The Deposit –refund Strategy of Monopoly Electronic Product Producer

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Abstract

In this paper, on the basis of the closed-loop supply chain, from the perspective of producer, considering the recessive and dominant two different deposit refund strategy, we build a two stage dynamic game model, analyze and compare the decision making and effect of two kinds of strategies to know their similarities and differences and help producers for electronic products provide decision-making support for better extension responsibility. Study found: in the monopoly electronic products market, dominant deposit-refund strategy in three different market conditions \( 0 < g, \leq P, P, \leq g, \leq 2P \text{ and } g, \geq 2P \), compared with the implicit deposit-refund strategy, a producer of total profits are high, which means that the explicit strategy has better economic benefits. At the same time, the environmental losses are smaller. Even under the condition \( g, \geq P \) of the market, the explicit strategy can achieve full recovery. Based on this, monopoly electronic product producers adopt explicit deposit–refund strategy is more conducive to assume their extended responsibilities, and can achieve the unity of economic benefits and environmental benefits.

Keywords

Closed-loop supply chain; Producer strategy; Implicit deposit-refund strategy; Explicit deposit-refund strategy.

1. The Introduction

As a major producer and consumer of electronic and electrical products, China has become the world’s largest producer of electronic waste, with the number of scrapped major electrical appliances reaching 200 million each year and the weight reaching 5 million tons (Jin Wei et al. 2018). Electronic waste has dual nature, on the one hand, the electronic waste may contain harmful ingredients, if not to recycle or reference of recycling, it will pollute the environment, damage to health. On the other hand, the electronic waste also contains many useful components, reasonable recycling waste not only can produce a good environmental benefit, also can generate considerable economic benefits, to save resources, recycling economy and sustainable development is of great significance. However, China’s environmental protection recycling of e-waste is facing a grim situation. On the one hand, the production of e-waste is increasing year by year, with an average annual growth rate of double digits. On the other hand, electronic product manufacturers lack effective strategies to recycle electronic waste and realize the maximum recycling of resources.

Deposit-refund system refers to a deposit added to the sale of potentially contaminated products. If these products are recycled or their remnants are sent to a designated collection system, the deposit will be returned to the buyer to avoid contamination (Wang Qian et al. 2017). Bohm (1981) divide the deposit-refund system into three types, one is formed by enterprises, one is regulated by the government and collects deposits from consumers, and the other is collected from producers. Xia Xiqiang etc (2017), Zheng Yanfang et al (2017), Xie
Tiancshuai, etc (2018) focus on the influence of government policies on the competition of recycling channels or the decision-making of government policy under channel competition. These documents belong to the second category. This paper mainly studies the deposit return system of the first type. As an important strategy for enterprises to assume extended responsibility, producers collect a certain amount of deposit from consumers when they sell products, so as to improve the probability of consumers returning electronic waste. Producer’s decision on deposit return strategy can be divided into two parts: deposit collection and return. The collection of the deposit can be included in the product pricing. Consumers do not know the amount of the deposit and the amount of the deposit when they buy the product. Accordingly, the return of the deposit is also included in the recycling pricing of the old product, which forms a hidden deposit return strategy. The collection of the deposit can also be separated from the product pricing. Consumers know that they are charged the deposit and its quantity when they buy the product. Accordingly, the return of the deposit is also separated from the recycling pricing of the old product, which forms an explicit deposit return strategy. In practice, implicit deposit return strategies are more common, but because the deposit is included in the price of the product. In the grid, it is difficult to clearly observe whether the producer collects and how much deposit in the sales stage, which is reflected through the recovery price or the discount rate of the old for new price in the recovery stage. Explicit deposit return strategy is often used by airports and supermarkets in European and American countries to recycle luggage carts and shopping carts (Ma Weimin et al. 2014). However, deposit is often taken into consideration in the pricing of products in the research, and the explicit charging of deposit is rarely made explicit, and the implicit and explicit strategies are not compared.

In the researches related to producers’ deposit return strategies, few researchers distinguish their implicit and explicit strategies. This paper will analyze and sort out the implicit and explicit deposit return strategies in these researches according to the definition. In the implicit deposit return strategy, consumers do not know the deposit and its amount. At this time, the deposit will be returned to consumers in the form of recycling price when they return the waste products. Consumers’ decisions at the purchase stage and the recycling stage are presented in different ways in the literature. Gao Ju-hong et al. (2017) study that in the case of considering the competition of remanufactured products, the product demand of consumers is set as the expected demand function related to the price of new products and remanufactured products, and the recycling quantity is a linear function related to the recycling price. Atamer (2013) and Gu Qiaolun et al. (2005) directly use an exponential function to reflect the recovery quantity and recovery price (deposit return amount) relationship. This paper assumes that there is a willingness to pay when consumers purchase electronic products and a return cost when they return electronic waste, both of which are uniformly distributed. As the dominant player in the closed-loop supply chain, producers make decisions with consumers as their decision-making objects and their goal is to maximize their own profits. Generally, retailers are not involved in this kind of literature, and the pricing problem between producers and consumers is directly studied. Li-jun meng et al. (2019) study that in the case of recycling risk, this paper analyzes the joint pricing strategy of recycling price of waste products by taking the manufacturer's expected profit maximization as the decision goal. Xiao-hua han etc. (2010) consider the market structure of manufacturer competition, the optimal wholesale price, recovery rate and retail price of manufacturer and retailer are determined under the goal of maximizing profit of two manufacturers and retailers. This paper takes the total profit of the electronic product manufacturer as the decision target, and on the basis of considering the decision-making behavior of consumers, the optimal selling price, recovery price and deposit refund amount of the producer are determined.

In the explicit deposit-refund strategy, consumers know the deposit and its quantity when they purchase the product, and the deposit will be returned when the waste product is returned.
When deposit is explicitly charged, consumers’ purchase and recovery decisions are different from those when deposit is implicitly charged. Kulshreshtha and Sarangi (2001) divide consumers into two categories: willing to return waste products and unwilling to return waste products according to their reaction to the deposit when buying products. Wojanowski et al (2007) investigate that the consumer’s purchase decision is related to the product’s utility, price and distance, and the return decision is combined with the environmental experience, distance and deposit discount. XiaoXueXun assume that consumer demand for products is only related to product price and recycling competition, and deposit does not affect demand. Most of the papers will return all the deposits when they study the explicit deposit return strategy. Partial returns are also considered in combination with the actual situation. At this time, the deposit has a greater impact on product sales. Wei Shuoguo et al. (2010) according to the quality of waste products to return the deposit, high quality grade of waste products, return the deposit is high. On the contrary, the waste products of low quality grade, return the deposit is low. Numata (2011) assumes the deposits charged to consumers in the study are also partially returned. This paper assumes that all deposits are returned to consumers and judges consumers’ decision-making behavior on explicit deposits according to the type of electronic products.

Based on the above analysis, on the basis of the closed-loop supply chain, from the perspective of monopoly electronic products producer, considering the recessive and dominant two different deposit refund strategy, we build a two stage dynamic game model in this paper, analyze and compare the decision making and effect of two kinds of strategies to know their similarities and differences and help producers for electronic products provide decision-making support for better extension responsibility.

2. Implicit Deposit-refund Strategy Model Description and Analysis

2.1. Model Assumptions
Hypothesis 1: The game involved in this paper is a complete information dynamic game, that is, the information required for decision-making, such as the distribution of consumers’ willingness to pay for products, the distribution of waste return costs, producers’ profit per unit waste disposal, the market price of products and the recycling price of wastes, is shared by all parties in the game.

2.2. Model Description
Consumer: In a cash recovery strategy, the selling price of an electronic product is $p$. At this point, consumers have a willingness to pay for electronic products $X$. $X$ subjects to the uniform distribution of $[0, P_x]$. When $X \geq p_s$, consumers will buy electronic products, then the number of electronic products sold $q_s$ is:

$$q_s = \int_{p_s}^{P_x} \frac{1}{P_x} \, dx = \frac{P_x - p_s}{P_x}$$

Among them, $p_x > p_s$. If $p_s \leq p_x$, there is no market for this electronic product. When the electronic product life cycle is over, the electronic product manufacturer in order to bear its extended responsibility, use the price $p_r$ to recover recycling electronic waste from consumers. At the same time, there is a cost for consumers to return e-waste $Y$. Subject to $[0, P_Y]$ The uniform distribution of. When $p_r \geq Y$, consumers will return the e-waste, then the amount of e-waste recycling $q_r$ is:
In the electronic product market, the amount of electronic waste recycling should not exceed the number of electronic products sold in line with the actual situation, i.e., and thus can be obtained, \( p_s \leq p_r \).

Electronic waste recovery rate \( r \) To:

\[
    r = \frac{q_r}{q_s} \times 100\%
\]

Producer: Electronic product producers adopt a cash recovery strategy to assume their extended responsibilities. In the selling stage, the producer uses the selling price \( p_s \), sells electronic products, and fails to inform consumers of the deposit and the amount of the deposit. In this case, the producer’s profit on sales \( \Pi_{MS} \) is:

\[
    \Pi_{MS} = q_s (p_s - \mu)
\]  

In the recovery phase, the producer takes the price \( p_r \), Recycling e-waste, and e-waste storage unit disposal profit \( \delta_r, \delta_s > 0 \). At this point, the producer’s profit is recovered \( \Pi_{MR} \) is:

\[
    \Pi_{MR} = q_r (\delta_r - p_r)
\]

The total profit of the electronic product producer’s supply chain is the sum of sales profit and recovery profit, so the total profit of the producer \( \Pi_{MT} \) is:

\[
    \Pi_{MT} = \Pi_{MS} + \Pi_{MR} = (p_s - c)q_s + (\delta_r - p_r)q_r
\]  

Society: Definitions \( \epsilon > 0 \) Is the environmental loss caused by unrecycled unit e-waste, is the total environmental loss caused by recycling \( \Pi_r \), (expressed as a negative value) is:

\[
    \Pi_r = -\epsilon (q_r - q_s) = -\epsilon \frac{(P_s - p_r)(P_e - p_s)}{p_r p_s}
\]

The sequence of events: firstly, the producer decides the product price and the recovery price (at this time, the recovery price is not disclosed as the private information of the producer) and then the consumer decides whether to buy the product; \( p_s, p_r \). At the end of the product’s life cycle, producers publish a predetermined recycling price, and consumers decide whether to sell the waste. \( p_r \). Although there are three natural time series, consumers’ decisions at two adjacent moments are not influenced by each other, and they can be regarded as decisions at the same stage after producers’ decisions, so it is still a two-stage dynamic game.

2.3. Model Analysis

Inverse induction method is used to solve the problem. There are two decisions in the second stage, namely, consumers’ product purchase decision and waste sale decision. The optimal decision has been given by Equation(6) and Equation(7) respectively. In order to solve the
optimal decision $p_i'(p_x)$ of the producer in the first stage, the function of recovery profit $(8)$ is firstly analyzed. The first derivative can solve the optimal recovery price $p_r'$, and then the producer’s optimal product price $p_i'$ can be solved by substituting it into the function $(9)$ of total profit of the producer.

### 2.3.1. Optimal Sales Price and Recovery Price

Proposition 1: The implicit deposit-refund equilibrium strategy of monopoly electronic product producers is given in Table 1.

#### Table 1. The optimal selling price and recovery price of the hidden deposit return strategy of the monopolistic electronic product manufacturer

<table>
<thead>
<tr>
<th>Condition</th>
<th>Optimal Selling Price $p_i'$</th>
<th>Optimal Recovery Price $p_r'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 &lt; g_r \leq 2P_y$</td>
<td>$\frac{4P_y(P_x + c) - g_r^2}{8P_y}$</td>
<td>$\frac{g_r}{2}$</td>
</tr>
<tr>
<td>$g_r \geq 2P_y$</td>
<td>$(P_x + c) - (g_r - P_y)$</td>
<td>$P_y$</td>
</tr>
</tbody>
</table>

Proposition 1 shows the optimal product price $p_i'$ of the electronic product producer is the production cost per unit product $c$, consumers' maximum willingness to pay $P_x$ and the maximum refund cost $P_y$ to the consumer increment function of unit waste disposal profit $g_r$. That is the producer’s product pricing will increase with the increase of production cost, consumer’s willingness to pay and consumer residual value estimation, and decrease with the increase of unit waste disposal profit. The optimal recovery price $p_r'$ is the unit waste disposal profit $g_r$, the maximum refund cost for consumers $P_y$. In other words, the recovery price of producers will increase with the increase of unit waste disposal profit and consumer return cost.

#### 2.3.2. Analysis of Equilibrium Results

#### Table 2. Equilibrium results of implicit deposit return for monopoly electronic product producers

<table>
<thead>
<tr>
<th>Condition</th>
<th>Optimal Selling Price $q_i'$</th>
<th>Optimal Recovery Price $q_r'$</th>
<th>Optimal Total Profit $\Pi_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 &lt; g_r \leq 2P_y$</td>
<td>$\frac{4P_y(P_x - c) + g_r^2}{8P_yP_y}$</td>
<td>$\frac{g_r(4P_y(P_x - c) + g_r^2)}{16P_yP_y}$</td>
<td>$\frac{(4P_y(P_x - c))^3 - g_r^4}{64P_yP_y^2}$</td>
</tr>
<tr>
<td>$g_r \geq 2P_y$</td>
<td>$(P_x - c) + (g_r - P_y)$</td>
<td>$(P_x - c) + (g_r - P_y)$</td>
<td>$\frac{(P_x - c)^3 - (g_r - P_y)^3}{4P_y}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\frac{g_r^2(4P_y(P_x - c) + g_r^2)}{32P_yP_y^2}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\frac{(4P_y(P_x - c) + g_r^2)^2}{64P_yP_y^2}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\frac{g_r^2(g_r - 2P_y)(4P_y(P_x - c) + g_r^2)}{16P_yP_y^2}$</td>
</tr>
</tbody>
</table>

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Take the producer’s optimal product price $p^*$ in proposition 1 substitute into the equation (10) to obtain the equilibrium sales quantity $q^*$. And then $q^*$ and the producer’s optimal price $p^*$ substitute into the equation (11) to obtain the equilibrium recovery quantity $q^*$. That will be $q^*$, $p^*$, substituting (12) and (7), the equilibrium recovery rate of electronic waste and the equilibrium environmental profit and loss can be obtained. $p^*$, $q^*$, $p^*$, $q^*$, substituting into Equations (4), (5) and (6), we can obtain the equilibrium sales profit $\Pi_{MS}$, equilibrium recovery profit $\Pi_{RE}$ and equilibrium total profit of the producer $\Pi_{MT}$. The results are shown in Table 2.

Table 2 shows that when the unit waste disposal profit is low ($g < 2p_x$), the optimal sales volume of electronic product manufacturers $q^*$, the optimal recovery quantity $q^*$ are consumers’ maximum willingness to pay, maximum refund cost and unit waste disposal profits $g$. The increment function of is the unit production cost $c$, that is, the number of electronic products sold will increase with the increase of consumers’ maximum willingness to pay, maximum return cost and unit processing profit, and decrease with the increase of unit production cost. So the recovery is less than 100%, which means that the electronic products sold by producers are not fully recycled and there is environmental damage. When the profit per unit waste disposal is high ($g > 2p_x$), when the producer implements the implicit deposit return strategy, the sales quantity is equal to the recovery quantity, which means that all the electronic products sold by the producer have been recovered after the end of their life cycle, and the recovery rate has reached 100%. There is no environmental problem. And the optimal sales quantity of the electronic product manufacturer $q^*$, the optimal recovery quantity $q^*$ are consumers’ maximum willingness to pay $p_x$. And unit waste disposal profits $g$. Is the maximum return cost $p_y$. And unit production costs $c$. That is, the number of electronic products sold will increase with the increase of consumers’ maximum willingness to pay and unit processing profit, and decrease with the increase of maximum return cost and unit production cost. In equilibrium, the producer’s sales profit, recovery profit, total profit of supply chain, and environmental profit and loss all have a complex relationship with consumers’ maximum willingness to pay, maximum return cost, unit production cost, unit waste disposal profit and other factors.

3. Description and Analysis of Deposit Return Strategy Model

3.1. Model Assumptions

Hypothesis 1: The game involved in this paper is a complete information dynamic game, that is, the information required for decision-making, such as the distribution of consumers’ willingness to pay for products, the distribution of waste return costs, producers’ profit per unit waste disposal, the market price of products and the recycling price of wastes, is shared by all parties in the game.

Hypothesis 2: Monopolistic electronic products are characterized by the fact that there are almost no substitutes in the market. The demand curve of consumers is the demand curve of the whole industry, which is affected by the product price. Because the deposit is clearly informed that consumers will be returned at the recycling stage, and there is no substitute product on the market.

3.2. Model Description

Consumers: Under the explicit deposit-refund strategy of electronic product manufacturers, consumers will charge a certain deposit $t$ when purchasing electronic products and get corresponding certificates. In the sales stage, consumers have a willingness $X$ to pay for electronic products, $X \in [0, p_x]$. Only $X > p$, then will consumers buy electronic products. At this time, the sales volume of electronic products $q$, is:
In the above formula \( p_x < P_x - t \), if \( p_x \geq P_x - t \) then there is no consumer to buy the electronic product and there is no such sales market.

After the end of the product life cycle, electronic waste into the recovery phase, the producers will recovery of electronic waste recycling price \( r_p \), consumers returned to return the cost of electronic waste \( Y \), at the same time return the e-waste recycling price \( r_p \) and can be obtained after the deposit \( t \), only when \( t + p \geq Y \) the consumer will return the electronic waste, electronic waste at this time for the number of return \( q \), is:

\[
q = q \int_{0}^{t+Y} \frac{1}{P_x} dx = \frac{q}{P_x}(t + p)
\]

In the market of electronic products, the amount of recycling of electronic waste should not exceed the amount of sales of electronic products to meet the actual situation, that is \( q \leq q_x \), from this can be obtained \( p \in [0, P_x - t], P_x - t \geq 0, t \leq P_x \). Usually, \( P_x > P_y \)

The e-waste recovery rate \( r \) is:

\[
r = \frac{q}{q_x} \times 100\%
\]

Producer: Electronic product producers adopt a deposit return strategy to assume their extended responsibilities. In the sales stage, the producer sells the electronic products at the sales price \( p \), and collects a deposit \( t \) from the consumer. The deposit will be returned after the consumer returns the electronic waste. At this time, the sales profit of the producer \( \Pi_{MS} \) is:

\[
\Pi_{MS} = (p_x - c)q_x
\]

In the recycling stage, the producer recycles the e-waste at a price \( r_p \), and the e-waste is stored in the unit disposal profit \( g \), \( c > g, g > 0 \). At this time, the recovery profit of the producer \( \Pi_{MR} \) is:

\[
\Pi_{MR} = (g - p_x)q_x + (q_x - q)\ell
\]

The total profit of the electronic product producer's supply chain is the sum of sales profit and recovery profit, so the total profit of the producer \( \Pi_{MT} \) is:

\[
\Pi_{MT} = \Pi_{MS} + \Pi_{MR} = (p_x - c)q_x + (g - p_x)q_x + (q_x - q)\ell
\]

Society: \( \varepsilon \) (\( \varepsilon > 0 \)) is defined as the environmental loss caused by unrecycled unit e-waste, then the total environmental loss caused by recycling (expressed in negative value) \( \Pi \), is:

\[
\Pi = -\varepsilon(q_x - q)
\]

Event sequence: in the sales stage, the electronic product manufacturer first decides the sales price \( p_x \), deposit amount \( t \) and recycling price \( r_p \) of the electronic product in the market (at this
time, the recycling price \( r_p \) is not disclosed as the private information of the electronic product manufacturer), and consumers decide whether to buy the electronic product according to their willingness to pay. When the life cycle of electronic products ends, electronic product producers will recycle electronic waste and publish the pre-determined recycling price in the recycling market. Consumers will decide whether to return electronic waste or not according to the return cost of electronic products and the amount of the deposit. This is a two-stage two-player dynamic game.

3.3. Model Analysis

According to the inverse induction method, there are two decisions in the second stage, namely, the product purchase decision and the waste sale decision of consumers. The optimal decision has been given by the selling quantity equation (8) and the recycling quantity equation (9) respectively. First, the derivative of the recovery price \( r_p \) in the producer’s recovery profit formula can get the optimal recovery price \( *r_p \). Substituting it into the total profit function formula (13) of the producer supply chain, the first-order partial derivative of the deposit amount \( t \) and the sales price \( sp \) can get the optimal deposit amount \( *t \) and the optimal sales price \( *sp \).

3.3.1. Optimal Sales Price, Recovery Price and Deposit

Proposition 2 The equilibrium strategy of deposit return for electronic product producers in the completely monopoly type is shown in Table 3:

<table>
<thead>
<tr>
<th>( 0 &lt; r_s \leq P_y )</th>
<th>( P_y \leq r_s \leq 2P_y )</th>
<th>( r_s \geq 2P_y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r_p^* )</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>( t^* )</td>
<td>( \frac{g_s + P_y}{2} )</td>
<td>( P_y )</td>
</tr>
<tr>
<td>( p_s^* )</td>
<td>( \frac{4P_y(c + P_y) - (g_s + P_y)^2}{8P_y} )</td>
<td>( \frac{c + P_y - g_s}{2} )</td>
</tr>
</tbody>
</table>

Proposition 4.2 shows that the above table reflects the conditions for electronic product producers to implement the explicit deposit-refund strategy and the corresponding optimal recovery price, optimal amount of deposit and optimal sales price. From the table, the electronics producer equilibrium strategies and unit deal with the relationship between the profit \( r_s \) and maximum return cost \( P_y \) and return the deposit \( t \) policy related to \( r_s \): (1) when units with low profits (that is \( 0 < r_s \leq P_y \)), namely the optimal price is zero, the optimal deposit as unit to deal with the increase of profit and the maximum return cost. The optimal selling price increases with the increase of unit production cost and maximum willingness to pay, but decreases with the increase of unit processing profit. However, the relationship with the maximum rebate cost is complicated, which increases in some cases and decreases in others.(2) When the unit processing profit is moderate (\( P_y \leq r_s \leq 2P_y \)), the optimal recovery price is still zero, the optimal deposit rebate amount is the maximum return cost, and the optimal sales price increases with the increase of unit production cost and maximum willingness to pay, but decreases with the increase of unit processing profit. (3) When the unit processing profit is high (\( r_s \geq 2P_y \)), the optimal recovery price is zero, the optimal deposit rebate amount is the maximum return cost, the optimal sales price increases with the increase of unit production cost and the maximum willingness to pay, but decreases with the increase of unit processing profit. It is

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worth noting that the optimal recovery prices under the explicit deposit return strategy are all zero, which indicates that the electronic product manufacturer only needs to return the amount of deposit greater than the return cost to the consumer in the recycling stage to obtain the electronic waste, and the optimal deposit return amount can maximize the profit.

3.3.2. Analysis of Equilibrium Results

Take the producer’s optimal product price \( p^*_i \) in proposition 2 substitute the sales quantity equation (8) to get the balanced sales quantity \( q^*_i \). And then \( q^*_i, p^*_i \). By substituting the recovery rate (10) and environmental profit and loss formula (14), the equilibrium recovery rate of electronic waste and equilibrium environmental profit and loss can be obtained. \( p^*_i, q^*_i, p^*_i, q^*_i \) substituting sales profit (11), recovery profit (12) and total profit formula (13) of supply chain, we can get balanced sales profit \( \Pi^*_{MS} \), balanced recovery profit \( \Pi^*_{MR} \) and balanced total profit \( \Pi^*_{MT} \) of the producer. The results are shown in Table 4.

<table>
<thead>
<tr>
<th>Table 4. Equilibrium results of dominant deposit return for monopoly electronic product producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 0 &lt; g_i \leq P_y )</td>
</tr>
<tr>
<td>( p^*_i )</td>
</tr>
<tr>
<td>( q^*_i )</td>
</tr>
<tr>
<td>( f^*_i )</td>
</tr>
<tr>
<td>( r^*_i )</td>
</tr>
<tr>
<td>( \Pi^*_{MS} )</td>
</tr>
<tr>
<td>( \Pi^*_{MR} )</td>
</tr>
<tr>
<td>( \Pi^*_{MT} )</td>
</tr>
<tr>
<td>( \Pi^*_{\varepsilon} )</td>
</tr>
</tbody>
</table>

It can be seen from Table 4 that the size of unit waste disposal profit will have an impact on the effect of explicit deposit return strategy implemented by electronic product producers. Lower profits when unit of waste management \( (0 < g_i \leq P_y) \), the number of dominant deposit returned to the sales strategy at this time is greater than the number of recycling, recovery rate is lower than, sales of electronic products, which means that the producer after the end of its life cycle did not achieve full recovery, not recycling of electronic waste can produce damage to the environment, environmental problems. 100% When the unit waste disposal profit is moderate.
or high \((P_r \leq g \leq 2P_r\) or \(g \geq 2P_r\)), the sales quantity under the explicit deposit return strategy is equal to the recovered quantity, and the recovery rate reaches, which means that the electronic products sold by the producer are completely recycled after the end of their life cycle, and there is no environmental protection problem, thus achieving a complete economic cycle. 100% In equilibrium, the producer’s sales quantity, recovery quantity, sales profit, recovery profit, total profit of supply chain and environmental profit and loss all have a complex relationship with consumers’ maximum willingness to pay, maximum return cost, unit production cost, unit waste disposal profit and other factors.

4. Comparative Analysis of Balancing Strategies and Results

This section will compare the differences between implicit and explicit deposit return strategies of competitive electronic product manufacturers. For the convenience of comparison, subscripts (representing recessive) and (representing dominant) are added to the result indicators in the above table to distinguish them. If and represent the equilibrium selling price of the producer in the implicit deposit return strategy and the explicit deposit return strategy respectively. \(\bar{P}_r, \bar{P}_e\)

Proposition 3: When \(0 < g \leq P_r\), \(\bar{P}_e > \bar{P}_r\), \(\bar{P}_e > \bar{P}_e\), \(\bar{P}_r > \bar{P}_e\), \(\bar{q}_r < \bar{q}_e\), \(\bar{q}_e < \bar{q}_e\), \(\bar{r}_H < \bar{r}_O\) \(\Pi_{H-H} > \Pi_{H-O}\), \(\Pi_{MT-H} > \Pi_{MT-O}\), \(\Pi_{H-H} > \Pi_{H-O}\).

As can be seen from Proposition 3, when the unit processing profit of the electronic product manufacturer is low \((0 < g \leq P_r)\), compared with the implicit deposit return strategy, the optimal selling price and optimal recovery price of the explicit deposit return strategy are both lower, and the amount of deposit return is increased. On strategy implementation effect, although both sell to implement electronic products are not fully recovery, but the dominant deposit returned to the sales strategy, the number of recycling and recovery of electronic waste were higher than that of recessive deposit refund strategy, this suggests that the dominant deposit refund strategy to some extent, can reduce the burden of electronic waste to environment, and is advantageous to the extended responsibility manufacturers of electronic products. At the same time, the total profit of the electronic product producer’s supply chain under the explicit deposit return strategy is higher. Specifically, when the sales profit is at a disadvantage, the recovery profit greatly increases the total profit of the producer, which reflects the importance of reverse recovery to the whole supply chain under the explicit deposit return strategy.

Proposition 4: When \(P_r \leq g \leq 2P_r\), \(\bar{P}_r > \bar{P}_e\), \(\bar{r}_H < \bar{r}_O\), \(\bar{q}_r < \bar{q}_e\), \(\bar{q}_e < \bar{q}_e\), \(\bar{r}_H < \bar{r}_O\) \(\Pi_{H-H} > \Pi_{H-O}\), \(\Pi_{MT-H} > \Pi_{MT-O}\), \(\Pi_{H-H} > \Pi_{H-O}\).

As can be seen from Proposition 4, when the unit processing profit of the electronic product manufacturer is moderate \((P_r \leq g \leq 2P_r)\), the comparison result of implicit deposit return strategy and explicit deposit return strategy is roughly the same as that of Proposition 3. The difference lies in the implementation effect of the strategy. Compared with the implicit deposit return strategy, the explicit deposit return strategy realizes the complete recovery of e-waste, which indicates that the explicit deposit return strategy avoids the burden caused by e-waste to the environment and is conducive to the extended responsibility of electronic product producers. At the same time, the total profit of electronic product producers under the explicit deposit return strategy is higher. Specifically, when the sales profit is at a disadvantage, the recovery profit greatly increases the total profit of the producer, which reflects the importance of reverse recovery to the whole supply chain in the explicit deposit return strategy.

Proposition 5: When \(g \geq 2P_r\), \(\bar{P}_r > \bar{P}_e\), \(\bar{r}_H = \bar{r}_O\), \(\bar{q}_r < \bar{q}_e\), \(\bar{q}_e < \bar{q}_e\), \(\bar{r}_H = \bar{r}_O\) \(\Pi_{H-H} > \Pi_{H-O}\), \(\Pi_{MT-H} > \Pi_{MT-O}\), \(\Pi_{e-H} = \Pi_{e-O}\).
As can be seen from Proposition 5, when the unit processing profit of the electronic product manufacturer is high ($g \geq 2P$), compared with the implicit deposit return strategy, the optimal selling price and optimal recovery price of the explicit deposit return strategy are both lower, and the deposit refunds of the two strategies are equal. In terms of the implementation effect of the strategy, the sales quantity and recycling quantity of the explicit deposit return strategy are both higher than that of the implicit deposit return strategy. The recovery rates of the two e-waste strategies are equal and the electronic products sold are completely recycled, which indicates that the two strategies have the same positive environmental effect and avoid environmental pollution. At the same time, the explicit deposit return strategy is lower than the implicit deposit return strategy in terms of sales profit, but the recovery profit and the total profit of the producer are higher. This indicates that the implicit deposit return strategy has advantages in the forward supply chain, while the explicit deposit return strategy has more advantages in the reverse supply chain, and its profitability makes up for the deficiency in the forward supply chain and improves the total profit of producers.

Based on analysis of available: in a monopoly electronic products market, dominant deposit refund strategy in three different market conditions ($0 \leq g \leq P$, $P \leq g \leq 2P$, and $g \geq 2P$), compared with the recessive deposit refund strategy, a producer profits are high, it means that the dominant strategy has better economic benefits, at the same time, the losses are smaller environment, even under the conditions $g \geq P$ of the market can achieve full recovery, this also means that the dominant strategy environmental benefits better. Therefore, compared with the implicit deposit return strategy, the explicit deposit return strategy has two significant advantages: first, the scope of implementation is large, and second, the implementation effect is excellent. Based on this, it is more advantageous for monopoly electronic product producers to take explicit deposit return strategy to assume their extended responsibilities, which can realize the unification of economic benefits and environmental benefits.

5. Conclusions and Prospects

In this paper, on the basis of the closed-loop supply chain, give full consideration to the consumer’s decision-making behavior, monopoly respectively electronics producers of recessive and dominant deposit refund strategy to build two stage dynamic game model, to analyze two strategies in different market under the condition of equilibrium strategy and equilibrium results, and compare two strategies, the market conditions of different electronic products producers, the optimal strategy in order to better extended producer responsibility. Study found: in the monopoly electronic products market, dominant deposit refund strategy in three different market conditions ($0 \leq g \leq P$, $P \leq g \leq 2P$, and $g \geq 2P$), compared with the recessive deposit refund strategy, a producer profits are high, it means that the dominant strategy has better economic benefits, at the same time, the losses are smaller environment, even under the conditions $g \geq P$ of the market can achieve full recovery, this also means that the dominant strategy environmental benefits better. Based on this, it is more advantageous for monopoly electronic product producers to take explicit deposit return strategy to assume their extended responsibilities, which can realize the unification of economic benefits and environmental benefits.

This paper mainly studies the fully competitive electronic product market, and then studies the implicit and explicit deposit return strategies for different types of electronic products, such as monopolistic and monopoly-competitive electronic products. At the same time, this paper does not consider the existence of informal recyclers in the electronic waste recycling market, which has a certain influence on the strategy choice of electronic product producers.
References


