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Decision-Making Mechanism and Evolutionary Game Analysis of the Seller's Remanufactured Price Deception Behavior

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Abstract: *In the early stage of the development of the remanufacturing industry, the confusion of market supervision and the influx of competitors in the same industry reduced the profits of remanufactured products. In order to obtain more profits, the seller conducted price deception of remanufactured products. This paper studies the evolution process of seller's remanufactured price deception behavior. Firstly, a three-party evolutionary game model consisting of the seller, governments and consumers is constructed. And the evolutionary stability of mixed strategies is analyzed by Lyapunov's first method matrix. The results show that: when the after-tax income of the seller who chooses not to disguise is greater than the difference between the after-tax income of disguise and the cost of disguise, the seller does not disguise and the consumer purchases. The market achieves an effective allocation at this time. Secondly, the internal evolutionary game model of the seller group is established. It is analyzed through the stability principle of differential equations. The results show that: the government increases incentives and punishments can both motivate the seller to choose not to disguise products.*

Keywords: *Remanufactured products, Price deception, Disguised costs, Evolutionary game*

1. Introduction

With the rapid development of the economy and the improvement of people's living standards, the speed of product replacement is accelerated. That results in a lot of waste and idle items. In order to promote the reuse of resources and the development of circular economy, the remanufacturing industry came into being. With the frequent occurrence of ecological problems, the country has also vigorously developed the remanufacturing industry. More enterprises transform and develop a circular economy. The influx of competitors has brought a huge impact on the remanufactured product market, reducing the profitability of the remanufacturing industry. Some sellers have packaged the remanufactured products as new products for sale at a certain cost of disguise in order to make huge profits, that is, remanufactured price deception. The lack of integrity seriously disrupts the market order, damages the interests of consumers, and hinders the development of my country's circular economy. Therefore, it is of great significance to study the problem of price deception of remanufactured products and make suggestions for the government from a theoretical point of view.

Regarding the remanufacturing problem in the closed-loop supply chain, Di et al. [1] constructed game systems under three scenarios: government-free, government-subsidized dealer remanufacturing, and government-subsidized manufacturer remanufacturing design, and analyzed the effect of different subsidy strategies on the influence of the decision-making of supply chain channel member enterprises. Cao et al. [2] constructed three models respectively without patent licensing without government regulation, with patent licensing without government regulation, with patent licensing and government regulation, and analyzed the impact of different models on enterprise production decisions and remanufacturing performance levels. Meng et al. [3] constructed a closed-loop supply chain game model under government consumption subsidies from the perspective of the government providing consumption subsidies to encourage consumers to choose to purchase remanufactured products. They analyzed the government's optimal consumption subsidy strategy and the effect of government consumption subsidies on the pricing of new products and remanufactured products, the total profit of the supply chain, consumer surplus, and the impact of social welfare. Liu et al. [4] constructed a closed-loop supply chain which is composed of manufacturers and authorized remanufacturers, and studied the impact of carbon emission policies on the number of new products, recycling prices, remanufactured prices, patent license fees, and the profits. Gao et al.[5] respectively constructed independent remanufacturers not entering and

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brand owners no longer manufacturing, independent remanufacturers not entering and brand owners remanufacturing, independent remanufacturers entering and brand owners no longer manufacturing, independent remanufacturers entering and brand owners remanufacture four market models, and analyzed the impact of consumers' brand loyalty characteristics on new product prices, remanufactured prices, and brand owners' profits under different models.

In the three-level supply chain of the seller, the government and the consumer, the consumer are usually in a weak position. They cannot directly observe the production process of products by the seller, nor can they directly observe the inspection process of the government. Therefore, the consumer is easily deceived. In the existing research, Zhen.[6] constructed a three-stage dynamic game model under the condition that consumers have transfer costs and is short-sighted. Then, she discussed the motivation of enterprises to "kill familiarity" in the oligopoly market and its impact on the interests of consumers. Li et al.[7] based on the different behavior characteristics of consumers, built a multi-stage repeated game model between buyers and sellers to explore the impact of consumer emotion on the "kill familiarity" of big data. Zhou et al.[8] based on the dual situations of government supervision and subsidy, applied the evolutionary game method to explore the impact of government supervision and subsidy measures on the price fraud in the process of crop trading. The above behaviors of deceiving consumers are mostly studied from the perspective of big data's ripeness and price fraud. When fraud occurs in the field of remanufacturing, it often occurs by spending a certain camouflage cost to camouflage the reproducts. Our paper studies the remanufactured price deception from the perspective of camouflage cost.

The vast majority of literatures mostly use static research methods in the study of government punishment measures. Few documents explore the impact of government punishment mechanism on decision-making from the perspective of dynamic punishment. Wang et al.[9] used the method of random evolution game to discuss the regulation effect of government static accountability mechanism and dynamic reward and punishment mechanism on different degrees of negative production enterprises. Liang et al.[10] based on the background of epidemic prevention and control, constructed the game models of the government and the public under static and three dynamic reward and punishment mechanisms respectively. They explored the impact of different punishment mechanisms on the evolutionary stability strategy of the game system. Yang et al.[11] based on the issue of food safety, constructed an evolutionary game model between food enterprises and local governments, and explore the impact of different reward and punishment mechanisms on food enterprises. Our paper introduces the dynamic punishment mechanism to explore the influence of government dynamic punishment on the players.

In our study, consumer complaint and dynamic punishment mechanism are introduced into the problem of remanufactured price deception. The tripartite evolution game model of the seller, the government and the consumer and the internal evolution game model of the seller is constructed respectively. Then, the evolution trajectory of the system is explored. Finally, the internal and external evolution games of the seller are compared in order to provide some suggestions for reproduct quality monitoring.

2. Model parameters and assumptions

2.1. Problem description

This paper considers a remanufactured market consisting of the seller, the government and the consumer, where the seller are responsible for the recovery and reuse of remanufactured products. Due to insufficient supervision and lack of laws in the remanufactured market, some the seller make more profits by disguising the remanufactured products as new products, that is remanufactured price deception. Such behavior seriously undermines the fairness of the market and causes disorderly competition in the remanufactured market. At this point, the government needs to take relevant measures to curb the seller' price gouging. With the enhancement of the consumer' awareness of protecting their own rights and interests in real life, the consumer is willing to publish his dissatisfaction with products on the Internet, which will affect the sales of the seller.

2.2. Model parameters

P_1: The price at which the seller sells the new product

P_2: The price at which the seller sells the remanufactured product

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C_1: Cost of remanufactured products for recycling and processing

C_2: Cost of disguise for packaging remanufactured into new product

L_1: Incentive for the seller who choose not to disguise when the government strictly supervises

L_2: Punishment for the seller who choose to disguise when the government strictly supervises

C_3: Inspection costs by the government

V_1: The utility of consumers purchasing new products

V_2: The utility of consumers purchasing remanufactured products

V_3: Consumer complaint sentiment

t: The government tax

2.3. Model assumptions

Assumption 1 The seller will spontaneously form a group during the game with the government and consumers, and will become a homogeneous and independent individual during the game within the dealer. The government in this article refers to a group of local governments. When the government strictly supervises, it can accurately identify whether the seller have fake product behaviors.

Assumption 2 This paper assumes that the seller can sell new products and remanufactured products, and all recovered products can be used for remanufacturing production, ignoring the loss in the production process.

Assumption 3 Referring to Liu et al.[12] for the dynamic rewards and punishments set when they study miners' violations, it is believed that the government's punishment to the seller is related to the probability of choosing to disguise, and the reward to the seller is related to the probability of choosing not to disguise.

Assumption 4 The cost of the seller and government rewards and punishments are not included in the scope of taxation and directly affect profits, where the tax rate $t \in [0,1]$.

Assumption 5 When the seller pretends to sell the remanufactured product, the consumer will gain the opportunity cost of not purchasing: $V_1 - V_2$, and will lose the opportunity cost of purchasing: $V_1 - V_2$.

Assumption 6 Based on the economic motivation of individual decision-making, the parameters in this paper have the following relationship: $V_1 > V_2, P_1 > P_2, V_1 > P_1, V_2 > P_2, P_1 - C_2 > P_2$.

3. Analysis of external evolutionary game for the seller

3.1. Return matrix

Table 1: Three-party evolutionary game return matrix.

Game party				Consumer	
				C1	C2
Seller	S1	Government	G1	$P_2(1-t) - C_1 + xL_1$ $P_2t - C_3 - xL_1$ $V_2 - P_2$	$-C_1 + xL_1$ $-C_3 - xL_1$ 0
			G2	$P_2(1-t) - C_1$ P_2t $V_2 - P_2$	$-C_1$ 0 0
	S2	Government	G1	$P_1(1-t) - C_1 - C_2 - (1-x)L_2$ $P_1t + (1-x)L_2 - C_3$ $V_2 - P_1 - V_3$	$-C_1 - C_2 - (1-x)L_2$ $(1-x)L_2 - C_3$ $V_1 - V_2$
			G2	$P_1(1-t) - C_1 - C_2$ P_1t $V_2 - P_1 - V_3$	$-C_1 - C_2$ 0 $V_1 - V_2$

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In order to explore the internal mechanism of the seller's remanufacturing price deception, a tripartite evolutionary game model of the seller, the government and the consumer is constructed. In the game process, the game subject adopts two strategies. The seller adopts two strategies of "not disguise" and "disguise", and the strategy set is {not disguise, disguise}, denoted as {S1, S2}. The government adopts two strategies of "supervise" and "not supervise", and the strategy set is {supervise, not supervise}, denoted as {G1, G2}. The consumer adopts two strategies of "purchase" and "not purchase", and the strategy set is {purchase, not purchase}, denoted as {C1, C2}. Based on the above assumption, the profit matrix of the seller, the government and the consumer are constructed, as shown in Table 1 below.

3.2. Build replicated dynamic equations

Let the probability of the seller adopting the "not disguise" strategy is x, and the probability of adopting the "disguise" strategy is $1-x$. Let the probability of the government adopting the "not supervise" strategy is y, and the probability of adopting the "supervise" strategy is $1-y$. Let the probability of the consumer adopting the "purchase" strategy is z, and the probability of adopting the "not purchase" strategy is $1-z$. According to the three-party evolutionary game profit matrix of the seller, the government and the consumer in Table 1, the expected return of the seller choosing the "not disguise" strategy and the "disguise" strategy are obtained as follows:

$$E_{RN} = yz[P_2(1-t) - C_1 + xL_1] + y(1-z)(-C_1 + xL_1) + (1-y)z[P_2(1-t) - C_1] - (1-y)(1-z)C_1 \quad (1)$$

$$E_{RY} = yz[P_1(1-t) - C_1 - C_2 - (1-x)L_2] + y(1-z)[-C_1 - C_2 - (1-x)L_2] + (1-y)z[P_1(1-t) - C_1 - C_2] + (1-y)(1-z)(-C_1 - C_2) \quad (2)$$

In the same way, the expected return of the government choosing the "supervise" strategy and the "not supervise" strategy are obtained as follows:

$$E_{GY} = xz(P_2 t - C_3 - xL_1) + x(1-z)(-C_3 - xL_1) + (1-x)z[P_1 t + (1-x)L_2 - C_3] + (1-x)(1-z)[(1-x)L_2 - C_3] \quad (3)$$

$$E_{GN} = xzP_2 t + (1-x)zP_1 t \quad (4)$$

In the same way, the expected return of the consumer choosing the "purchase" strategy and the "not purchase" strategy are obtained as follows:

$$E_{CY} = xy(V_2 - P_2) + x(1-y)(V_2 - P_2) + (1-x)y(V_2 - P_1 - V_3) + (1-x)(1-y)(V_2 - P_1 - V_3) \quad (5)$$

$$E_{CN} = (1-x)y(V_1 - V_2) + (1-x)(1-y)(V_1 - V_2) \quad (6)$$

According to evolutionary game theory, the replication dynamic equations of the seller, the government and the consumer are constructed, so as to analyze the strategy evolution process of the three game subjects. From equations (1) and (2), the replication dynamic equation of the seller choosing the "not disguise" strategy can be obtained as:

$$F(x) = \frac{dx}{dt} = x(1-x)(E_{RN} - E_{RY})$$

$$= x(1-x)\{z[P_2(1-t) - P_1(1-t)] + C_2 + xyL_1 + (1-x)yL_2\} \quad (7)$$

In the same way, from equations (3) and (4), the replication dynamic equation of the government choosing the "supervise" strategy can be obtained as:

$$F(y) = \frac{dy}{dt} = y(1-y)(E_{GY} - E_{GN})$$

$$= y(1-y)\{x(-C_3 - xL_1) + (1-x)[(1-x)L_2 - C_3]\} \quad (8)$$

In the same way, from equations (5) and (6), the replication dynamic equation of the consumer choosing the "purchase" strategy can be obtained as:

$$F(z) = \frac{dz}{dt} = z(1-z)(E_{CY} - E_{CN})$$

$$= z(1-z)[x(V_2 - P_2) + (1-x)(2V_2 - P_1 - V_1 - V_3)] \quad (9)$$

The replication dynamic equations composed of the seller, the government and the consumer can be obtained from equations (7)-(9) as:

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$$\begin{cases} F(x) = x(1-x)\{z[P_2(1-t) - P_1(1-t)] + C_2 + xyL_1 + (1-x)yL_2\} \\ F(y) = y(1-y)\{x(-C_3 - xL_1) + (1-x)[(1-x)L_2 - C_3]\} \\ F(z) = z(1-z)[x(V_2 - P_2) + (1-x)(2V_2 - P_1 - V_1 - V_3)] \end{cases}$$

3.3. Stability analysis

Since mixed-strategy Nash equilibria are neither asymptotically stable nor evolutionarily stable strategies, only the asymptotic stability of pure-strategy equilibria is considered in this study. The above replicated dynamic equations can describe the evolution process of the seller, the government and the consumer. According to the local stability principle proposed by Friedman, the stability of the equilibrium point can be obtained from the Jacobian matrix of the replicated dynamic equations. Let $F(x)$=$F(y)$=$F(z)$=0, get the local equilibrium point of system evolution. By replicating the dynamic equations, the Jacobian matrix of the system is calculated, and then the stability of each local equilibrium point is explored.

According to modern control theory, Lyapunov's first method can be used to describe the stability of dynamical systems. Lyapunov's first method determines the stability of the system by studying the distribution of the eigenvalues of the linearized state equation of the nonlinear system. When all the eigenvalues of the linearized state equation have negative real parts, the equilibrium state of the original nonlinear system is asymptotically stable. According to this principle, this paper calculates the eigenvalues of the Jacobian matrix at 8 pure strategy combinations, and then analyzes its asymptotic stability.

Table 2: Eigenvalues of Jacobian Matrix of Tripartite Evolutionary Game.

Combination	Eigenvalueλ_1	Eigenvalueλ_2	Eigenvalueλ_3
$P_1(1,1,1)$	$P_1(1-t) - P_2(1-t) - C_2 - L_1$	$C_3 + L_1$	$P_2 - V_2$
$P_2(1,1,0)$	$-C_2 - L_1$	$C_3 + L_1$	$V_2 - P_2$
$P_3(1,0,1)$	$P_1(1-t) - P_2(1-t) - C_2$	$-C_3 - L_1$	$P_2 - V_2$
$P_4(1,0,0)$	$-C_2$	$-C_3 - L_1$	$V_2 - P_2$
$P_5(0,1,1)$	$P_2(1-t) - P_1(1-t) + C_2 + L_2$	$C_3 - L_2$	$P_1+V_1+V_3 - 2V_2$
$P_6(0,1,0)$	$C_2 + L_2$	$C_3 - L_2$	$2V_2 - P_1 - V_1-V_3$
$P_7(0,0,1)$	$P_2(1-t) - P_1(1-t) + C_2$	$L_2 - C_3$	$P_1+V_1+V_3 - 2V_2$
$P_8(0,0,0)$	C_2	$L_2 - C_3$	$2V_2 - P_1 - V_1-V_3$

In the dynamic replication system of multi-agent evolutionary game, the evolutionary stable strategy is the asymptotically stable state, and the asymptotically stable state must be the evolutionary stable strategy. Based on the assumptions in this paper and the relevant data in Table 2, the positive and negative signs of the eigenvalues corresponding to different equilibrium points are judged, and the following propositions are obtained.

Proposition 1: When $P_2(1-t) - P_1(1-t) + C_2 > 0$, there is an asymptotically stable point $P_3(1,0,1)$, and the corresponding evolutionary stabilization strategy is (not disguise, not supervise, purchase).

Proposition 2: When $P_2(1-t) - P_1(1-t) + C_2 < 0 < P_2(1-t) - P_1(1-t) + C_2 + L_2$, if $L_2 < C_3$ and $P_1+V_1+V_3 < 2V_2$, there is an asymptotically stable point $P_7(0,0,1)$, and the corresponding evolutionary stabilization strategy is (disguise, not supervise, purchase).

Proposition 3: When $P_2(1-t) - P_1(1-t) + C_2 + L_2 < 0$, there are two situations:

(1) If $L_2 < C_3$ and $P_1+V_1+V_3 < 2V_2$, there is an asymptotically stable point $P_7(0,0,1)$, and the corresponding evolutionary stabilization strategy is (disguise, not supervise, purchase).

(2) If $L_2 > C_3$ and $P_1+V_1+V_3 < 2V_2$, there is an asymptotically stable point $P_5(0,1,1)$, and the corresponding evolutionary stabilization strategy is (disguise, supervise, purchase).

3.4. Evolution result analysis

The above three propositions give different equilibrium conditions for the evolutionary stable point of the seller. The following is an analysis of the stable state of the system for these conditions and an explanation in the sense of economic management.

When $P_2(1-t) - P_1(1-t) + C_2 > 0$, that is, the after-tax income that the seller chooses not to

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disguise is greater than the difference between the after-tax income that chooses disguise and the cost of disguise. The seller chooses not to disguise, the government chooses not to strictly supervise, and the consumer chooses to purchase. When the seller lacks remanufacturing technology and needs to pay more disguised costs for disguised remanufactured products, the additional income is more than the seller's gain. At this time, the seller chooses not to camouflage. Since the government's strict supervision requires a certain inspection cost and will also reward the seller, the high cost makes the government speculative. At this time, the government chooses not to strictly supervise. As consumers pay more attention to remanufactured products and increase their awareness of environmental protection, the consumer's willingness to purchase remanufactured products increases. Therefore, the consumer's willingness to purchase remanufactured products is greater than their own prices. At this time, the consumer chooses to purchase.

When $P_2(1-t)-P_1(1-t)+C_2<0, L_2<C_3$ and $P_1+V_1+V_3<2V_2$, that is, the after-tax income that the seller chooses not to disguise is less than the difference between the after-tax income that chooses disguise and the cost of disguise. The government punishment is less than the inspection cost. And the difference of the utility for purchase and the consumer's complaint is greater than the opportunity loss. The seller chooses to disguise, the government chooses not to strictly supervise, and the consumer chooses to purchase. With the advancement and development of science and technology, the cost of disguising a remanufactured product as a new product has been greatly reduced, thereby reducing the cost of the seller. When the cost of disguise is lower, it is more profitable for the seller to choose camouflage than not to camouflage. The government can charge a certain penalty to the seller who choose to disguise, but when the inspection cost of the government is greater than the penalty charged, and the income cannot cover the expenditure, at this time, the government chooses not to strictly supervise. Due to the improvement of the consumer's awareness of remanufactured products, the consumer's willingness to purchase remanufactured products increases, even exceeding the price of new products. Even if the seller purchases disguised products, the difference of the utility for purchase and the consumer's complaint is greater than the opportunity loss. At this time, the consumer chooses to purchase.

When $P_2(1-t)-P_1(1-t)+C_2+L_2<0,\ L_2>C_3$ and $P_1+V_1+V_3<2V_2$, that is, the after-tax income that the seller chooses not to disguise is less than the difference between the after-tax income that chooses disguise, the cost of disguise, and government punishment. The government punishment is greater than the inspection cost. And the difference of the utility for purchase and the consumer's complaint is greater than the opportunity loss. The seller chooses to disguise, the government chooses strict supervision, and the consumer chooses to purchase. When the government strictly supervises, the seller is given certain incentives to choose not to disguise. However, due to the existence of the price difference between remanufactured products and new products, the sum of the after-tax income of the seller who chooses not to disguise and the government incentives is still less than the profit of choosing disguise. When the government's inspection cost is less than the penalty charged, the government's strict supervision is profitable. Similarly, when the difference of the utility for purchase and complaint of the consumer's is greater than the opportunity loss. At this time, the consumer chooses to purchase.

4. Analysis of internal evolutionary game for the seller

4.1. Return matrix

Each seller is an individual with randomness and heterogeneity, so there is also an evolutionary game process of random pairing within the seller group. It is assumed that the remanufactured market consists of the seller R_1 and the seller R_2, and both the seller adopt two strategies of "not disguise" and "disguise". So the strategy set is {not disguise, disguise}, denoted as {S1, S2}. Based on the assumptions, a 2×2 symmetric return matrix of individual seller under the condition of the government supervision and the consumer purchasing is established, as shown in Table 3.

Table 3: The 2×2 symmetric return matrix of seller.

SellerR_1	SellerR_2	
	S1	S2
S1	$P_2(1-t)-C_1+xL_1$ $P_2(1-t)-C_1+xL_1$	$P_2(1-t)-C_1+xL_1$ $P_1(1-t)-C_1-C_2-(1-x)L_2$
S2	$P_1(1-t)-C_1-C_2-(1-x)L_2$ $P_2(1-t)-C_1+xL_1$	$P_1(1-t)-C_1-C_2-(1-x)L_2$ $P_1(1-t)-C_1-C_2-(1-x)L_2$

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4.2. Stability analysis

Let the probability of the seller adopting the "not disguise" strategy is x, and the probability of adopting the "disguise" strategy is 1-x. According to the Table 3, the expected return of the seller choosing the "not disguise" strategy and the "disguise" strategy are obtained as follows:

$$E_{R1} = x(P_2(1-t) - C_1 + xL_1) + (1-x)(P_2(1-t) - C_1 + xL_1) \tag{10}$$

$$E_{R2} = x(P_1(1-t) - C_1 - C_2 - (1-x)L_2) + (1-x)(P_1(1-t) - C_1 - C_2 - (1-x)L_2) \tag{11}$$

According to the Malthusian principle, the replication dynamic equation of the internal evolutionary game of the seller is constructed, so as to analyze the evolutionary stability strategy of the seller. From equations (10) and (11), the replication dynamic equation of the seller can be obtained as:

$$F(x) = \frac{dx}{dt} = x(1-x)(E_{R1} - E_{R2})$$

$$= x(1-x)[P_2(1-t) - P_1(1-t) + xL_1 + C_2 + (1-x)L_2]$$

Let $F(x) = 0$, three local stable points of the seller's internal evolutionary game are obtained, which are$x_1 = 0$、$x_2 = 1$ and $x_3 = \frac{P_2(1-t)-P_1(1-t)+C_2+L_2}{L_2-L_1}$(if and only if $0 \le x_3 \le 1$).

According to the stability principle of differential equations, when $\frac{dF(x^*)}{dx^*} < 0$ is satisfied, the obtained x^* is the evolutionary stable point of the system. Taking the derivative of the system replication dynamic equation $F(x)$ with respect to x, the following equation is obtained.

$$\frac{dF(x)}{dx} = (1-2x)[P_2(1-t) - P_1(1-\beta) + C_2 + xL_1 + (1-x)L_2] + x(1-x)(L_1 - L_2)$$

In order to facilitate subsequent calculations, let $A = P_2(1-t) - P_1(1-t) + C_2 + L_2$, $B = P_2(1-t) - P_1(1-t) + C_2 + L_1$, thus the equilibrium condition of the system evolutionary stability strategy can be obtained.

Proposition 4: (1) When $A < 0$ and $B < 0$, the evolutionary stable point of the system is x_1.

(2) When $A < 0$ and $B > 0$, the evolutionary stable points of the system are x_1 and x_2.

(3) When $A > 0$ and $B > 0$, the evolutionary stable point of the system is x_2.

(4) When $A > 0$ and $B < 0$, the evolutionary stable point of the system is x_3.

4.3. Evolution result analysis

Proposition 4 gives the different equilibrium conditions of the evolutionary stable point of the seller. The following is an analysis of the stable state of the system for these conditions and an explanation in the sense of economic management.

When $A < 0$, that is, the after-tax income of the seller choosing not to disguise is less than the difference between the after-tax income that chooses disguise, the cost of disguise, and government punishment, $x_1 = 0$ is the stable point of the system evolution. At this time, although the seller disguised and sold remanufactured products need to face the government punishment. With the advancement of production technology, the seller develops new technologies to reduce their disguising costs. When the seller is profitable, the "disguise" strategy is the seller's evolutionary stable strategy.

When $B > 0$, that is, the sum of the disguised after-tax income and government incentives is greater than the difference between the after-tax income that chooses disguise and the cost of disguise, $x_2 = 1$ is the stable point of the system evolution. At this time, if the seller chooses not to disguise, he can obtain additional government incentives for the seller's remanufacturing, so that the seller's income from selling remanufactured products will increase. At the same time, for some areas where remanufacturing technology is lacking, the cost of disguise for the seller increases greatly. When the high cost of disguise and selling remanufactured products outweighs the gains, the "not disguise" strategy is the seller's evolutionary stable strategy.

When $A > 0$ and $B < 0$, that is, the after-tax income when the seller chooses not to disguise is greater than the difference between the after-tax income that chooses disguise, the cost of disguise, and government punishment, and the sum of the disguised after-tax income and government incentives is less than the difference between the after-tax income that chooses disguise and the cost of disguise, x_3 is the stable point of the system evolution. At this time, the seller will sell the disguised product with the

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probability of x_3 or not sell the disguised product with the probability of $1 - x_3$. It depends on the government's reward and punishment. When one seller chooses to disguise, the other seller finds that disguised sales of remanufactured products will face government penalties. So they choose not to disguise. And one seller chooses not to disguise, the other seller finds that despite disguised products face government penalties. When the government incentives are too low, the seller can still make profits by sell disguised products. So they choose to disguise.

Comparing Proposition 1 and Proposition 4(3), it can be seen that when the condition that the seller sells remanufactured products becomes an evolutionary stable strategy, the seller's external game needs to satisfy that the after-tax income that the seller chooses not to disguise is greater than the difference between the after-tax income that chooses disguise and the cost of disguise. And the internal game of the seller only needs to satisfy after-tax income of the seller choosing not to disguise and the government reward is greater than the difference between the after-tax income of choosing disguise and the cost of disguise.

Corollary 1: Comparing the seller's external game with the internal game, the seller's external game meeting the condition of choosing not to disguise to be an evolutionary stable strategy is more stringent than the seller's internal game.

Corollary 1 shows that the seller's internal game proposal is based on strict government supervision and consumer purchase, the external environment is relatively stable, and the income situation can be imagined. When the seller plays external games, it is necessary to consider the uncertain role played by the government in the game. If the "not disguise" strategy is to become a long-term evolutionary strategy, it must be ensured that the seller choose not to disguise to be more deterministic income than to choose disguise.

Comparing Proposition 3(2) and Proposition 4(1), it can be seen that when the condition that the seller disguise remanufactured products become an evolutionary stable strategy, the seller's external game needs to satisfy that the after-tax income that the seller chooses not to disguise is less than the after-tax income that chooses to disguise, the cost of disguise, and government punishment. And the internal game of the seller needs to satisfy that the after-tax income of the seller choosing not to disguise is smaller than the difference between the after-tax income that chooses disguise, the cost of disguise, and government punishment that choose to disguise.

Corollary 2: Comparing the seller's external game with the internal game, the seller's external game meeting the conditions of choosing to disguise to be an evolutionary stable strategy is the same to the seller's internal game.

5. Conclusions

Our study uses evolutionary game theory to analyze the problem of the seller's remanufactured price deception. Firstly, by establishing the external and internal evolutionary game models of the distributors, the influence of the government, the consumer and the competitor in the same industry on the distributors' strategic choices is analyzed. Then, the evolutionary game model is solved, and the external and internal evolutionary stable states of the seller under different conditions are obtained. And further explanations in the sense of economic management are made. Finally, the influence of external environment and internal environment on the seller is compared and analyzed, and the following conclusions are drawn:

(1) In the external evolution process of the seller, the government and the consumer, the behavior decisions of the three restrict each other, and it is difficult to reach a stable state in which the seller do not disguise, the government is strictly supervised, and the consumer purchases. When the after-tax income that the seller chooses not to disguise is greater than the difference between the after-tax income that chooses disguise and the cost of disguise. The seller does not disguise, the government does not strictly supervise, and the consumer purchases, and the market achieves effective allocation. If the government wants to promote the development of the remanufactured market to an efficient state, it must sacrifice its own interests. When the government is not functioning, disincentives for the seller to disguise products require raising the cost of disguise.

(2) In the process of internal evolution of the seller and competitors in the same industry, it is easy to produce mutual influence. In order to prevent the seller from choosing to disguise, the government needs to intervene financially on the seller, and the government can increase incentives and penalties to encourage the seller to choose not to disguise.

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(3) The comparative study found that in the early stage of the development of the remanufactured market, the government's regulatory measures were particularly important. The government's measures are an important factor affecting the behavior of the seller and the consumer. Therefore, the government needs to regulate the remanufactured market through financial means, increase incentives and penalties, and promote the development of the market to an efficient state.

Of course, our paper still has some deficiencies. Firstly, the model is based on expected utility theory and lacks consideration of the psychological factors of the game subject. Secondly, there is no empirical analysis for specific cases, which makes the theory lack practical support. The above aspects can be improved in the future. We hope you find the information in this template useful in the preparation of your manuscript.

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