when the government constrains to the third party, it can effectively motivate the recovery behavior of the third party, only the unit incentive factor V and the minimum recovery rate M satisfied the conditions

$\mathrm{v}+2(\mathrm{r}\theta-\mathrm{c}_3)>4m(r\theta-\mathrm{c}_3+\mathrm{v})$.

Conclusion 3.9 the profit of the supply chain members under the government's incentive is greater than there is no incentive, and increases with the increase of the government's unit incentive, so the government's incentive policy can play an effective role.

4. Numerical Example

The following numerical study was conduct simulation design and analysis by adopting the example of closed loop supply chain of recycling of waste electronic products in China's electronic product manufacturing industry to demonstrate the effect of the change of different parameters on the recovery rate and the profits of the members in the closed loop supply chain.

In order to make the government's incentive effective, the value of the relevant parameters are in accordance with the 2.1 section parameter range, so it is scientific and reasonable. $\mathrm{c}_1>\mathrm{c}_2$, $\theta=\mathrm{c}_1-\mathrm{c}_2$, $\mathrm{c}_3\leq\mathrm{b}\leq\mathrm{c}_1-\mathrm{c}_2$ Conditions of the validity of incentive: $\mathrm{v}+2(\mathrm{r}\theta-\mathrm{c}_3)>4m(r\theta-\mathrm{c}_3+\mathrm{v})$. Suppose the relevant parameters of manufacturer, retailer and the third party： $\mathrm{c}_1=100$ $\mathrm{c}_2=50$ $\alpha=1000$ $\beta=5$ $\mathrm{k}=3000$

4.1 The simulation experiment of the government taking incentive to the manufacture

According to the above parameters and model, the optimal solution is obtained as shown in table 1.2, table 1.1 and figure 1.2.

Table 1.1 $\mathrm{c}_3=5$,r=0.6,m=0.3,v=10 the profits of supply chain members in three situations

	Manufacture's profit	Retailer's profit	The third party's profit	Total profit
No-recycling	6250	3125	0	9375
Recycling without government incentive	6685.23	3575.39	232.77	10493.39
Recycling under government incentive	6740.77	3863.37	492.98	11097.12

In table 1.1 it can be seen, the profits of recycling waste electronic products and remanufacturing is higher than not. After the government take incentive to the behavior of manufacturer's recycling and remanufacturing, the closed-loop supply chain members' profits is higher than no recovery of waste products and no incentive when recycling of waste electronic products .

In table 1.2(1) When the government take incentive to the behavior of manufacturer's recycling and remanufacturer, manufacturer's recovery rate is significantly higher than the recovery rate without incentive, It is show that the government's behavior can effectively motivate the manufacturers to recycle the waste electronic products. So as to achieve the resources recycling.

(2)The recovery rate of the manufacturer is increasing with the increase of the remanufacture rate of product.

(3)In the situation of government take incentive to manufacturers, the recovery rate of manufacturers is not always increase with the increase of the minimum recovery rate that set by the government. So the government should consider the actual situation when set the minimum recovery rate, utmost stimulate the recycling and remanufacturing behavior of manufacturers.

(4)In the situation of the government take incentive to manufacturers, recovery rate of waste electronic products increases with the increase of the government unit incentive factor.

Table 1.2 The influence of different parameters change on the optimal recovery rate

variable parameters			Optimal recovery rate	
r	m	v	No incentive	incentive
0.5	0.3	10	16%	27.02%
0.6	0.3	10	21.73%	33.45%
0.7	0.3	10	27.86%	40.5%
0.7	0.3	15	27.86%	47.5%
0.7	0.3	20	27.86%	52.7%
0.6	0.2	10	21.73%	33.79%
0.6	0.4	10	21.73%	31.1%

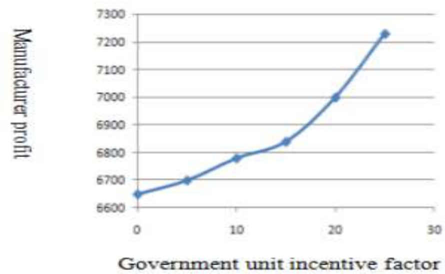

Fig1.2 The relationship between the government unit incentive factor and manufacture profit

It can be seen from Fig1.2, the profit of manufacturer increases with the increasing of government's unit incentive factor. Based on the above analysis, we can see that the government's incentive policy can motivate the recycling behavior of manufacturers and improve the profit of whole closed-loop supply chain system.

4.2 The simulation experiment of the government taking incentive to the third party

According to the above parameters and the model, the optimal solution is obtained as shown in table 1.3, table 1.4 and figure 1.3.

Table1.3 $c_3 = 5$,r=0.6,m=0.3v=10 the profits of supply chain members in three cases

	Manufacturer's profit	Retailer's profit	The third party's profit	Total profit
No-recycling	6250	3125	0	9375
Recycling without government incentive	7185.63	4130.66	537.85	11854.14
Recycling under government incentive	8391.61	5633.53	934.23	14959.37

In table 1.3 it can be seen, when recycling and remanufacturing, the profit of members in supply chain is higher than no recycling. When the government take incentive to the behavior of recycling and remanufacturing, the profits of members in closed-loop supply chain are higher than there is no recovery and no incentive

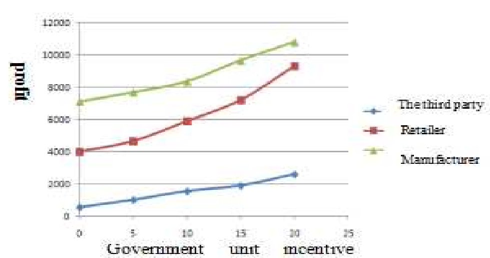

Fig1.3 The relationship between the government unit incentive factor and the profits of supply chain

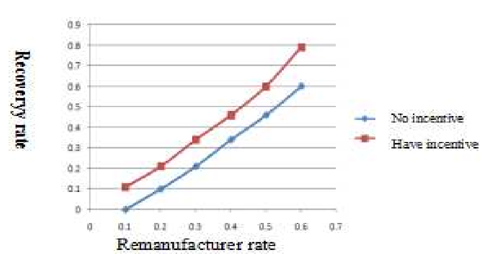

Figure 1.4 The relationship between the recycling rate and the remanufacturing rate under the incentive

It can be seen from Fig1.3, the profit of all members in closed loop supply chain is increasing with the increasing of the government unit incentive factor. It is obvious that appropriate unit incentive factor can effectively motivate the members in the supply chain.

It can be seen from Fig1.4, (1) When the government takes incentive to the third party, the recovery rate is significantly higher than which without incentive

(2)The recovery rate of waste electronic product is increasing with the increasing of remanufacturer, It is shows that the industry can improve the recovery rate of waste products by improving the technology of remanufacturing.

It can be seen from Fig1.5、Fig1.6, (1)The third party's recovery rate of waste electronic products increases with the increasing of the government unit incentive factor, this shows that the government's incentive strategy can effectively guide the third party's recovery.

(2)The recovery rate of waste electronic products decreases with the increase of unit cost of recovery.

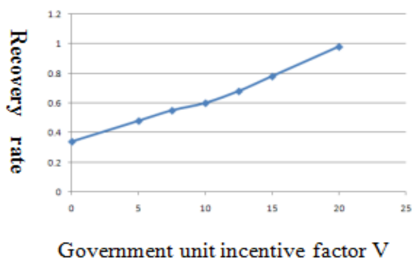

Fig1.5 The relationship between the government unit incentive factor and recovery rate

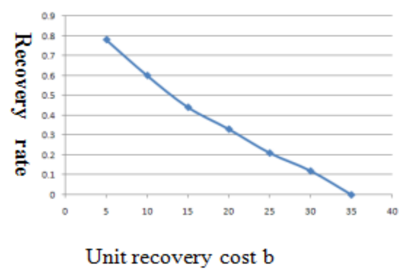

Fig1.6 The relationship between the unit recovery cost and recovery rate

From the above analysis we can see that the government's incentive policy can motivate the recycling behavior of all members in the supply chain. The greater the units incentive factors of the government, the higher the recycling rate, and it can be more able to motivate the manufacturer's recycling behavior and improve the profit of whole closed-loop supply chain system. But the recovery rate of waste electronic products is not always increasing with the increasing of minimum recovery rate that set by the government. So the minimum recovery rate should be set scientific, it can not be blindly increasing, and should select appropriate recovery rate to utmost stimulate the recycling and remanufacturing behavior of manufacturers.

5. Conclusion

This paper establish the model of remanufacturing close-loop supply chain based on the third party who is responsible for recycling, aim at the problem of low recovery rate of waste electronic products, design the incentive function between the government, the manufacturers and the third party, and respectively discussing the optimal strategy under the three cases: the case manufacturers didn't recycling, the case manufactures recycling with government incentive and the case manufactures recycling without government incentive. Obtaining the government incentive strategy can effectively motivate the recycling and remanufacturing of the supply chain system via the effect of parameter variation on recovery rate and profit of supply chain system. Simultaneous the data suggests that, the greater the units incentive factors of the government, the higher the recycling rate, and it can be more able to motivate the manufacturer and the third party's recycling behavior and can improve the profits of the whole closed-loop supply chain system, but the government should base on the actual situation when setting the minimum recovery rate, utmost stimulate the recycling and remanufacturing behavior of the manufacturer and the third party.

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