The Impact of Government Guidance Mechanisms on the Industry Chain of Take-out Packaging Recycling

—an evolutionary game and analogue simulation study based on green economy

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Abstract: In recent years, with the popularization of smart phones and people's further demand for convenient life, the take-out industry has developed rapidly, which further stimulates economic consumption. However, while the take-out industry has been generating higher revenues, the problems of the disposal of take-out packaging have become increasingly severe. The rapid increase of take-out packaging has not only caused ecological pollution, but also led to a considerable degree of resource waste. Therefore, under the current premise of promoting circular economy and green economy, the recycling of take-out packaging has become an urgent problem to be solved. Given the fact that the recycling of take-out packaging involves different interest subjects, this study is conducted from a collaborative symbiotic and evolutionary perspective of related subjects. An evolutionary game model of consumers and take-out enterprises is built. By comparing the regulation of the government guidance mechanisms with non-regulation, the dynamic relationships among the government, enterprises and consumers in the industry chain of take-out recycling is explored.Based on the evolutionary game model, this study further reveals the important role played by the government in the construction of the industry chain of take-out recycling, which is of certain guiding significance for optimizing the structure and configuration of the industry chain and promoting the deepening development of circular economy.

1. Introduction

With the popularity of smart phones, online shopping and ordering services are becoming more and more abundant, thus giving rise to the prosperity of the take-out industry. According to *The Research Report China's Take-out Industry (the first half year of 2019)* jointly released by Meituan Institute and the Take-out Special Committee of China Hotel Association, in the first half year of 2019, the scale of China's take-out industry was about 262.3 billion yuan. The take-out industry kept fast growth, and its volume of business transactions was expected to increase to 603.5 billion yuan in 2019 from 461.3 billion yuan in 2018. Residential area is the scenario with the highest overall consumption proportion of take-outs. More than 300 million users have registered for relevant take-out platforms. The popularity of take-out not only facilitates the life of consumers, but also benefits countless stakeholders in the industry chain through the huge scale of employment it promotes.

The good cognition of recycling economy and take-out recycling of consumers, together with the guidance mechanisms of relevant government departments, can have a positive impact on the formation of a well-functioning industry chain of take-out waste recycling, thus promoting resource recycling, reducing energy consumption and waste, and optimizing economic structure. Therefore, analyzing and assessing the participation of consumers, enterprises and the government in the industry chain of take-out waste recycling can help obtain good dynamic strategies which combine the three parties, which has important practical significance for China to realize the strategic transformation to green economy and circular economy.

2. Literature Review

At present, in terms of waste recycling, the academic field focuses on the structural aspect of recycling study, such as the establishment and improvement of the recycling system and the diversity and expansion of recycling channels. Savaskan, Bhattacharya and Wassenhove (2004) classify waste recycling patterns from the closed-loop supply chain. Ostlin, Sundin and Bhorkman(2008) classify the recycling by the time and quality of recycling, and study the impact of waste recycling in the closed-loop supply chain. Webster and Mitra (2007) classify the constructed recycling systems and study the impact of discarded product recycling. Johnson, M.R, Wang, M.H (1998) design a new quantitative disassembly analysis method and analyze the impact of economic factors on the recycling efficiency. Lyons and Donald.I (2007) discuss the impact of geographical scale on waste recycling in closed-loop supply chain. In China, most researches focus on the influence of incentive mechanisms and governmental reward and punishment mechanisms on waste recycling. Fan and Lou (2011) analyze the role of governmental rewards and punishment in the outsourcing decision of waste recycling. From the perspective of manufacturers, Wang and Da (2013) study the role of reward and punishment mechanism in the decision making of waste recycling made by competitive manufacturers. Xu and Yang (2013) study the role of government subsidy in the recycling of discarded goods under closed-loop supply chain competition. Zhang and Yu (2016) further provide optimized incentive contract design and government subsidy schemes for the discarded goods recycling in closed-loop supply chain. Wang and Deng (2016) classify the regulation behaviors of government and compare the roles of reward and punishment mechanisms and tax-subsidy mechanisms in reverse supply chain.

Among the researches on specific types of recycling, the research results are concentrated on the recycling of express waste. Some researchers are carried out with universities as the main carrier. Yang and Liang (2016) discuss the possibility of establishing a mature system of recycling express packaging in colleges and universities. Wang and Zhang (2018) improve and re-optimize the existing delivery recycling process in universities. Zhu and Ye (2016) study the recycling of express packaging waste from the perspective of logistics enterprises. Wang (2019) design and study an intelligent express cabinet with the function of packaging recycling to improve the efficiency of recycling.

In conclusion, the academic circle has made a lot of achievements on structural studies of recycling and some specific recycling types, but there are still few researches on the strategic choices of various stakeholders in the process of take-out waste recycling. The take-out industry, as a growing system with fast development like the express delivery industry, needs to be paid more attention, and more detailed and in-depth scheme designs should be carried out. Therefore, from the perspective of the coevolution of multiple interest subjects, in this study, evolutionary game models of “consumer- take-out enterprise- the government” with and without government regulation are constructed, so as to explore the participation and influence of consumers, enterprises and the government in the construction of the industry chain of take-out recycling. At the same time, by replicating dynamic equations and other related formulas, the evolutionary stable strategies and corresponding laws of interest subjects can be obtained, which could provide a theoretical guidance for the construction and optimization of the industry chain of take-out recycling.

3. The Evolutionary Game Model

3.1 Establishment of Models

From the perspective of consumers, if consumers have a good sense of environmental protection and are willing to contribute to waste recycling, they will voluntarily classify garbage, wash and dry the take-out garbage by themselves after meals, and put the garbage into the corresponding recycling bins. However, for other consumers who do not have good awareness for environmental protection, due to the time and cost involved in disposing take-out garbage, they will still treat take-out garbage as the same as other wastes and all garbage will be packaged and discarded together without sorting. For take-out enterprises, from the point of long-term benefits, the

establishment of the take-out recycling industry chain can improve the efficiency of recycling, promote resource reuse and reduce resource waste. However, building such a chain needs corresponding operating costs. To be specific, the enterprise needs to add processing links in the traditional take-out supply chain and invest specialized manpower and material resources for planning. In the short term, this could bring decline in profits. From the perspective of enterprise, if the return brought by the construction of take-out recycling industry chain is lower than the costs for construction and operation, enterprises will have no willingness to participate in construction of take-out recycling industry chain.

3.2 Parameters and Game Pay-off Matrix

First, the evolutionary game model, "consumer-take-out enterprise" under the free market will be discussed.

Based on the above analysis, the hypotheses can be proposed as follows:

Hypothesis 1: consumer and the corresponding take-out enterprise are both bounded rational.

Hypothesis 2: the strategic choice of consumers is {consciously do the recycling, not do recycling}. When consumers choose the strategy of "consciously do the recycling", the revenue can be obtained is R_1 and the cost is C_1. When consumers choose the strategy of "not do recycling", the revenue can be obtained is R_2, and the cost required is C_2.

Hypothesis 3: only when the revenue obtained when consumer is choosing "consciously do the recycling" is higher than the revenue obtained when choosing "not do recycling", namely R_1-C_1>R_2-C_2, consumers will take the initiative to participate in the industry chain of take-out recycling.

Hypothesis 4: the strategic choice of take-out enterprises is {construct take-out recycling industry chain, not construct take-out recycling industry chain}. When a take-out enterprise chooses to "construct take-out recycling industry chain", it means that it needs to pay extra construction cost C_3, but can obtain revenue R_3. When the take-out enterprise chooses "not construct take-out recycling industry chain", the enterprise will obtain products through the original way, obtain revenue R_4 and pay cost C_4.

Hypothesis 5: only when the revenue obtained when enterprise is choosing "construct take-out recycling industry chain" is higher than the revenue obtained when choosing "not construct take-out recycling industry chain", namely R_3-C_3-R_2> R_4-C_4, take-out enterprises will take the initiative to participate in the industry chain of take-out recycling.

Hypothesis 6: when the strategic choice of consumer and take-out enterprise is {consciously do the recycling, construct take-out recycling industry chain}, take-out enterprises can construct take-out recycling industry chain, and further process the take-out garbage based on the recycling of consumers. The game revenue of both parties is $(R_1$-C_1,R_3-C_3-$R_2)$; when the strategic choice of consumer and take-out enterprise is {consciously do the recycling, not construct take-out recycling industry chain}, due to the lack of a complete take-out recycling industry chain, the revenue of consumers is R_2; the game revenue of take-out enterprises remains the same; the game revenue of both parties is $(R_2$-C_1,R_4-$C_4)$; when the strategic choice of consumer and take-out enterprise is {not do recycling, construct take-out recycling industry chain}, since consumers do not make early stage processing for the garbage and enterprises obtain products with the original method, the game revenue of both parties is $(R_2$-C_2,R_4-C_3-$C_4)$; when the strategic choice of consumer and take-out enterprise is {not do recycling, not construct take-out recycling industry chain}, the game revenue of both parties is $(R_2$-C_2,R_4-$C_4)$.

Hypothesis 7: the probability for consumers to choose "consciously do the recycling" is p, $0<p<1$; the probability for take-out enterprises to choose "construct take-out recycling industry chain" is q, $0<q<1$.

3.3 Solving Models

Considering the evolutionary process of the replicator dynamics of the subjects, when consumers choose "consciously do the recycling", the expected revenue is:

$$S_1=q(R_1-C_1)+(1-q)(R_2-C_1)=qR_1-C_1-qR_2+R_2 \quad (1)$$

When consumers choose “not do the recycling”, the expected revenue is:

$$S_2=q(R_2-C_2)+(1-q)(R_2-C_2)=R_2-C_2 \quad (2)$$

The average expected revenue is:

$$\bar{S}=pS_1+(1-p)S_2$$

Based on formulas (1) and(2), the replicator dynamics equation of consumers’ choice on the treatment of take-out garbage can be obtained:

$$X=\frac{dS}{dt}=p(1-p)(S_1-S_2)=p(1-p)[q(R_1-R_2)-C_1+C_2] \quad (3)$$

In the same way, the expected revenue when take-out enterprise choose “construct take-out recycling industry chain” is:

$$T_1=p(R_3-C_3-R_2)+(1-p)(R_4-C_3-C_4)=p(R_3-R_4+C_4-R_2)+R_4-C_3-C_4 \quad (4)$$

The expected revenue when take-out enterprise choose “not construct take-out recycling industry chain” is:

$$T_2=p(R_4-C_4)+(1-p)(R_4-C_4)=R_4-C_4 \quad (5)$$

The average expected revenue is:

$$\bar{T}=qT_1+(1-q)T_2$$

Based on formulas (4) and(5), the replicator dynamics equation of take-out enterprises’ choice on whether construct take-out recycling industry chain can be obtained:

$$Y=\frac{dT}{dt}=q(1-q)(T_1-T_2)=q(1-q)[p(R_3-R_4+C_4-R_2)-C_3] \quad (6)$$

Based on replicator dynamics equations(3) and (6), a two-dimensional dynamic system (I) can be obtained:

$$\begin{cases} \frac{dS}{dt}=p(1-p)(S1-S2)=p(1-p)[q(R1-R2)-C1+C2] \\ \frac{dT}{dt}=q(1-q)(T1-T2)=q(1-q)[p(R3-R4+C4-R2)-C3] \end{cases} \quad (7)$$

Make $\frac{dS}{dt}=0$, and $\frac{dT}{dt}=0$, the system(I) is solved.

Five partial equilibrium points of this evolutionary game matrix can be obtained. Four of them, namely (0, 0), (0, 1), (1, 0), (1, 1) are pure strategy equilibrium points. (p’,q’) and $(p'=C_3/R_3-R_4+C_4-R_2, q'=C_1-C_2/R_1-R_2)$ are mix-strategy equilibrium points.

Calculated by the population dynamics in differential equations proposed by Friedman, the stability analysis of the equilibrium points can be obtained through the partial stability of the Jaconbian matrix.

3.4 Model Analysis

If the following conditions are met:

(1) tr J $= a_{11}+a_{22}<0$

(2) det J $=\begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix}>0$

Then the equilibrium point of the replicator dynamics equation is local asymptotic stability, which is evolutionary stable strategy (ESS).

The equilibrium points of the evolutionary game and their stability are discussed within the plane R={(p,q)|0≤p,q≤1}. P and q represent for the proportions of individuals among consumers and take-out enterprises who choose a particular strategy. The stability analyses of the five partial equilibrium points are successively conducted, and Table 1 is obtained.

Tab.1 Analysis of the stability of partial equilibrium points

Partial equilibrium points	detJ	trJ	Analysis
(0,0)	+	-	ESS
(1,1)	+	-	ESS
(0,1)	+	+	Instability strategy
(1,0)	+	+	Instability strategy
($p'=C_3/R_3-R_4+C_4-R_2, q'=C_1-C_2/R_1-R_2$)	+	0	Saddle point

The analyses show that when Hypothesis 3 and Hypothesis 5 are met at the same time, namely, $R_1-C_1>R_2-C_2$ and $R_3-C_3-R_2> R_4-C_4$, the revenue when consumers and take-out enterprises choose to participate in the take-out garbage recycling industry chain will be higher than the revenue gained from maintaining the original strategy. Therefore, both parties will be more initiative in the construction of take-out garbage recycling industry chain.

3.5 The influence of governmental regulation on the evolutionary game model

The evolutionary game studied above is in a free market model undisturbed by the government. Consumer and take-out enterprise continue to learn from the evolutionary path obtained by the replicator dynamics equation and finally together converge to an ideal state.

In this process, the evaluations of consumer and take-out enterprise on their own revenues and costs play an important role in determining whether they can construct a well-functioning take-out garbage recycling industry chain. Without the regulation from the government, both parties judge whether to participate in the recycling process of the industry chain entirely based on their own expected profits. In the game, it is reflected as the fact that the evolution process takes a long time, and it is difficult for them to co-evolve to an ideal state.

Therefore, the impact of government involvement is added. The government will offer allowances when take-out enterprises choose “construct take-out recycling industry chain”, while fine them when they choose “not construct take-out recycling industry chain”. By observing the changes of the evolutionary game after adding the factors of governmental regulation and comparing the results with those under the state of free market, the role that governmental regulation plays in the construction of recycling industry chain can be obtained.

In the model with governmental regulation, while other hypotheses remain unchanged, the following hypotheses are added:

Hypothesis 8: When a take-out enterprise chooses “construct take-out recycling industry chain”, the government gives it allowance A_1; when the enterprise chooses “not construct take-out recycling industry chain”, the government imposes a fine F_1 to it. The game payoff matrix after governmental regulation is shown in Table 2.

Tab.2 Game payoff matrix between enterprise and consumer with governmental regulation

Consumer	Take-out enterprise	
	Construct take-out recycling industry chain	Not construct take-out recycling industry chain
Consciously do the recycling	$(R_1-C_1, R_3-C_3-R_2+A_1)$	$(R_2-C_1, R_4-C_4-F_1)$
Not do the recycling	$(R_2-C_2, R_4-C_3-C_4+A_1)$	$(R_2-C_2, R_4-C_4-F_1)$

When $C_3-A_1-F_1<0$ *and* $R_3-C_3-R_2+A_1-(R_4-C_4-F_1)>0$, the fine of the government (F_1) on the take-out enterprise when it chooses “not construct take-out recycling industry chain” is higher than the initial cost of the take-out enterprise (C_3) when it chooses “construct take-out recycling industry chain”. Therefore, with the governmental regulation, take-out enterprises would take the option “construct take-out recycling industry chain” to avoid penalties; when the industry chain is constructed, the enterprises can gain higher revenues with the allowance from the government, which could increase their motivation for constructing the industry chain. At this point, there is only one ESS in the system :{consciously do the recycling, construct take-out recycling industry chain}.

When $C_3-A_1-F_1>0$ *and* $R_3-C_3-R_2+A_1-(R_4-C_4-F_1)>0$, and governmental regulation is introduced, with other conditions unchanged, compared with the situation of free market, the initial state is

p_1'<p; the probability that the final game result converges to the good state increases. This is because when the government intervenes into the construction of take-out recycling industry chain, the corresponding control measures could reduce the relative costs of the construction and stimulate the enthusiasm of take-out enterprises. The stability analysis of the partial equilibrium points is shown in Table 3.

Tab.3 Stability analysis with governmental regulation

Partial equilibrium points	detJ	trJ	Analysis
(1,1)	+	-	ESS
(0,0)	-	unsure	unstable
(1,0)	+	+	unstable
(0,1)	-	unsure	unstable
(p'=(C_3-A_1-F_1)/R_3-R_4+C_4-R_2,q'=C_1-C_2/R_1-R_2)	-	0	Saddle point

4. Conclusion

From the perspective of the co-evolution of both parties and based on the hypotheses of their "bounded rationality", this study analyzes the evolutionary game processes of both parties, namely "consumer-take-out enterprise", about their decision-making on "construct take-out recycling industry chain" under the circumstances of free market and governmental regulation. The analysis results show that:

(1) Under the condition of free market, two factors leads to the result that the evolutionary game system finally converges to a good state: the ratio of strategic choice of consumer and take-out enterprise in the initial state, and the expected benefits of both parties.

In the initial state, if consumers have stronger awareness of environmental protection and a preference for recycling economy, a larger proportion of them would choose the strategy of "consciously do the recycling" and a higher proportion of enterprises would choose the strategy of "construct take-out recycling industry chain". Consumer is the main service object of take-out enterprise. Consumers' behavior decision plays an important role in the decision-making and implementation of enterprises.

When the expected benefits of both parties are less than zero, the proportion of consumers who choose "not do the recycling" will increase. Similarly, enterprises will be less inclined to participate in the construction of industry chain. Then both parties will evolve to the bad state.

On the contrary, if the expected benefits of both parties are greater than zero, consumers will have higher enthusiasm to get involved in the disposal of take-out garbage, and enterprises will be more initiative to participate in the construction of industry chain.

In short, under the condition of marketization, achieving the good state {consciously do the recycling, construct take-out recycling industry chain} by self-adjustment relies on certain conditions, which could hardly be realized.

(2) Under the condition of governmental regulation, when the government takes measures of rewards and punishment on enterprises, based on allowances and fines, the stability strategy evolves to {consciously do the recycling, construct take-out recycling industry chain} with an obviously faster speed. The government's regulation plays an important role in promoting the recycling economy.

To sum up, in order to facilitate the healthy and sustainable development of the economy, the following suggestions are made:

(1) The government should actively guide consumers' cognition of environmental protection, create a positive atmosphere of public opinion in society, practice the concept of green life, and improve people's awareness of environmental protection. The government can give full play to the power of grassroots and self-governed organizations; each community can honor residents as "advanced environmental protection individuals" to commend and encourage the consumers who actively practice the green life.

(2) The government should strengthen the awareness of social responsibility of take-out enterprises, effectively guide the transformation and upgrading of enterprise to circular economy and green economy through rewarding and punishing measures, improve the enthusiasm of take-out garbage recycling, and optimize the configuration of structure.

(3) The government should strengthen infrastructure construction related to take-out garbage recycling and introduce documents and regulations related to garbage classification to provide convenience for consumers to actively participate in take-out garbage recycling.

In this study, the issue about the construction of take-out garbage recycling industry chain has been elaborated. According to the role of "consumer- take-out enterprise" co-evolution, a evolutionary game model has been established, and the effect of governmental regulation has been investigated. In real life, take-out garbage includes meal boxes, tableware, paper towels, plastic packaging, etc., which need further refined processing. In future studies, the refinement and deepened processing of different types of take-out garbage can become a new study point.

References

[1] Fan Tijun, Lou Gaoxiang, Wang Chenlan. Chen Rongqiu. Analysis of outsourcing decision-making on used products collection for green remanufacturing. Journal of Management Science and Engineering, 2011,14(08):8-16.

[2] Friedman D. Evolutionary game in economics [J]. Economy Erica, 1991, 59(3):637-666.

[3] Johnson,M.R, Wang,M.H.Economical evaluation of disassembly operations for recycling, remanufacturing and reuse. International Journal of Production Research. Dec1998, Vol. 36 Issue 12, p3227-3252.

[4] Lyons, Donald I. A Spatial Analysis of Loop Closing Among Recycling, Remanufacturing, and Waste Treatment Firms in Texas. Journal of Industrial Ecology. Winter2007, Vol. 11 Issue 1, p43-54.

[5] Ostlin.J,Sundin.E,Bhrokman.M. Importance of closed-loop supply chain relationships for product remanufacturing [J].International jounal of production economics,2008,115(2)：336-348.

[6] Savaskan.R.C, Bhattacharya.S,Wassenhove.L.N.Closed-loop supply chain models with product remanyfacturing [J].Management Science,2004,50(2):239-252.

[7] Wang Yuyan, Li Bangyi, Shen Liang. A study of the evolutionary game of two manufacturer's reverse supply chain[J]. Systems Engineering:Theory & Practice,2008,(4):43-49.

[8] Wang Jing. Design of Green Three-in-one Intelligent Express Cabinet with Package Recycling Function. Logistics Technology, 2019,38(04):95-99.

[9] Wang Ziyi, Zhang Xuebin, Jiang Dali, Fang Haiyang. Reengineering and Optimization of College's Express Package Recycling Process Based on Intelligent Logistics. Packaging Engineering. 2018,39(23):20-24.

[10] WANG Wen-bin,DENG Wen-wen. Comparison between the Reward-penalty Mechanism with the Tax-subsidy Mechanism for Reverse Supply Chain. Chinese Journal of Management Science, 2016, 24(04):102-110.

[11] Wang Wenbing,Da Qingli.The Decision Making of Manufacturers for Collection and Remanufacturing Based on Premium and Penalty Mechanism under Competition Environment. Chinese Journal of Management Science,2013,21(05):50-56.