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Retailer's Decision to Replace New and Used Energy Vehicles based on Evolutionary Game

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Abstract

Studying the behavioral choices of consumers and retailers in the context of information asymmetry and bounded rationality in the process of new energy vehicle transactions is of great significance for promoting the promotion of new energy vehicles and reducing carbon emissions. Based on the evolutionary game theory, this paper constructs an evolutionary game model between automobile retailers and consumers, studies the strategic choice of game players and uses MATLAB for numerical simulation. The results show that the system has four evolutionary equilibrium strategies. In the optimal evolution strategy, consumer low-carbon preference, policy subsidies, and punishment are the key factors that affect the strategic choices of consumers and retailers. Only when consumers tend to buy new energy vehicles and retailers actively make product substitution decisions can the promotion of new energy vehicles have further development.

Keywords

Low-carbon Preferences; Policy Subsidies; New and Old Energy Vehicles; Alternative Decision-making; Evolutionary Game.

1. Introduction

With the global climate change problem becoming more and more prominent, the international action to deal with climate change has been accelerated comprehensively. In September 2020, at the seventy-five UN General Assembly, Xi announced China's carbon summit target by 2030 and its carbon neutral vision by 2060[1], Nations around the world have pledged to be carbon neutral. Speeding up the transformation of energy development mode and promoting new energy substitution is the key to solve the problem of carbon emission. In the field of transportation, it is an important measure to develop electric and hydrogen vehicles and realize the transition from oil to electric (hydrogen) drive[2]. As the world's largest developing country and carbon emitter, China has been actively promoting policy subsidies and other positive incentives to encourage enterprises to transform, to encourage consumers to buy new energy vehicles. As new energy vehicles are still at the initial stage of development, most of their support strategies are based on the perspectives of government subsidies, regulation and enterprise preferences, ignoring the impact of consumers'low carbon preferences on the marketing promotion of new energy vehicles, as a result, its current promotion is not satisfactory. Therefore, we should step up the publicity of green concepts such as low-carbon and environmental protection, and increase consumers'sensitivity to low-carbon. At the same time, we should take into account the impact of policies and changes in consumers'low-carbon preference strategies, and make appropriate interventions from both supply and demand perspectives, to speed up the further promotion of new energy vehicles, carbon emission reduction work to contribute to a force.

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At present, in the related research on the impact of new and old energy vehicle retailers on product substitution decision-making, Zhang Haibin and others have used multi-Agent method to construct the incentive model of government subsidy to automobile sales enterprises, this paper explores the influence of government dynamic subsidy on the new energy vehicle market [3]. Oikawa and Managi[4],I think inclusive subsidies are a better incentive to develop new energy vehicles than selective subsidies. Jiang cai lou[5]I studied the impact of government subsidies on the independent R & D and Technology Import Strategies of new energy vehicle enterprises.Liu quan ming[6]I consider whether the manufacturers involved in the construction of the two-party and three-party new and old energy logistics car replacement model. When it comes to retailers'product substitution decisions, Odríguez-Ibeas[7]I consider the effects of different levels of environmental product differentiation on corporate earnings and social well being.When the total market demand is uncertain, Liang hong yan[8] study the optimal ordering strategy of the retailer considering the risk preference, consumer choice preference and the substitutability of the two products. Xu ya ping [9]use Bass model to explore the impact of price factors on the promotion of new energy vehicles. Li you dong[10]consider the case where the manufacturer produces both low-carbon products and ordinary products with substitution, introduce incentive compatibility mechanism, construct a cooperative decision contract model, and discuss the coordination of two-stage low-carbon supply chain.Guo jin sen[11] In the framework of symmetric information, I study the operation decision-making problem of dual-channel supply chain for retailers with capital constraints based on Game Theory.

To sum up, in the research on product substitution decision-making of new energy vehicle retailers, the research on the impact of policy subsidies and low-carbon preferences of consumers on substitution decision-making is relatively independent, but in fact, consumers'low-carbon preferences may also be affected by policy subsidies, or both may influence retailers'product substitution decisions. As China's new energy vehicle market is changing from policy-oriented to demand-oriented, it is important to explore the impact of policy subsidies and consumers'low-carbon awareness on the new energy supply chain in the new energy market. At the same time, considering the influence of consumers'low-carbon preference and policy subsidy on the retailers'sales substitution decision of new and old energy vehicles is of great significance to the promotion of new energy vehicles, most of the existing research is based on the information symmetry, in fact, there must be a Information asymmetry problem between retailers and consumers. Based on this, under the condition of game Information asymmetry and limited rationality, considering the effects of policy regulation and consumers'low-carbon preference, this paper explores the relationship between retailers and consumers in the transaction process of new energy vehicles, how to improve consumers'low-carbon sensitivity, the probability of retailers'product substitution and the probability of consumers'low-carbon preference and purchase of new energy vehicles are the main contents of this paper.

2. Game Model of New and Old Energy Vehicle Substitution Decision

2.1. Problem Description

In the transaction process of new energy vehicle, retailers and consumers will be affected by policy regulation when they make decisions, and the decision-makers will also influence each other. For Consumers, there is a low-carbon preference to buy new energy vehicles, not a low-carbon preference to choose to buy conventional energy vehicles; Consumers will pay more attention to the extra benefits they can reap when they have low-carbon preferences and whether the policy subsidies are higher than the extra costs incurred in pursuing low-carbon preferences. Retailers can choose to start selling new energy vehicles with product substitution,

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or they can choose to continue selling traditional energy vehicles without product substitution, in the auto trading process, more attention should be paid to whether the cost of the transition needed to convert the sale of new energy vehicles can be exchanged for higher additional revenue and government subsidies. In addition, in the case of choosing not to do product substitution, conventional Energy retailers also need to consider whether the proceeds from the sale of conventional vehicles can cover the penalty costs of not replacing them. Therefore, there are four scenarios in this problem, scenario 1 is that consumers have a low carbon preference to buy new energy vehicles, and retailers switch to selling new energy vehicles instead, both consumers and retailers receive subsidies because of the low-carbon nature of their transactions. Case 2 is that Consumers have a low carbon preference to buy new energy vehicles but retailers do not make the sales transition, when consumers receive policy subsidies, retailers get policy penalties and consumer losses for not making the sales transition. Scenario 3 is that consumers do not have a low carbon preference for buying conventional energy vehicles, and retailers switch to selling new energy vehicles when consumers do not receive policy subsidies or penalties, and retailers receive policy subsidies, but because there is no demand from consumers, retailers will not get the extra revenue from the sales transition. Scenario 4 is that consumers don't have low carbon preferences and retailers don't make sales transitions, where consumers don't get subsidies or punishment, and retailers get punishment.

2.2. Model Hypothesis and Variable Description

2.2.1. Model Hypothesis

According to the retailers and consumers in the actual situation in the transaction made the following assumptions.

(1) There is limited rationality between the retailer and the consumer, the Information asymmetry and the consumer.

(2) The strategy choice space of traditional energy retailer is product substitution and not product substitution, the strategy choice space of consumers is low carbon preference to buy new energy vehicle and no low carbon preference to buy traditional energy vehicle.

(3) The retailers mentioned in this article are all traditional energy vehicle retailers. If they choose to substitute products and start selling new energy vehicles, they will have to bear some transformation costs and gain additional revenue and government subsidies.

(4) When retailers do not substitute products but consumers have low-carbon preference, retailers have to bear the loss and penalty cost, which will be affected by consumers'low-carbon sensitivity.

(5) Consumers who have a low-carbon preference will reap additional benefits and policy subsidies.

(6) Under the premise of product substitution, the extra cost of consumers with low carbon preference is less than that without product substitution.

(7) In the current market, the cost of new energy vehicles is higher than that of traditional energy vehicles.

(8) Consumer's preference for new and old energy vehicles is only reflected in whether there is a low-carbon preference, brand, performance and other characteristics are neutral.

2.2.2. Variable Description

The specific variable description is shown in Table 1.

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Table 1. Variable description table

variable	Implications	variable	Implications
L	The general return of a retailer without product substitution	ΔL	Additional revenue from product substitution by retailers
C	The general cost to a retailer of not replacing a product	ΔC	The additional cost to the retailer of product substitution
H	Consumers have no general cost of low carbon preferences	β	Low Carbon sensitivity of consumers
I	General benefit of consumers with no low carbon preference	ΔI	Consumers have the added benefit of a low carbon bias
ΔH_2	Consumers have the added cost of a low carbon preference without the retailer's product substitution	ΔH_1	The extra cost of low-carbon preferences for consumers when retailers make product substitutions
x	The probability that consumers will have a low carbon preference and buy new energy vehicles	y	The probability that a retailer will start selling new energy vehicles by making product substitutions
S1	Consumers have a low carbon preference for buying new energy vehicles with government subsidies	S2	A subsidy provided by the government when retailers begin selling new-energy vehicles through product substitution
g	Penalties for retailers who do not substitute products		

2.3. Benefit Matrix Analysis of Two-party Evolutionary Game

Case 1: Considering the policy subsidies, consumers have a low carbon preference to buy new energy vehicles and retailers carry out product substitution to start selling new energy vehicles, Revenue for consumers and retailers, $I+\Delta I-H-\Delta H_1+S_1$, $L+\Delta L-C-\Delta C+S_2$.

Case 2: Considering the policy subsidies, consumers have a low carbon preference to buy new energy vehicles, but retailers do not carry out product substitution and still sell traditional energy vehicles, Revenue for consumers and retailers $I+\Delta I-H-\Delta H_2+S_1$, $L-C-\beta\Delta L-g$.

Case 3: Consider subsidies, where consumers don't have a low carbon preference for conventional energy vehicles, and retailers switch from alternative products to new energy vehicles, Revenue for consumers and retailers $I-H$, $L-C-\Delta C+S_2$.

Case 4: Considering the policy subsidies, consumers have no low carbon preference to buy traditional energy vehicles, retailers do not carry out product substitution and still sell traditional energy vehicles, In this case, consumer and retailer revenue $I-H$, $L-C-g$.

Based on the above analysis, the choice-return Matrix between retailers and consumers can be obtained as shown in Table 2.

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Table 2. Return Matrix of retailer and consumer choice

Consumer Strategy	Retailer Strategy	
	Product substitution	No product substitution
Buy A new energy car	$I+\Delta I-H-\Delta H_1+S_1$ $L+\Delta L-C-\Delta C+S_2$	$I+\Delta I-H-\Delta H_2+S_1$ $L-C-\beta\Delta L-g$
Don't buy new energy vehicles	$I-H$ $L-C-\Delta C+S_2$	$I-H$ $L-C-g$

3. Stability and Equilibrium Analysis of Evolutionary Game Strategies

In this model, the transaction process of new energy vehicle involves consumers and retailers, and the bounded rationality hypothesis of Evolutionary game theory is more suitable to the reality. By solving the copy dynamic equations of consumers and retailers respectively, their evolutionary stable strategies are obtained, and the factors influencing the further promotion of new energy vehicles are analyzed scientifically.

3.1. Analysis of Replication Dynamic Equation

3.1.1. Dynamic Equation of Consumer Replication

The following results can be obtained from the retailer-consumer choice-return Matrix:
The expected payoff for consumers with a low carbon bias is:

$$U_{c1}=y(I+\Delta I-H-\Delta H_1+S_1)+(1-y)(I+\Delta I-H-\Delta H_2+S_1) \tag{1}$$

The expected payoff for consumers with no low carbon bias is:

$$U_{C2}=y(I-H)+(1-y)(I-H) \tag{2}$$

The average expected return for consumers is:

$$\overline{U_C}=xU_{C1}+(1-x)U_{C2} \tag{3}$$

Thus, the replication dynamic equation for the probability that Consumers have a low carbon preference strategy is:

$$F(x)=\frac{dx}{dt}=x(U_{C1}-\overline{U_C})=x(1-x)(-y\Delta H_1+\Delta I-\Delta H_2+y\Delta H_2+S_1) \tag{4}$$

$$F(x)=0,\ x_1=0,x_2=1,\ y^*=\frac{\Delta H_2-\Delta I-S_1}{\Delta H_2-\Delta H_1}.$$

3.1.2. Dynamic Equation of Retailer Replication

Similarly, according to the retailer and consumer choice income matrix, the copy dynamic equation of the retailer's product substitution strategy probability is as follows:

$$F(y)=\frac{dy}{dt}=y(1-y)[x(1+\beta)\Delta L-\Delta C+S_2+g] \tag{5}$$

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$$F(y)=0,\ y_1=0, y_2=1, \text{x*=}\frac{\Delta C-S_2-g}{(1+\beta)\Delta L}$$

It can be concluded that the five equilibrium points in the game system between consumers and retailers are: (0,0)(0,1)(1,0)(1,1)(x*, y*).

$$\text{x*=}\frac{\Delta C-S_2-g}{(1+\beta)\Delta L},\ \text{y*=}\frac{\Delta H_2-\Delta I-S_1}{\Delta H_2-\Delta H_1},\ (0\le\frac{\Delta C-S_2-g}{(1+\beta)\Delta L}\le 1, 0\le\frac{\Delta H_2-\Delta I-S_1}{\Delta H_2-\Delta H_1}\le 1)$$

3.2. Analysis of Stable Strategy in Evolutionary Game between Two Sides

A two-dimensional power system can be derived from formulas 4 and 5:

$$\begin{cases} F(x)=\dfrac{dx}{dt}=x(U_{C1}-\overline{U_C})=x(1-x)(-y\Delta H_1+\Delta I-\Delta H_2+y\Delta H_2+S_1) \\ F(y)=\dfrac{dy}{dt}=y(U_{R1}-\overline{U_R})=y(1-y)[x(1+\beta)\Delta L-\Delta C+S_2+g] \end{cases} \quad (6)$$

According to Formula (6), we take partial derivatives of X and Y, and we get Jacobian Matrix and determinant J as:

$$J=\begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}=\begin{pmatrix} (1-2x)(-y\Delta H_1+\Delta I-\Delta H_2+S_1+y\Delta H_2) & x(1-x)(-\Delta H_1+\Delta H_2) \\ y(1-y)(\Delta L+\beta\Delta L) & (1-2y)(x\Delta L-\Delta C+S_2+x\beta\Delta L+g) \end{pmatrix}$$

Table 3. Analysis of local equilibrium point of game system between consumers and retailers

Equilibrium point	a11	a12	a21	a22
(0,0)	$\Delta I-\Delta H_2+S_1$	0	0	$-\Delta C+S_2+g$
(0,1)	$-\Delta H_1+\Delta I+S_1$	0	0	$\Delta C-S_2-g$
(1,0)	$\Delta H_2-\Delta I-S_1$	0	0	$(1+\beta)\Delta L-\Delta C+S_2+g$
(1,1)	$\Delta H_1-\Delta I-S_1$	0	0	$-[(1+\beta)\Delta L-\Delta C+S_2+g]$
(x*, y*)	0	A’	B’	0

When the equilibrium satisfies the Jacobian Matrix and determinant criteria tra J=a11+a22<0,det J=a11a22-a12a21>0, The equilibrium point is a locally asymptotically stable fixed point in an evolutionary dynamic process, For (X * , y *) , Det must be less than 0, which is the saddle point, and the stability of the other four equilibria is affected by each variable.On this basis, the value of a11, a12, a21, a22 and the size relationship among the variables in Table 2 are further analyzed. $\Delta H_2>\Delta H_1$.

The analysis is as follows:

(1) When $\Delta H_2<\Delta I+S_1$, $\Delta C<S_2+g$, $\Delta C-(S_2+g)<(1+\beta)\Delta L$,The system converges to (1,1) when the consumer buys a new energy vehicle and the retailer substitutes the product.In this case, under the support of policy subsidies, consumers are more willing to buy new energy vehicles, and enterprises have higher extra income. New Energy vehicles can be further promoted.

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(2) When $\Delta H_2 < \Delta I + S_1$, $\Delta C > S_2 + g$, $\Delta C - (S_2 + g) > (1+\beta)\Delta L$,The system converges to (1,0) when a consumer buys a new energy vehicle, the retailer does not implement product substitution strategy.In this case, with the support of policy subsidies, consumers are more willing to buy new energy vehicles, but enterprises are less willing to carry out product substitution because they need to bear higher transformation costs, easy to cause the new energy automobile market supply and demand imbalance situation.At this point, the government should introduce other related preferential measures on the basis of policy subsidies to encourage car retailers to sell new energy vehicles instead.

(3) When $\Delta H_1 < \Delta I + S_1 < \Delta H_2$, $\Delta C > S_2 + g$, $\Delta C - (S_2 + g) < (1+\beta)\Delta L$,The system converges to (0,0) or (1,1) .On the whole, when the retailer carries out product substitution, the consumer will buy the new energy vehicle under the premise of the retailer's product substitution, the specific situation is as follows (1) .Consumers will not buy new energy vehicles if retailers do not carry out product substitution sales. Due to the relatively low level of government subsidies and consumers'weak awareness of low carbon, retailers and consumers will not sell or buy new energy vehicles. Therefore, it is necessary for the government to step up publicity on the concepts of environment, green, low carbon, etc. cultivate low carbon preferences among consumers.

(4) When $\Delta H_1 < \Delta I + S_1 < \Delta H_2$, $\Delta C < S_2 + g$, $\Delta C - (S_2 + g) > (1+\beta)\Delta L$,The system's not stabilizing. In this case, the decision-making of retailers and consumers will be affected to a great extent by the policy. When the policy subsidies gradually withdraw from the market, the decision-making of retailers and consumers will return to the original state, will cause continued turmoil in the new energy vehicle market. The government should increase the publicity and education of the concept of green and low-carbon environmental protection, cultivate consumers'low-carbon preference, and enable them to buy new energy vehicles spontaneously; As the prices of new energy vehicles on the market are generally higher than those of traditional energy vehicles, the government can increase the cost that consumers have to pay for traditional energy vehicles through other means of regulation when the policy subsidies recede, or the adoption of restrictions such as the use of traditional energy to reduce the interests of consumers to buy cars.

(5) When $\Delta I + S_1 < \Delta H_1$, $\Delta C > S_2 + g$, $\Delta C - (S_2 + g) > (1+\beta)\Delta L$,The system converges to (0,0) . Consumers have no low-carbon preference to buy conventional energy vehicles, and retailers do not substitute products. Due to the relatively low level of government subsidies and consumers'weak awareness of low carbon, retailers and consumers will not sell or buy new energy vehicles. Therefore, it is necessary for the government to step up publicity on the concepts of environment, green, low carbon, etc., fostering low-carbon consumer preferences will also require a shift in sales of new-energy vehicles through increased subsidies for retailers to switch and penalties for not doing so.

(6) When $\Delta I + S_1 < \Delta H_1$, $\Delta C < S_2 + g$, $\Delta C - (S_2 + g) < (1+\beta)\Delta L$,The system converges to (0,1) when the consumer buys a conventional Energy Vehicle, the retailer tends to substitute the product. In this case, with the support of policy subsidies, consumers will switch to traditional energy vehicles because they have to bear higher costs, and retailers will insist on product substitution transformation because of the higher additional revenue they will gain from product transformation, however, because of the imbalance between supply and demand of new energy vehicles, it is easy to lead to the product backlog of new energy vehicles. The government should actively help the new energy vehicle sales enterprises to expand sales channels, and at the same time, through increasing the publicity of low-carbon concept, to cultivate new consumer groups.

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(7) At the equilibrium point (x*, y*), tra J = a11 + a22 = 0, which does not satisfy the Jacobian Matrix and determinant stable equilibrium condition,so (x* , y*) is not the equilibrium stable point of the system.

According to the above analysis, by calculating the trace traJ of Jacobi Matrix J at each equilibrium point and the value of determinant Det J, it is concluded that there are four equilibrium points in the game system between retailer and consumer which are stable, (0,0), (0,1), (1,0), (1,1) are evolutionarily stable strategy (x*, y*) is Saddle point.

4. Numerical Simulation Analysis

In order to show more intuitively the behavior strategy of consumers and retailers in the transaction process of new energy vehicles, in this paper, the ODE45 function in Matlab is used to simulate the evolution and stability strategy of the retailer and the consumer under different conditions. The proportion of low-carbon consumers who prefer to buy new energy vehicles and the proportion of retailers to substitute products are 0.1-0.9 and 0.1, respectively.

(1) When the constraint is $\Delta H_2 < \Delta I + S_1$, $\Delta C < S_2 + g$, $\Delta C - (S_2 + g) < (1+\beta)\Delta L$,make the parameter be $\Delta I = 9, \Delta H_1 = 5, \beta = 0.8$, $\Delta C = 18, \Delta L = 13, \Delta H_2 = 8$, $S_1 = 3, S_2 = 7, g = 12$ .Through the simulation with MTALAB, the evolutionary game graph shown in figure 1 is obtained. It is found that under the constraint, the strategies of consumers and retailers converge to (1,1), that is, consumers buy new energy vehicles and retailers substitute products.

(2) When the constraint is $\Delta H_2 < \Delta I + S_1$, $\Delta C > S_2 + g$ $\Delta C - (S_2 + g) > (1+\beta)\Delta L$,make the parameter be $\Delta I = 9, \Delta H_1 = 5, \beta = 0.8$, $\Delta C = 19, \Delta L = 9, \Delta H_2 = 8$, $S_1 = 5, S_2 = 1, g = 1$ Through the simulation with MTALAB, the evolutionary game graph shown in figure 2 is obtained. It is found that under the constraint, the strategy of consumers and retailers converges to (1,0), that is, consumers buy new energy vehicles and retailers do not substitute products.

(3) When the constraint is $\Delta H_1 < \Delta I + S_1 < \Delta H_2$, $\Delta C > S_2 + g$, $\Delta C - (S_2 + g) < (1+\beta)\Delta L$,make the parameter be $\Delta I = 4, \Delta H_1 = 5$, $\beta = 0.5, \Delta C = 15, \Delta L = 12, \Delta H_2 = 7$, $S_1 = 2, S_2 = 5, g = 6$ Through the simulation with MTALAB, the evolutionary game graph shown in figure 3 is obtained. It is found that under the constraint conditions, the strategy of consumer and retailer converges to (0,0) or (1,1) .When the retailer chooses the product substitution and the consumer chooses to buy the new energy vehicle, it converges to (1,1) , that is, the consumer buys the new energy vehicle and the retailer substitutes the product; When the retailer chooses not to replace the product and the consumer buys the traditional energy vehicle, it converges to (0,0), that is, the consumer buys the traditional energy vehicle and the retailer does not replace the product.

(4) When the constraint is $\Delta H_1 < \Delta I + S_1 < \Delta H_2$ $\Delta C < S_2 + g$, $\Delta C - (S_2 + g) > (1+\beta)\Delta L$ make the Parameter be $\Delta I = 4, \Delta H_1 = 5$, $\beta = 0.5, \Delta C = 15, \Delta L = -8, \Delta H_2 = 7$, $S_1 = 2, S_2 = 6, g = 11$ By simulation with MTALAB, the simulation graph of evolutionary game as shown in figure 4 is obtained. It is found that the system has no stable point under the constraint.

(5) When the constraint is $\Delta I + S_1 < \Delta H_1$, $\Delta C > S_2 + g$, $\Delta C - (S_2 + g) > (1+\beta)\Delta L$,make the Parameter be $\Delta I = 3, \Delta H_1 = 5, \beta = 0.2$, $\Delta C = 18, \Delta L = 11, \Delta H_2 = 6$, $S_1 = 1, S_2 = 1, g = 2$ through the simulation with Mtalab, we get the evolutionary game simulation graph shown in figure 5, and find that under this constraint, the strategy of consumers and retailers converge to (0,0) , that is, consumers buy traditional energy vehicles, retailers do not substitute products.

(6) When the constraint is $\Delta I + S_1 < \Delta H_1$, $\Delta C < S_2 + g$, $\Delta C - (S_2 + g) < (1+\beta)\Delta L$,make the Parameter be $\Delta I = 3, \Delta H_1 = 5, \beta = 0.2$, $\Delta C = 12, \Delta L = 7, \Delta H_2 = 6$, $S_1 = 1, S_2 = 6, g = 8$ Through the simulation with MTALAB, the evolutionary game graph shown in figure 6 is obtained. It is found

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that under the constraint, the strategies of consumers and retailers converge to (0,1), that is, consumers buy traditional energy vehicles and retailers substitute products.

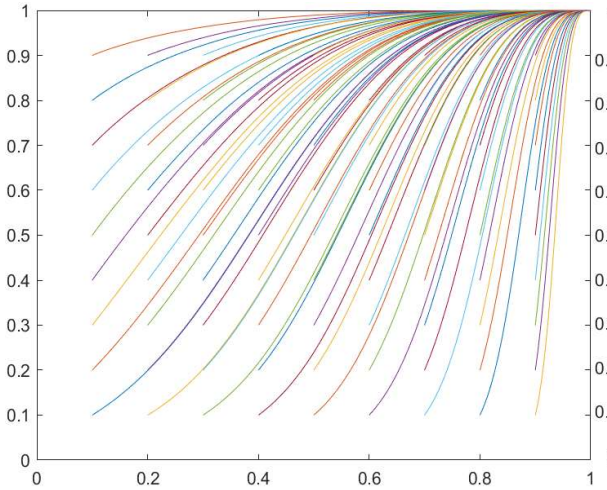

Fig. 1 (1)Evolution simulation diagram

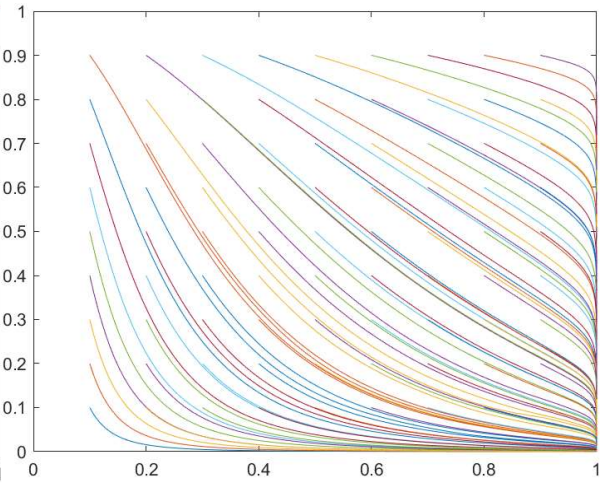

Fig. 2 (2)Evolution simulation diagram

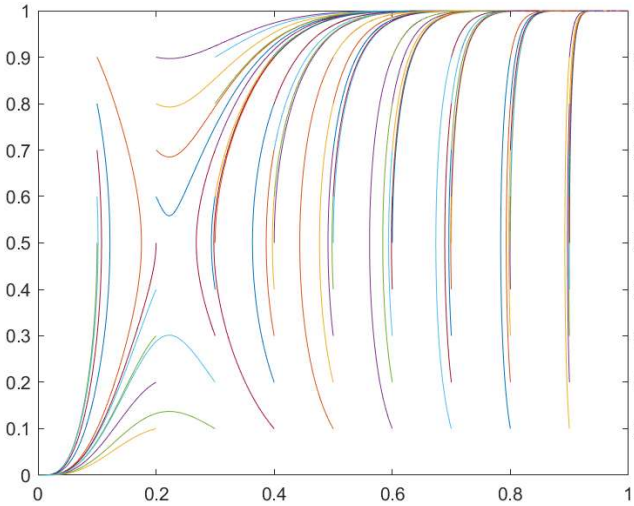

Fig. 3 (3)Evolution simulation diagram

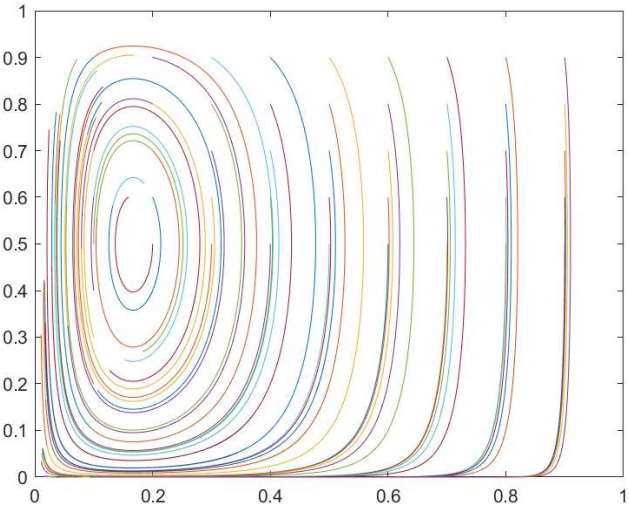

Fig. 4 (4)Evolution simulation diagram

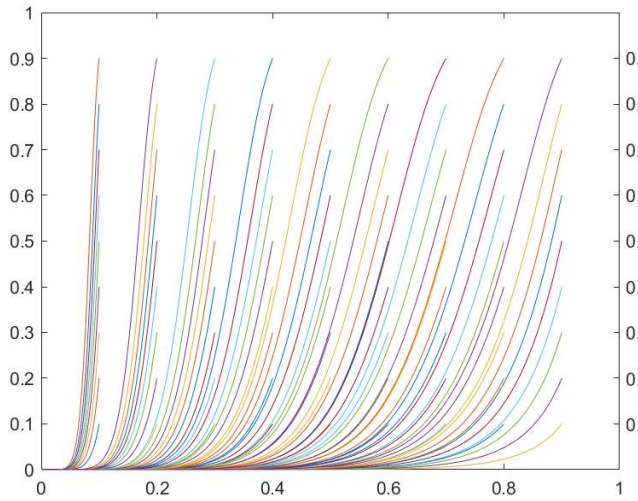

Fig. 5 (5)Evolution simulation diagram

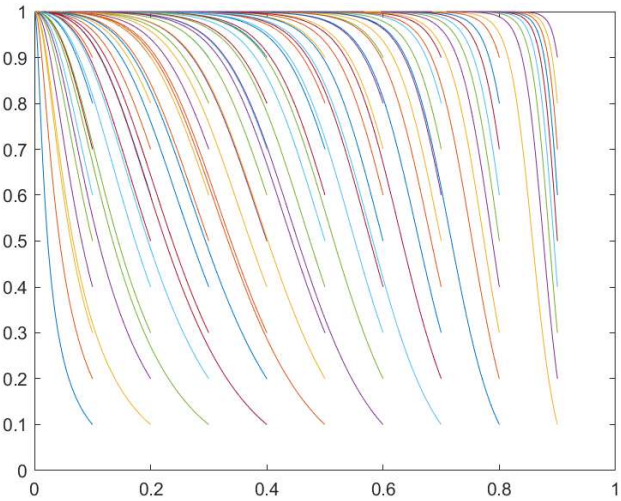

Fig. 6 (6)Evolution simulation diagram

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In order to show more intuitively the effects of consumers'low carbon preference, policy subsidy and penalty cost on consumers'probability of purchasing new energy vehicles and retailers'probability of product substitution in the transaction process of new energy vehicles, this paper uses Matlab software to carry out numerical simulation experiment. In order to make the system evolve to a more reasonable strategy (1,1),it is assumed that the initial probability of consumer and retailer strategy is (0.5,0.5),the following simulations are performed under the condition that the evolutionary strategy converges to (1,1) ,it need to be satisfied $\Delta H_2 < \Delta I + S_1$, $\Delta C < S_2 + g$, $\Delta C - (S_2 + g) < (1+\beta)\Delta L$,the parameters are $\Delta C = 18, \Delta L = 13, \Delta H_2 = 8$, $\Delta I = 9, \Delta H_1 = 5$.

As can be seen from the analysis in figure 7, when the value of consumer's low-carbon preference β (expressed in e for convenience in Matlab) is small, the convergence rate of the retailer's product substitution probability is faster in the simulation case, which means the retailer's product substitution probability is higher, and consumers are less likely to buy new-energy vehicles. In the early days of new-energy vehicle promotion, it is often cheaper for retailers to enter a new business area to complete the transformation, so in the early development of new energy vehicle market, even if the consumer demand for new energy vehicles is not substantial, combined with policy trends, environmental requirements, retailers will still choose to make product substitution decisions to sell new energy vehicles. As consumers'low carbon preference becomes higher, the convergence rate of retailers'product substitution probability tends to slow down, and the probability of consumers'purchasing new energy vehicles becomes higher. The simulation shows that the low carbon preference of consumers has a significant impact on whether consumers buy new energy vehicles, and also affects the sustainability of the promotion of new energy vehicles by retailers.

Controlling for other variables, so that β = 0.2, consumers'low carbon preferences are weaker, and in order to incentivize consumers to buy new energy vehicles, the subsidies that consumers get for buying new energy vehicles, S1 = 4,5,6,7, the simulation results are shown in figure 8. The analysis shows that with the increase of the subsidy S1, the probability of retailers'product substitution converges faster, because S1 is a subsidy for consumers to buy new energy vehicles, the bigger the S1, the stronger the tendency for consumers to buy new energy vehicles, and in this context, the greater the probability for retailers to make product substitutions. Through the analysis of the results, it is shown that the bigger the subsidy for consumers to purchase new energy vehicles, the more effective the probability of product substitution for retailers is S1 = 4, β = 0.2, and S2 = 7,8,9,10, S2 = 7,8,9,10, S1 = 4, β = 0.2, S2 = 0,(In order to facilitate representation in Matlab, H is used to represent)The simulation results are shown in figure 9. It is found that with the increase of subsidy S2, the rate of convergence of the retailer's product substitution probability is faster, which means that the higher the policy incentive subsidy value is, the faster the expansion of the new energy vehicle market is.

The other variables are the same, β=0.8(A strong preference for low carbon), S2=7, This paper discusses the influence of the penalty imposed on retailers for not doing product substitution on the product substitution decision probability, g=6,7,8,9, (In order to facilitate representation in Matlab, K representation) The simulation results are shown in figure 10. The analysis shows that when the penalty cost is small enough, the probability of the retailer's product substitution for the consideration of the transition cost tends to zero, when the penalty cost is large, the probability of product substitution is higher for retailers. The results show that when the policy penalty is large enough, the probability of product substitution strategy can be increased, and the new energy vehicle market can be expanded effectively.

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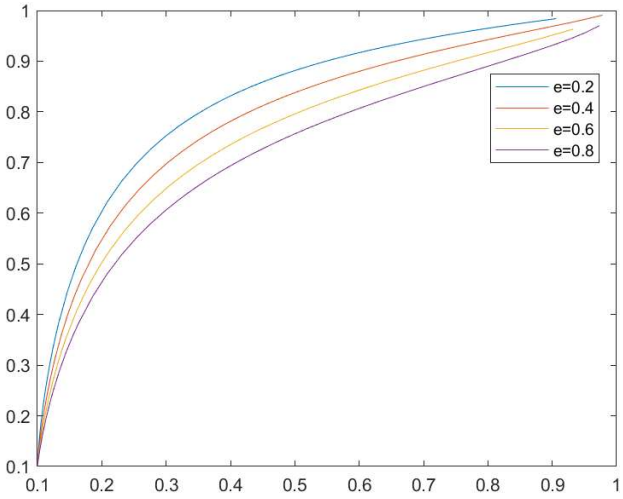

Fig. 7 Influence of low carbon preference on Retailer's product substitution probability

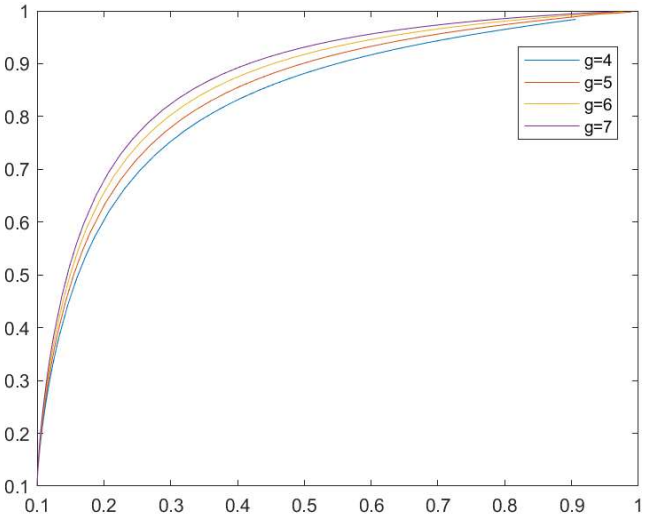

Fig. 8 Effect of policy subsidy S1 on the probability of product substitution by retailers

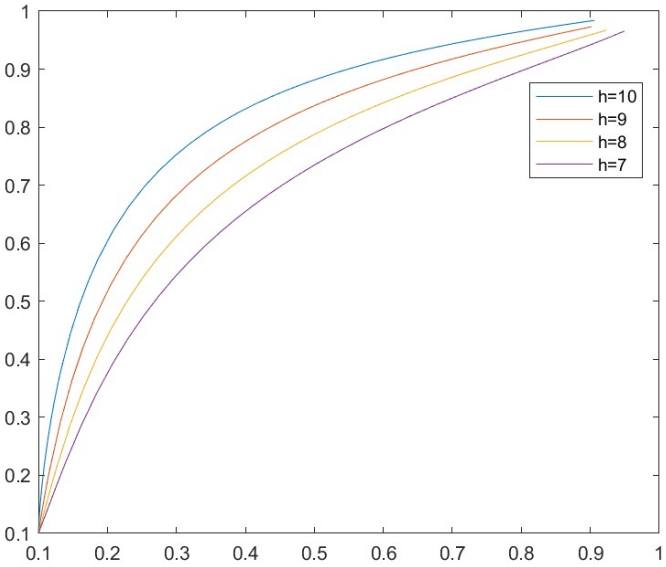

Fig. 9 Probability of policy subsidy S2 to retailers' product substitution decision

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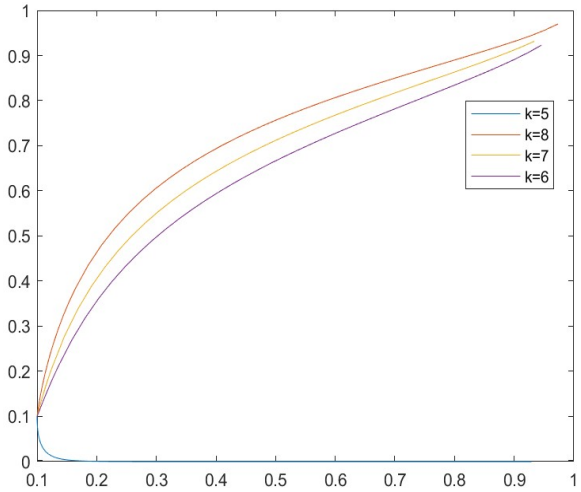

Fig. 10 The influence of policy punishment on the probability of product substitution by retailers

5. Conclusion

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By using the evolutionary Game Theory, it is concluded that there are four equilibrium strategies and one unstable strategy in the two-echelon supply chain system composed of retailers and consumers, the four equilibrium strategies are (buy new energy vehicle, do product substitution) , (buy new energy vehicle, don't do product substitution) , (don't buy new energy vehicle, do product substitution) , (don't buy new energy vehicle, don't do product substitution) . Taking the relatively reasonable (purchase the new energy vehicle, carry on the product substitution) strategy as the research object, carries on the further analysis through the Matlab simulation,it concludes that the factors that influence retailers'product substitution decision-making mainly include the following:

(1) Consumers'low carbon preference. According to the simulation analysis, it can be seen that when consumers'low carbon preference is low, the threshold for retailers to make the transition is low, and the cost of the transition is relatively low, it is a good time for retailers to carry out product substitution work, and the probability of retailers'product substitution is higher. With the increase of consumers'low carbon preference, consumers'demand for new energy vehicles increases, and market access requirements become higher, the probability of product substitution by retailers is reduced.

(2) Policy Subsidy. The policy subsidies in this paper are divided into two kinds, one is the subsidy for consumers, the other is the subsidy for retailers. Through simulation analysis, it is found that the policy subsidies can affect the decision-making choices of consumers and retailers, when the sum of the extra income and the policy subsidy is greater than the cost of transition, the retailer has a higher probability of product substitution. With the increase of the policy subsidy, the convergence rate of the transition probability of the retailer is faster, the higher the policy subsidy is, the higher the probability of product substitution is.

(3) Policy punishment. When retailers do not substitute products, they will not only bear the loss of customers'profits, but also face the policy penalty. The simulation analysis shows that when the policy penalty is relatively small, it is difficult to influence the retailers'product substitution strategy, that is, the probability of retailer's product substitution is small, and with the increase of policy penalty, the convergence rate of the probability of retailer's product

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substitution is faster, and the probability of retailer's product substitution is highest under the same consumer purchasing trend.

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