

Evolutionary Game Analysis between Government and E-Commerce Enterprises in the Recovery of Express Packages

Ying-Dong JI^{1,a}, Pei-Qin YANG^{2,b,*}

^{1,2}School of Management Science and Engineering, Shanxi University of Finance and Economics, Taiyuan, Shanxi, China, 030006

^a13934564176@126.com, ^b1789124298@qq.com

*Corresponding author

Keywords: Express Package, Recycling, Evolutionary Game

Abstract. In recent years, the boom in online shopping has led to a sharp increase in the volume of express delivery, which in turn has led to problems such as excessive packaging of express packaging, great consumption of resources, and environmental pollution. Based on the evolutionary game analysis method, this paper first establishes the payment matrix of the government and the e-commerce enterprises, and constructs the replication dynamic equations of both sides of the game. Then, according to the Jacobian matrix, the strategy choices of each player in different situations are obtained. The conclusions of the study can provide some theoretical references and references for the government and e-commerce enterprises in the recycling of express packaging.

Introduction

In recent years, the boom in online shopping has led to a sharp increase in the volume of express delivery. Online shopping is favored by consumers because of its low price, wide variety of products, and convenient online transactions. Data from the state post bureau in 2017 showed that the national express delivery business volume reached 1.06 billion pieces in 2006, and reached 31.3 billion pieces in 2016, with a 30-fold increase in 10 years. In 2012, China's online retail sales amounted to only 1.3 trillion Yuan, by 2016, the number soared to 5.2 trillion Yuan, and China became the world's largest online retailer [1]. However, behind the rapid development of the express delivery industry, it is followed by the difficulty of recycling packaging materials. From the current situation, the recycling rate of recycling packaging materials is very low. Therefore, how to effectively recycle express packaging is of great practical significance.

Foreign scholars' discussion on the construction of reverse logistics system is mostly focused on the game relationship between enterprises and enterprises [2-3]. There are relatively few studies on the game between government and enterprises. However, many literatures have recognized the important role played by the government in promoting the construction of reverse logistics systems [4-5]. In recent years, many scholars in China have also conducted more research on the recycling of express packaging in reverse logistics. Zhang Yingchuan (2016) analyzed the development status of green packaging in China's express delivery industry, the reasons for the resistance and the development trend, emphasizing that packaging "burden reduction" is an important direction for the future development of green packaging in China's express delivery industry [6]. Chen Yifei, Zou Fangfang (2017) combed the problems of China's express packaging and the corresponding solutions [7]. Zheng Zhanzhi, Guan Jie et al. (2018) used structural equation modeling to explore the factors affecting the recycling of express packaging, through empirical analysis, it was concluded that recycling awareness, recycling convenience, and recycling facility experience all positively affected recycling efficiency [8]. Li Ping (2017) pointed out that logistics enterprises are the direct promoters of express packaging recycling by establishing a dynamic game model of e-commerce platform, logistics enterprises and consumers [9]. Most of the existing researches are analyzed from a static perspective, and there is no further research on the use of dynamic evolutionary game methods to analyze the recycling of express packaging. Therefore, based on the evolutionary game analysis method, this paper constructs the game model of the government and

e-commerce enterprises, and obtains the strategy choices of each player in different situations, in order to provide some theoretical references and references for the government and e-commerce enterprises in the recycling of express packaging.

Model Construction

Hypothesis 1: There are only two participants in the game, the government and the e-commerce enterprises. For the recycling of express packaging, the government's strategic space is {"supervision", "no supervision"} = $\{A_1, A_2\}$, strategic space of e-commerce enterprises is {"recycling", "no recycling"} = $\{B_1, B_2\}$.

Hypothesis 2: Variables affecting government decision-making include: in order to encourage e-commerce enterprises to implement green logistics, the government will subsidize e-commerce enterprises, as S , when the government chooses to supervise, it will pay a certain supervision cost, as C_0 . Under the supervision of the government, if e-commerce enterprises choose to recycle the packaging, it will benefit the whole society, so the government will get a certain amount of revenue, which will be recorded as R_0 , at the same time, reward the recycled enterprises, which will be recorded as R_1 ; if e-commerce enterprises choose not to recycle the packaging, the government will impose a certain fine on enterprises, which will be recorded as P . Under the condition that the government does not supervise, the social harm caused by e-commerce enterprises choosing not to recycle packaging is borne by the government, and the cost to be paid is recorded as C_1 .

Hypothesis 3: The variables that affect the decision-making of e-commerce companies include that if e-commerce enterprises recycle the packaging, the recovery cost required is recorded as C_2 , and the government will reward R_1 . If they choose not to recycle, they will be punished by the government, as P .

Hypothesis 4: The probability that the government chooses "supervision" is x , the probability of "unsupervised" is $1-x$; the probability that e-commerce companies choose "recycling" is y , and the probability of "no recycling" is $1-y$, and $0 \leq x, y \leq 1$.

According to the above assumptions, the payment matrix of the game between the government and the e-commerce enterprises is shown in Table 1 (where the first element represents the government's revenue and the second element represents the revenue of the e-commerce enterprises).

Table 1, Payment matrix between government and e-commerce enterprises

		e-commerce enterprises	
		recycling	no recycling
government	supervision	$(R_0 - S - R_1 - C_0, S + R_1 - C_2)$	$(P - C_0 - S - C_1, S - P)$
	no supervision	$(R_0 - S, S - C_2)$	$(-S - C_1, S)$

Evolutionary Game Analysis of Express Packaging Recycling

Stability Analysis of the Game

From Hypothesis 4 and Table 1, the expected revenue of the government's choice of "supervision" is:

$$U_x = y(R_0 - S - R_1 - C_0) + (1-y)(P - C_0 - S - C_1) = y(R_0 - R_1 - P + C_1) + (P - C_0 - S - C_1). \quad (1)$$

The expected revenue of the government's choice of "no supervision" is:

$$U_{1-x} = y(R_0 - S) + (1-y)(-S - C_1) = y(R_0 + C_1) - (S + C_1). \quad (2)$$

The average revenue of the government is:

$$\overline{U}_1 = xU_x + (1-x)U_{1-x} = -xy(R_1 + P) + x(P - C_0) + y(R_0 + C_1) - (S + C_1). \quad (3)$$

The replication dynamic equation of government is constructed as follow:

$$\frac{dx}{dt} = x(U_x - \overline{U}_1) = x(1-x)[(P - C_0) - y(R_1 + P)]. \quad (4)$$

Similarly, the replication dynamic equation of e-commerce companies is:

$$\frac{dy}{dt} = y(U_y - \overline{U}_2) = y(1-y)[x(R_1 + P) - C_2]. \quad (5)$$

Let $\frac{dx}{dt} = 0$, $\frac{dy}{dt} = 0$, getting the 5 equilibrium points of the system, which are:

$$E_1(0,0), E_2(0,1), E_3(1,0), E_4(1,1) \text{ and } E_5\left(\frac{C_2}{R_1 + P}, \frac{P - C_0}{R_1 + P}\right).$$

According to the method proposed by Friedman (1991) [10], by calculating the partial derivatives of x and y for the above equations (4) and (5), the Jacobian matrix of the system can be obtained:

$$J = \begin{pmatrix} (1-2x)[(P - C_0) - y(R_1 + P)] & x(x-1)(R_1 + P) \\ y(1-y)(R_1 + P) & (1-2y)[x(R_1 + P) - C_2] \end{pmatrix} \quad (6)$$

If the local equilibrium point is solved by the replication dynamic equation such that the determinant of the Jacobian matrix is $\det(J) > 0$ and the trace of the Jacobian matrix is $\text{tr}(J) < 0$, then the equilibrium point is an evolutionary stabilization strategy (ESS). By bringing the equilibrium points E_1, E_2, E_3, E_4 and E_5 into (6) respectively, $\det(J) > 0$ and $\text{tr}(J) < 0$ of the Jacobian matrix to each equilibrium point can be obtained. As shown in Table 2.

Table 2, $\det(J) > 0$ and $\text{tr}(J) < 0$ of the Jacobi matrix of game system

equilibrium point	$\det(J)$	$\text{tr}(J)$
E_1	$C_2(C_0 - P)$	$P - C_0 - C_2$
E_2	$-C_2(C_0 + R_1)$	$C_2 - C_0 - R_1$
E_3	$(C_0 - P)(R_1 + P - C_2)$	$C_0 + R_1 - C_2$
E_4	$-(C_0 + R_1)(R_1 + P - C_2)$	$C_0 + C_2 - P$
E_5	$\frac{C_2(P - C_0)(R_1 + P - C_2)(R_1 + C_0)}{(R_1 + P)^2}$	0

The specific discussion results are shown in Table 3.

Table 3, Local stability analysis results of game system

condition	equilibrium point	$\det(J)$	$tr(J)$	result
$C_0 - P > 0$ $R_1 + P - C_2 > 0$	E_1	+	-	ESS
	E_2	-	-	Instability point
	E_3	+	+	Instability point
	E_4	-	+	Instability point
$C_0 - P > 0$ $R_1 + P - C_2 < 0$	E_1	+	-	ESS
	E_2	-	+/-	Instability point
	E_3	-	+/-	Instability point
	E_4	+	+	Instability point
$C_0 - P < 0$ $R_1 + P - C_2 > 0$	E_1	-	+/-	Instability point
	E_2	-	+/-	Instability point
	E_3	-	+/-	Instability point
	E_4	-	+/-	Instability point
	E_5		0	saddle point
$C_0 - P < 0$ $R_1 + P - C_2 < 0$	E_1	-	-	Instability point
	E_2	-	+	Instability point
	E_3	+	-	ESS
	E_4	+	+	Instability point
	E_5		0	saddle point

Evolutionary Phase Diagram

According to Table 3, the results of the five local equilibrium points in the Jacobian matrix are different for different conditions.

When $C_0 - P > 0$, regardless of the positive or negative of $R_1 + P - C_2$, the system has only a ESS, that is $E_1(0,0)$, its evolution phase diagram is shown in 1(a). That is, when the government's supervision cost C_0 is greater than the penalty P imposed by the government, the government will choose not to supervise because of the high supervision cost, and the e-commerce enterprises also will choose not to recycle because of the low fine. Therefore, in order to maximize the overall welfare of the society, the government should strive to reduce the supervision costs for e-commerce enterprise, and at the same time increase the penalties for e-commerce enterprises that do not recycle packaging materials, and encourage e-commerce enterprises to actively participate in the construction of green logistics.

When $C_0 - P < 0$ and $R_1 + P - C_2 > 0$, that is, when the government's supervision cost C_0 is less than the penalty P imposed by the government, and the government's reward R_1 for e-commerce enterprises and the penalty P for enterprise are greater than the cost C_2 of recycling packaging for e-commerce enterprises, E_1 , E_2 , E_3 , E_4 are not evolutionary stable strategies.

When $C_0 - P < 0$ and $R_1 + P - C_2 < 0$, the system has only a ESS, that is $E_3(1,0)$, its evolution phase diagram is shown in 1(b). That is, when the government's supervision cost C_0 is less than the penalty P imposed by the government, and the government's reward R_1 for e-commerce enterprises and the penalty P for enterprises are less than the cost C_2 of recycling packaging for e-commerce enterprises, the government will choose the supervision strategy, because the government's supervision cost is small, and the e-commerce enterprises will choose not to recycle the packaging strategy, because the recycling cost of the e-commerce enterprises are too high. Therefore, e-commerce enterprises should strengthen internal management, adopt advanced technology, and optimize work processes and other measures to reduce the cost of recycling packaging. At the same time, the government should increase incentives and penalties for recycling packaging enterprises,

so that enterprises are forced to actively implement the recycling strategy, making the stability point evolves from E_3 to E_4 .

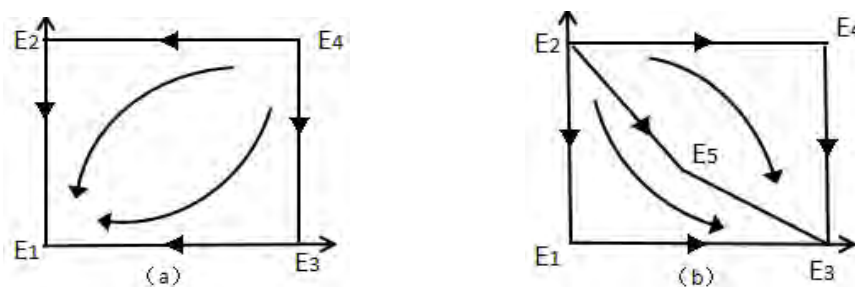


Fig. 1, Evolutionary phase diagram of game between government and e-commerce enterprises

Summary

Conclusions and Recommendations

The recycling of express packaging is of great significance for building green logistics, recycling resources and protecting the ecological environment. This paper takes the express package as the research object, and uses the evolutionary game method to construct the game model of the government and the e-commerce enterprises, and analyzes the strategy choice of each player in different situations. Through the specific analysis, it can be known that the strategic choice of both sides of the game depends on the given initial parameters, because the initial parameters setting determine the respective revenues of the government and the e-commerce enterprise. Starting from the overall interests of society, only e-commerce enterprises actively participate in the recovery of express packages can benefit mankind for a long time and maximize the interests of the whole society.

However, in order to improve the enthusiasm of e-commerce enterprises, the government's support is indispensable. For the government, first, the government should provide certain subsidy and preferential policies for recycling express packaging enterprises and provide corresponding supporting services, such as providing tax subsidies, establishing corresponding recycling sites, and improving the construction of recycling systems to assist e-commerce enterprises in recycling; Second, the government must rationally use rewards and punishments, only when the government increases the rewards and penalties for recycling packaging can enterprises be induced or forced to participate in the recovery of express packages. Third, the government needs to reduce the supervision cost of recycling express packages for e-commerce companies, such as using the Internet to establish an online monitoring platform and combining it with offline supervision to maximize the whole society benefit.

For e-commerce enterprises, the survival and development of enterprises require the support of the government, society and consumers. While maximizing their own interests, enterprises must consider the interests of the whole society, only in this way can enterprises develop for a long time and gain long-term benefits. At present, e-commerce companies are over-packaging and packaging materials are not environmentally friendly. E-commerce companies should pay attention to the "simple packaging" and "no packaging" of commodities, and strengthen management and work processes by adopting new packaging technologies and new environmentally friendly materials. These measures not only reduce the burden of packaging and the consumption and waste of resources, but also for enterprises to reduce the costs of packaging recycling, and truly contribute to the green logistics.

Deficiencies and Prospects

The recycling of express packaging is an important part of implementing green logistics; it requires the joint efforts of government, e-commerce enterprises and consumers. This study only

considers the game between the government and the e-commerce enterprises, but does not consider the e-commerce platform and consumers. Subsequent research can introduce e-commerce platform and consumers to study the game under multi-party participation. In addition, the parameters set in the game model of this paper are limited, and some parameters can be added in the future to further improve the reliability and comprehensiveness of the model.

Acknowledgements

This research was financially supported by the Shanxi philosophy and social science research project (Grant No. [2017]2), the Special Research Foundation of the Cooperative Innovation Center for Transition of Resource-based Economies (Grant No.ZX2017304).

References

- [1] State Post Bureau. State Post Bureau publishes express package trend report. Green packaging. 1 (2018).
- [2] Majumder, Pranab, and H. Groenevelt. COMPETITION IN REMANUFACTURING. *Production & Operations Management*. 10.2 (2010): 125-141.
- [3] Savaskan, R. Canan, S. Bhattacharya, and L. N. V. Wassenhove. Closed-Loop Supply Chain Models with Product Remanufacturing. *Management Science*. 50.2 (2004): 239-252.
- [4] Mitra, Supriya, and S. Webster. Competition in remanufacturing and the effects of government subsidies. *International Journal of Production Economics*. 111.2 (2008): 287-298.
- [5] Tsai, W. T., and Y. H. Chou. Government policies for encouraging industrial waste reuse and pollution prevention in Taiwan. *Journal of Cleaner Production*. 12.7 (2004): 725-736.
- [6] Zhang Yingchuan. Status and trends of green packaging development in China's express delivery. *Logistics Technology and Applications*. 21.4 (2016).
- [7] Chen Yifei, Zou Fangfang. Problems and solutions in China's express packaging. *Logistics Technology*. 36.9 (2017): 37-40.
- [8] Zheng Zhanzhi et al. Research on the recycling rate of express packaging based on structural equation model——Taking Beijing University as an example. *Logistics Technology*. 2 (2018).
- [9] Li Ping. Recycling incentive mechanism of express packaging under the game model. *Journal of Beijing University of Posts and Telecommunications (Social Science Edition)*. 4 (2017): 35-40.
- [10] Friedman, Daniel. Evolutionary Games in Economics. *Econometrica*. 59.3 (1991): 637-666.