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PAPER

Research on the Incentive Model of Express Packaging Recycling Based on the Three-Party Game Model

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ABSTRACT

Reverse logistics, a new logistics model with the advantages of resource conservation and environmental protection, has emerged in response to the strong negative externalities of traditional logistics. However, in a fully competitive market environment, enterprises generally do not actively implement reverse logistics based on their own profitability and competitiveness considerations. In order to explore the impact of various factors on the implementation of reverse logistics by enterprises, an incentive model based on the three-party game model for express packaging recycling is constructed from the perspective of the participating subjects in the process of reverse logistics. This is a three-party evolutionary game model that includes the government, express packaging recycling enterprises, and consumers, then analyzes the stability of strategic choices and equilibrium points of the game system of the three-party subjects in the implementation of the reverse logistics. The results show that when the incentives from the central government can fully cover the cost of the local government's choice of active regulation strategy, it will lead the system to stabilize at the strategy combination of implementing reverse logistics, actively regulating, and participating in reverse logistics.

KEYWORDS

reverse logistics, government subsidies, express packaging recycling, three-way game, incentive mechanism

1 INTRODUCTION

Game theory as an analytical tool is widely used in various fields; in recent years, there have been many domestic scholars based on evolutionary game theory, quantitative research on express packaging greening, and recycling issues. To improve the enthusiasm of enterprises and consumers to participate in recycling, it is necessary to increase the revenue of the two sides to participate in recycling and reduce the cost of participation [1]. By constructing two game models of the government and express packaging suppliers, e-commerce recycling enterprises, and consumers, it is concluded that both government subsidies and fines affect the

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behavior of the government and express packaging suppliers, and the benefits and costs of e-commerce recycling enterprises and consumers under different strategies are important factors affecting their behaviors [2]. The two sides can get the maximum benefit only by cooperation; then the recycling enterprise is treated as a whole, and the gaming behaviors of the government, the enterprise, and the consumers are explored, and it is concluded that active participation of all three sides can form the benign ecosystem of the closed loop. [3] Taking regional green competitiveness as the topic, we define five actors: government, enterprises, social media, green organizations, and consumers; construct the evolutionary game model among the actors; and use numerical simulation to explore the specific influence of many factors on the actors [4]. Through the construction of the game model between the government, e-commerce enterprises, and consumers, it is concluded that in the early stage of industrial development, the government gives certain subsidies and incentives to enterprises and consumers in order to promote the recovery of express packaging, and at the same time, the financial subsidies should be moderately regulated [5]. Through the simulation analysis of the tripartite game between government, industry, and academia, it is concluded that the government entrusts the universities to carry out innovative R&D investment to reach a certain critical value to promote enterprises to carry out green innovation [6]. The three-party game of government, industry, and academia is analyzed from a stakeholder's perspective. The results show that government propaganda, innovation incentives, and pollution taxes can promote enterprises to carry out green technological innovation [7].

From the recycling logistics cost-benefit level, foreign scholars mainly analyze the development strategy and logistics to create value in two aspects. Among them, in the study, the retailer recycling incentive policy coordination feedback mechanism is introduced specifically, and the corresponding Pareto optimal game decision is proposed [8]. In the context of e-commerce return recovery policy, a profit maximization model is constructed to analyze the cost of recovery logistics and the revenue trade-off [9]. Focusing on the relationship between the cost of recycling logistics and the return policy, it is shown that companies can use recycling logistics to achieve the effect of expanding profit margins [10]. The relationship between the cost of recycling logistics and return policies is analyzed. Based on the analysis of the cost-sharing framework for recycling packaging waste, the analysis of the German Green Dot program is highlighted, with a comparative analysis of the cost components of each recycling leader [11]. The best solution for manufacturers should be based on the mixed recycling model between manufacturers and retailers [12]. On the basis of the choice of recycling channels by manufacturers in a two-level closed-loop supply chain, it is pointed out that manufacturers mostly outsource the recycling of waste products to retailers and others if they perform better in terms of outsourcing [13]. In the implementation of the reverse logistics recycling process, although the government has introduced relevant policies and regulations to promote the recycling of express packaging, some logistics companies have also begun to try to set up express packaging recycling points, but due to the lack of a standardized recycling system and improved incentive mechanism, the recycling effect of express packaging is not ideal [14]. When the courier enterprise recycles, as the reuse rate of the courier packaging increases, the profits of all parties in the supply chain show a trend of decreasing and then increasing, and the government subsidizes the recycling in the early stage of recycling, which will enhance the enthusiasm of the enterprise to recycle [15]. The profit of e-commerce enterprises under government subsidy is the largest when the government subsidy coefficient meets certain conditions [16]. The government's rewards and punishments, incentive costs, and the size of benefits are the key factors affecting the strategy choices of the three main players of the game. Meanwhile, the participation ratio of recyclers and consumers has a significant effect on the government's behavioral choice [17].

Through the reading and combing of domestic and foreign literature, it was found that scholars at home and abroad for the express packaging recycling research are relatively rich; most scholars are involved in the process of express packaging recycling involved in the main body of the study, but the greening of express packaging can not only solve the recycling of the realization but also the entire industrial chain to participate in the whole industry chain, from the source of the quantitative reduction, the subsequent recovery and recycling, and re-use to promote the greening of the transformation of express packaging. The greening of courier packaging cannot be realized only by solving the recycling. Based on this, this paper is based on the principles of source reduction and recycling, reuse, and other principles to build a tripartite game model, that is, the government, courier packaging recycling enterprises, and consumers between the three game models, to explore how to promote the cooperation of the three parties and jointly promote the implementation of the reverse logistics of courier packaging recovery.

2 MODEL CONSTRUCTION

2.1 Description of the problem

Under the express packaging recycling system, its corresponding actors mainly include the government, express packaging recycling enterprises, consumers, and so on. But the current express packaging reverse logistics in the implementation of the cooperation process of the three parties has a conflict of interest. On the one hand, the government, as a national policy implementer, controls the overall situation from the macro level in the express packaging recycling action to pay more attention to social benefits, the pursuit of social welfare maximization, and therefore will formulate a variety of policies requiring the implementation of express packaging recycling enterprises reverse logistics and giving a certain number of subsidies to incentives. On the other hand, most express packaging recycling enterprises need to pay a large number of costs to implement reverse logistics in which they have interests in the game and other issues, resulting in the implementation of express packaging recycling enterprises reverse logistics enthusiasm not being strong. So that it is contrary to the government's pursuit of the concept of coordinated development of ecological and economic.

In reverse logistics, the consumer becomes the source of the logistics terminal. Accordingly, in reverse logistics, if consumers fail to participate in it, it is difficult to ensure that reverse logistics can achieve the established effect. Consumers are also the direct users of express packaging. Since the conflict of interest between the three parties is clear, the following evolutionary game theory is used to construct a game model between the government, express packaging recycling enterprises, and consumers; analyze the factors affecting the behavior of the three parties; and explore how to promote the feasibility of reverse logistics recovery in express packaging. The three strategies affect each other and are limited rationality, the parties' strategy in dynamic change, in order to maximize their own interests, constantly adjusting the strategy, and ultimately the three-party strategy tends to stabilize to achieve game equilibrium. The logical relationship between the three parties' evolutionary game subjects is shown in Figure 1.

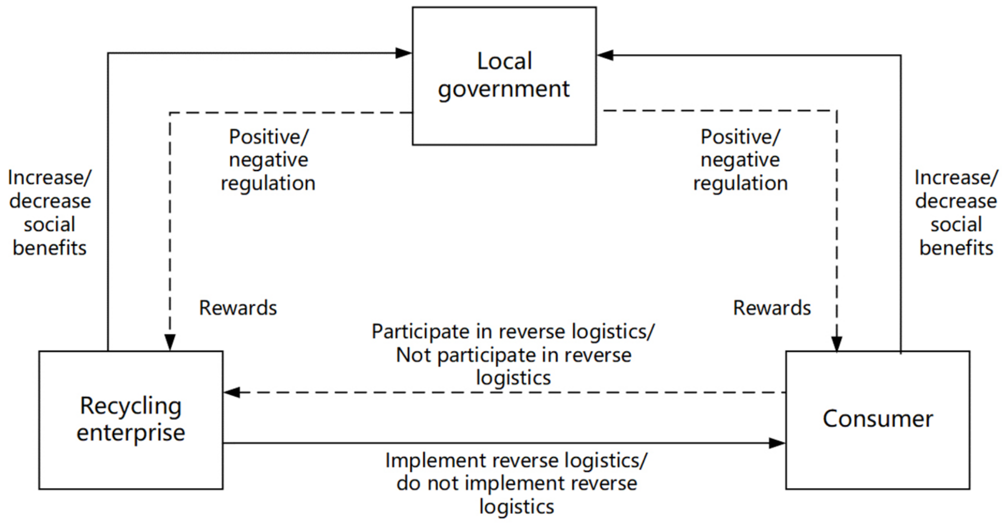

Fig. 1. Logic of the three-party evolutionary game model

Model assumptions. Assumption 1: All three parties have two strategies to choose from. The probability that the express packaging recycling enterprise chooses to implement reverse logistics is $x(0 \leq x \leq 1)$, and the probability that it does not implement reverse logistics is $(1 - x)$. The probability that the local government chooses to actively regulate is $y(0 \leq y \leq 1)$, and the probability of negative regulation is $(1 - y)$. The probability that a consumer chooses to participate in reverse logistics is $z(0 \leq z \leq 1)$ and the probability of not participating in reverse logistics is $(1 - z)$.

Hypothesis 2: If express packaging recycling enterprises choose to implement reverse logistics, you need to invest in a variety of higher costs and set the implementation cost of C_p. local governments choose active regulatory strategy means that the implementation of reverse logistics enterprises to carry out strict supervision and set the new regulatory cost of C_g; consumers who choose to participate in reverse logistics will be more than not involved in reverse logistics to pay a higher cost, set the increase in the cost of C_b.

Assumption 3: The local government that chooses to actively regulate will give certain incentives to express packaging recycling enterprises and consumers that are willing to participate in the implementation of reverse logistics, so the total amount of incremental incentives is set to be R. Among them, the incremental incentive coefficient of express packaging recycling enterprises is λ, and the incremental incentive coefficient of consumers is $1 - \lambda$.

Scenario 4: The incremental operating gains brought by express packaging recycling enterprises choosing to implement reverse logistics depend on the cost of government overpayment, so it is set to $\alpha C_b(0 < \alpha < 1)$. The local government obtains the benefits of two types of scenarios: First, if the express packaging recycling enterprises choose to implement reverse logistics, the influence of the regional public to enhance the acquisition of the incremental social benefits of B_g; Second, the local government to adopt a proactive regulatory strategy will receive the central government's incentives for A. To ensure that the incentives are effective, the incentives A should be at least covered by the local government to actively regulate the cost of regulatory costs and bear the public investment cost minimization ($A > C_g$). The incremental utility that consumers involved in the implementation of reverse logistics will receive is B_a.

Scenario 5: Market transaction gains and losses. When the greening products can better meet the market demand, the two sides reach a deal, and the transaction cost is low, the synergistic gain obtained by each side is I. On the contrary, the synergistic gain of the market transaction is lost, the courier packaging recycling enterprise will face the dilemma of stagnant sales of the products, and the development of the regional economy will be negatively impacted, so let the loss of the local government be for the L_g, the courier packaging recycling enterprise's losses are L_p. In addition, the rise of national environmental awareness and the universality of consumer goods determine the local and city purchase is the choice of the vast majority of consumers, so assume that $0 < B_a - C_b < I$.

Benefits matrix. Based on the above modeling assumptions, the return matrix of the model is obtained as follows: Table 1 is shown.

Table 1. Matrix of returns

		Local Government	Consumers	
			Participation in Reverse Logistics (z)	Not Involved in Reverse Logistics ($1 - z$)
Express packaging recycling enterprises	Implementation of the reverse Logistics (x)	Active supervision (y)	$\alpha C_b + \lambda R - C_p + I$	$\lambda R - C_p - L_p$
			$B_a + A - R - C_g$	$B_a + A - \lambda R - C_g - L_g$
			$B_a + (1 - \lambda)R - C_b + I$	0
		Negative regulation ($1 - y$)	$\alpha C_b - C_p + I$	$-C_p - L_p$
			B_g	$B_g - L_g$
			$B_a - C_b + I$	0
	Non-implementation of reverse Logistics ($1 - x$)	Active supervision (y)	$-L_p$	I
			$A - L_g - C_g$	$A - C_g$
			$-C_b + B_a$	I
		Negative regulation ($1 - y$)	$-L_p$	I
			$-L_p$	0
			$-C_b + B_a$	I

2.2 Model analysis

Analysis of evolutionary stabilization strategies

1. Replicated dynamic equations for strategy choice of express packaging recycling firms

   The expected return from implementing reverse logistics is E_{11}, the expected return from not implementing reverse logistics is E_{10}, and the average expected return is E_1.

$$E_{11} = yz[(\alpha C_b + \lambda R - C_p + I)] + y(1 - z)[\lambda R - C_p - L_p] + (1 - y)\, z(\alpha C_b - C_p + I) + (1 - y)(1 - z) - C_p - L_p$$

$$E_{10} = yz(-L_p) + y(1 - z)\, I + (1 - y)\, z(-L_p) + (1 - y)(1 - z)I$$

$$E_1 = xE_{11} + (1 - x)E_{10}$$

The replication dynamic equation for the strategy choice of express packaging recycling firms is:

$$F(x) = dx/dt = x(E_{11} - E_1) = x(1 - x)[-(C_p + L_p + I) + y\lambda R + z(\alpha C_b + 2I + 2L_p)]$$

2. Replicated dynamic equations for local government strategy choice

The expected return for local governments choosing positive regulation is E_{21}, the expected return for negative regulation is E_{20}, and the average expected return is E_2.

$$E_{21} = xz(B_g + A - R - C_g) + x(1 - z)[B_g + A - \lambda R - C_g - L_g] \\ + (1 - x)\, z(A - L_g - C_g) + (1 - x)(1 - z)(A - C_g)$$

$$E_{20} = xzB_g + x(1 - z)(B_g - L_g) + (1 - x)z(-L_g)$$

$$E_2 = yE_{21} + (1 - y)E_{20}$$

The replication dynamic equation for local government strategy choice is:

$$F(y) = dy/dt = y(E_{21} - E_2) = y(1 - y)[A - C_g - \lambda Rx + xz(\lambda R - R)]$$

3. A replicated dynamic equation for consumer strategy choice

Let the expected return for consumers choosing to participate in reverse logistics be E_{31}, the expected return for not participating in reverse logistics be E_{30}, and the average expected return be E_3.

$$E_{31} = xy[(1 - \lambda)R - C_b + B_a + I] + x(1 - y)[-C_b + B_a + I] \\ + (1 - x)\, y(-C_b + B_a) + (1 - x)(1 - y)(-C_b + B_a)$$

$$E_{30} = (1 - x)yI + (1 - x)(1 - y)I$$

$$E_3 = zE_{31} + (1 - z)E_{30}$$

The replication dynamic equation for consumer strategy choice is:

$$F(z) = dz/dt = z(E_{31} - E_3) = z(1 - z)[-C_b + B_a - I + (1 - \lambda)Ryx + 2Ix]$$

Evolutionary game equilibrium analysis. A three-way subject strategy stability equation:

$$F(x) = dx/dt = x(1 - 2x)[-(C_p + L_p + I) + y\lambda R + z(\alpha C_b + 2I + 2L_p)]\ F(y) = dy/dt \\ = y(1 - 2y)[A - C_g - \lambda Rx + xz(\lambda R - R)]\ F(z) = dz/dt \\ = z(1 - 2z)[-C_b - B_a - I + (1 - \lambda)Ryx + 2Ix]$$

On the basis of the stability analysis of the individual subject's strategy, the stability of the equilibrium point of the three-party subject's evolutionary game system is further analyzed, and the equilibrium point of the system can be obtained from $F(x) = 0$, $F(y) = 0$ and $F(z) = 0$. Since the asymmetric game requires that the evolutionary stabilization strategy must be a strict Nash equilibrium, this paper only needs to discuss the stability of the eight pure strategy equilibrium points of $E_1(0, 0, 0)$, $E_2(1, 0, 0)$, $E_3(0, 1, 0)$, $E_4(0, 0, 1)$, $E_5(1, 1, 0)$, $E_6(1, 0, 1)$, $E_7(0, 1, 1)$, $E_8(1, 1, 1)$. It can be obtained by calculating the Jacobian matrix of the three-subject evolutionary game system:

Among them:

$J = [a_{11}\ a_{12}\ a_{13}\ a_{21}\ a_{22}\ a_{23}\ a_{31}\ a_{32}\ a_{33}]$ *MACROBUTTON MTPlaceRef \ * MERGEFORMAT SEQ MTEqn \h \ * MERGEFORMAT (SEQ MTSec \c * Arabic \ * MERGEFORMAT 1. SEQ MTEqn \c * Arabic * MERGEFORMAT 14)*

$$a_{11} = (1 - 2x)[-(C_p + L_p + \mathrm{I}) + \beta\lambda R + z(\alpha C_b + 2I + 2L_p)].$$

$$a_{12} = x(1 - x)\lambda R,\ a_{13} = x(1 - x)(\lambda C_b + 2I + 2L_p).$$

$$a_{21} = \beta(1 - \beta)[-\lambda R + z(\lambda R - R)],\ a_{22} = (1 - 2\beta)[A - C_g - \lambda Rx + xz(\lambda R - R)].$$

$$a_{23} = \beta(1 - \beta)[(\lambda R - R)x],\ a_{31} = z(1 - z)[(1 - \lambda])R\beta + 2I].$$

$$a_{32} = z(1 - z)(1 - \lambda)Rx,\ a_{33} = (1 - 2z)[-C_b + B_a - I + 1 - \lambda R\beta x + 2Ix].$$

In order to analyze the stability of the equilibrium point, the Routh-Hurwitz criterion is used. If all three eigenvalues are negative, then it is an evolutionary stabilization strategy; if there are three eigenvalues with a positive number, then it is an unstable point. Calculating the eigenvalues of the matrix (1.14) at each equilibrium point yields the evolutionary stabilization strategy of the replicated dynamic system, as Table 2 shows.

Table 2. Evolutionary stabilization strategies for replicated dynamical systems

Balance Point	Jacobian Matrix Eigenvalues		Stability Conclusions	Prerequisite
	$\lambda_1, \lambda_2, \lambda_3$	Real Symbol		
$E_1(0, 0, 0)$	$B_a - C_p - I, A - C_g, -C_p - L_p - I$	(–, +, –)	Point of instability	/
$E_2(1, 0, 0)$	$B_a - C_p - I, A - C_g - \lambda R, C_p + L_p + I$	(–, *, +)	point of instability (math.)	/
$E_3(0, 1, 0)$	$B_a - C_p - I, C_g - A, -L_p - I - C_p - \lambda R$	(–, –, –)	ESS	/
$E_4(0, 0, 1)$	$A - C_g, C_b - B_a + R, L_p - C_p + R + \alpha C_b$	(+, +, *)	point of instability (math.)	/
$E_5(1, 1, 0)$	$C_g - A + \lambda R, 1 - \lambda R - C_b + B_a + I, C_p + L_p + I - \lambda R$	(*, +, *)	point of instability (math.)	/
$E_6(1, 0, 1)$	$C_b - B_a + 3I, A - C_g - R, C_p - L_p - I - \alpha C_b$	(+, +, –)	point of instability (math.)	/
$E_7(0, 1, 1)$	$C_g - A, C_b - B_a + I, L_p - C_p + I + \alpha C_b + \lambda R$	(–, +, *)	point of instability (math.)	/
$E_8(1, 1, 1)$	$C_g - A + R, C_b - B_a - 1 - \lambda R + 3I, C_p - L_p - I + \alpha C_b - \lambda R$	(*, *, *)	ESS	a

Notes: *Represents the positive or negative sign of the real part of the eigenvalue that cannot be determined and denotes the condition that can make the model stable at the equilibrium point $E_8(1, 1, 1)$. We can find a sufficient condition that makes the model (1.13) asymptotically stable at the point $E_8(1, 1, 1)$, and the three parties are willing to jointly participate in the reverse logistics implementation.

$$A - C_g - R > 0,\ (B_a - C_b - C_p + 2I + L_p + R + C_b\alpha) > 0,$$
$$B_a - C_b + I + R - R\lambda C_p - I - L_p - C_b\alpha - R\lambda) < 0$$

In addition, the characteristic equation of model (1.13) at $E_8(1, 1, 1)$ can be derived as:

$$(A - C_g - R + x)(x_2 + x(B_a - C_b - C_p + 2I + L_p + R + C_b\alpha)$$
$$- (B_a - C_b + I + R - R\lambda)(C_p - I - L_p - C_b\alpha - R\lambda)) = 0$$

Equation (1.16) has one root $x_1 = C_g - A + R$. Further from the relationship between roots and coefficients of a quadratic equation, all eigenvalues of equation (1.16) are negative when condition (1.15) holds, so the model is asymptotically stabilized at point $E_8(1, 1, 1)$.

Inference. Based on the results of the evolutionary stabilization strategy, the possible equilibria are analyzed to obtain Corollary 1 and Corollary 2, respectively.

Corollary 1: According to the model assumption, under the premise of no additional conditions, there is a stable point $E_3(0, 1, 0)$ in the replicated dynamic system, so the incentive from the central government can motivate the local government to choose the positive regulatory strategy to a certain extent. However, when local government funds are insufficient to create incentives for express packaging recycling enterprises and consumers, it will not be able to effectively incentivize the three parties to jointly participate in the implementation of reverse logistics.

Corollary 2: By calculating the eigenvalues, it is necessary to add the stabilization condition so that $E_8(1, 1, 1)$ becomes the asymptotic stabilization point of the system. When the incentive from the central government can fully cover the cost of supervision and bonus costs of the local government to choose active regulatory strategies, the local government has less financial pressure to choose active regulatory strategies and can mobilize express packaging recycling enterprises and consumers to participate in the implementation of reverse logistics through bonuses.

3 CONCLUSIONS AND RECOMMENDATIONS

Based on the practical background of reverse logistics implementation, the three-party evolutionary game model is constructed to systematically analyze the strategy choices of the three parties and the equilibrium point of the game system. The results show that there are two evolutionary stable strategy combinations in the three-party evolutionary game system: <implement reverse logistics, actively supervise, and participate in reverse logistics> and <don’t implement reverse logistics, actively supervise, and don’t participate in reverse logistics>. Based on the maximization of their own interests, the three-party subjects are affected by information asymmetry, and there will be an equilibrium point in the game of interests in the implementation of reverse logistics in the process of courier packaging recycling. Therefore, in order to ensure the better development of enterprise reverse logistics activities, the need for government to establish a perfect incentive system, so that enterprises from their own interests can implement reverse logistics, thus helping consumers consciously participate in the implementation of reverse logistics action.

Based on the above conclusions, the following suggestions are given: First, the central government should increase the number of incentives for local governments to adopt positive regulatory strategies, reduce the financial pressure on local governments to participate in the implementation of reverse logistics, and local governments should play a correct guiding role in the implementation of reverse logistics. Secondly, express packaging recycling enterprises should operate scientifically, take the initiative to assume social responsibility, balance social responsibility and economic interests, and give full play to the role of supporting and leading the upgrading of consumption in the implementation of reverse logistics. Establish a good image of the enterprise, cultivate, and consolidate consumer inertia to participate in reverse logistics. Fourth, from the consumer level, through school education and moral education, consumers should understand the importance of recycling activities to protect the environment and conserve resources, play a demonstration role, and motivate others to really contribute to green logistics. Even in the future, when the reward and punishment mechanism is withdrawn, consumers will still be able to complete the recycling on their own initiative, realizing spontaneous recycling for all.

4 DECLARATIONS

4.1 Competing interests

The authors declare no competing interests.

4.2 Author contribution

All authors contributed to the conception and design of the study. The literature inquiry, modeling analysis, and article proofreading were carried out by Qiu Jianwei, Pang Wenbin, and Yang Shanshan, respectively. The first draft of the manuscript was written by Pang Wenbin, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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