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Original Research

A Study of Green Strategy Choice and Behavioral Evolution of Consumers and Producers under the Double Subsidy Policy

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Abstract

Consumer behavior is an important factor influencing the green production of enterprises from the demand side, in order to explore the game relationship between producers and consumers under the government's double subsidy policy, the article combines the factors affecting the choice of consumers and producers, and based on the replication of dynamic equations, constructs a game model of the evolution of production behavior and consumption behavior and a simulation to analyze the evolution of the system. Through an in-depth analysis of the Chinese refrigerator market, we explore how different parameter settings affect the choice of strategies for system evolution. These parameters include the initial probability, the multiple ways of subsidies provided by the government, the product price, the perceived value of consumers, and the value of perceived loss. The results of the simulation experiment show that the whole system is more likely to evolve in the direction of green production and green consumption if firms have a stronger initial willingness toward green production and consumers are more inclined to green consumption. In addition, when the government implements both purchase subsidies and production subsidies, it can push the system to reach a steady state more quickly than if only a single subsidy measure is used. At the same time, price changes of different types of refrigerators can affect the evolution strategy of the system in different ways. After a series of analyses, we finally provide feasible suggestions for promoting green production by enterprises and green consumption by consumers, and at the same time, make a certain contribution to the reduction of air pollution.

Keywords: government subsidy, green production, green consumption, evolutionary game, air pollution

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Introduction

Green production refers to a comprehensive measure to minimize the production of pollutants by implementing pollution control in the whole process of industrial production with energy saving, consumption reduction, and pollution reduction as the goal and management and technology as the means. Green consumption not only refers to the consumer products being green but also includes the consumption behavior being green. The new green consumption is not single, episodic, but spans numerous times to carry out the long-term habits of life, which has a pulling effect on the production and circulation of green. In recent years, in the face of the deteriorating ecology, resource scarcity, frequent occurrence of extreme weather, and other serious environmental problems, people have gradually realized that although the crude and high energy consumption mode of production will bring about social progress, it will at the same time cause great external diseconomies. For example, the Freon refrigerant used in traditional refrigerators not only has a greenhouse effect on the atmosphere, but also destroys the ozone layer. Freon is a chemical containing elemental chlorine that destroys the ozone layer 15 to 25 kilometers above the earth, thus causing more ultraviolet rays from the sun to reach the surface, jeopardizing human health. The greenhouse effect occurs due to the fact that Freon generates a large amount of greenhouse gases, such as CO_2, during its chemical decomposition, thus causing the temperature of the earth to keep rising. The above are the adverse effects of using traditional refrigerators on the air environment. With the continuous development of science, now the refrigerator uses a refrigerant chemical composition that has no fluorine elements. In order to realize sustainable development, consumers buy mostly green refrigerators, but the high price of green refrigerators will also hinder the consumer's desire to buy to a certain extent. Therefore, under the government's double subsidy policy, it is of great practical significance to accelerate the development of green transformation and promote the construction of Chinese-style modernization by giving full consideration to the consumer's consumption behavior and studying the evolutionary game between the green production of enterprises and the green consumption of consumers.

This paper studies the evolutionary game process of green production of enterprises and green consumption of consumers. Firstly, the construction of the evolutionary model is carried out, according to a series of premise assumptions, to construct the payment matrix of the two sides of the game of enterprises and consumers. Secondly, the replication equation is listed and the Jacobi matrix is constructed. Thirdly, the parameters are assigned values according to the case data, and different factors are taken into account. Numerical simulation is conducted with a focus on consumer subsidies in the government's double subsidy policy. Finally, based on the conclusions drawn, corresponding recommendations are provided.

Material and Methods

Literature Review

By combing through the literature, it can be seen that at present, most of the relevant studies at home and abroad are aimed at a single system or the correlation between the two systems, and there are relatively few studies on the coordinated relationship between the two systems of green production and green consumption under the consideration of consumer behavior.

In terms of green production, Wang and Liu introduced the extra utility of green products and the responsiveness of consumers to the extra utility of green products, and explored the evolution paths and laws of the tripartite decision-making bodies of enterprises, consumers, and the government under the market-oriented mechanism [1]. In terms of external influences, Wang et al. investigated the mixed-strategy evolution game between the government and enterprises, and concluded that dynamic penalties are conducive to reaching game equilibrium and improving the environment [2]. Encarnacao et al. constructed an evolutionary game model of government, firms, and consumers and found that the synergy between the government and the public is crucial [3]. Xu et al. argued that on the basis of exogenous guidance of government behavior, emphasis should be placed on stimulating the important moderating effect of public participation [4]. Ma and Xia suggested that government subsidies for technological innovation and consumer green consumption utility influence firms' strategic choices [5]. Cao and Zhang, through simulation analysis, concluded that the government's public environmental protection publicity, innovation incentives, and pollution taxes and fees have a promotional effect on enterprises' green technological innovation [6].

In terms of green consumption, earlier studies on green consumption willingness and behavior mainly focused on the formation causes of green consumption, influencing factors, and how to promote green consumption. Firstly, in the exploration of influencing factors and causes, Hung et al. elaborated on the reasons for choosing green consumption from the perspective of consumer perception [7]. Consumers' environmental concern [8], green purchasing intention [9], and other intrinsic factors were also found to significantly influence green consumption intention and behavior. Secondly, regarding how to promote green consumption, Wang et al. [10] studied how to promote green consumption empirically. Yang et al. used strategy simulation to establish a dynamic decision-making model of green consumption behavior based on social networks, and used it to study the mechanism of green consumption promotion [11], while Zhang et al. used mathematical modeling to study differentiated pricing strategies under the win-win-win objective of enterprises, consumers and society based on historical information and consumer classification. In addition, in order to promote green consumption [12]. Kong et al. studied the role of green advertising information dissemination on green consumption behavior. It is not difficult to find that the research on green consumption willingness,

tendency, and behavior has become the focus of scholars' attention recently [13].

In terms of the relationship between green production and green consumption, Li et al. analyzed the game relationship between green production and green consumption by taking the manufacturing industry and agriculture as the research objects respectively [14]. Jin established a coupled coordination degree model to analyze the coupled coordination relationship between green production and green consumption in the Yangtze River Delta region as an example [15]. Shen et al. explored the coupled relationship between green production and green consumption by establishing a coupled coordination degree model using panel data in China's Yangtze River Delta region [16]. Other scholars have studied the green product pricing problem based on consumer behavior, the green production strategy of enterprises, and the impact of increased consumer environmental awareness on the green production decisions of governments and enterprises [13–16].

Compared with the existing literature, the research findings on the evolutionary game between corporate green production and consumer green consumption have been developed and supplemented in the following aspects [4, 8, 9–12, 15]. Firstly, the research findings reveal more deeply the synergistic evolutionary relationship between corporate green production and consumer green consumption. Existing literature tends to focus on unilaterally analyzing the green production behavior of enterprises or the green consumption behavior of consumers, but less on comprehensively analyzing both under the same framework. Secondly, the findings emphasize the importance of reducing corporate green production costs in promoting green consumption. While existing literature also mentions the issue of costs, it often fails to explore them in depth as a key factor affecting green consumption [17]. In addition, the findings highlight the important role of government subsidies in promoting green production and consumption. While the existing literature also mentions the role of the government, it tends to focus on policy formulation and regulatory aspects. This study further suggests that governments should increase incentives for green production and penalties for non-green production, which are key to promoting green production by enterprises. This finding helps governments to formulate and implement relevant policies more precisely in order to promote the synergistic development of green production and consumption [18].

Comprehensive analysis of the above, consumer green preference and purchasing power of green products are important factors to drive the green production of enterprises. In the existing research on the relationship between enterprises and consumers, most scholars take on the perspective of government subsidies and consumer behavior or perform a comprehensive consideration of government subsidies under the strategic behavior of the consumer to carry out the relevant research. There is little literature on consumer behavior used in the green production of enterprises and green consumption of consumer strategy games. Moreover, this paper not only considers the roles of multiple market players, but also includes the examination of consumer subsidies, so as to provide practical suggestions for each participant involved in green behaviors [19, 20]. At the same time, the cognitive parameters of the subject are introduced to make the evolutionary game process more relevant to reality and better portray the evolutionary game process of consumers' green consumption.

Evolutionary Model Construction

Premise Assumptions

In this paper through our in-depth analysis of the refrigerator market, it is assumed that the market is imperfectly competitive, specifically characterized by monopolistic competition. In this market structure, a large number of enterprises compete by offering differentiated products, and although the market share of each enterprise may be small, the barriers to entry and exit from the market are relatively low. Because of this, we employ an evolutionary game theory model to explore the evolutionary dynamics of enterprises' green production and consumers' green consumption strategies. We argue that evolutionary game theory models can effectively simulate the process of strategy adjustment between firms and consumers based on mutual influence in the absence of a central coordination mechanism. In order to adapt to a monopolistically competitive market environment, we make necessary adjustments to the model, including considering the impact of product differentiation on consumer choice and how firms adjust their green production strategies in response to market feedback. With these adjustments, we re-run the simulation analyses to verify the applicability and accuracy of our findings in the current market environment. The following is the basic setup of the model.

(1) Enterprises face two choices of green or traditional production in the production process, with probabilities α and $1 - \alpha$. Consumers also face two choices of purchasing green or traditional products, with probabilities β and $1 - \beta$, respectively.

(2) The enterprises price the green product at p_1 and the cost of producing the green product is c_1, and the enterprises price the traditional product at p_2 and the cost of producing the traditional product is c_2. By default, the enterprise's cost increases when it produces the green product, so $p_1 > p_2$ and $c_1 > c_2$.

(3) Assuming that the market supply and demand are in equilibrium, the quantity of green products purchased by consumers is Q_{p1}, the quantity of traditional products purchased is Q_{p2} , and the sum of the two is the total output of the enterprises Qs.

(4) Assume that the government encourages both green consumption and green production, and in order to stimulate the enthusiasm of consumers and producers, the government subsidizes green consumption by t and green production by t'.

(5) Assume that different consumers have different preferences and that both green products and traditional products can bring satisfaction to consumers. The value of consumers purchasing green products is recognized

as V_{g1}, and the value of purchasing traditional products is recognized as V_{g2}.

(6) Due to the market supply and demand equilibrium, if consumers cannot buy their favorite products, they will turn to buy another kind of goods, but it brings different subjective intentions. Assuming that the consumer's satisfaction with having to buy green products is r, the satisfaction with having to buy traditional products is 1 – r. Consumers who cannot buy their preferred products will incur a psychological loss, if they buy green products, the psychological perceived loss is L_1, and if they buy traditional products, the perceived loss is L_2. Based on the above assumptions of the evolutionary game model, the payment matrix of the two sides of the game between the enterprise and the consumer can be constructed, specifically.

If enterprises employ green production and consumers consume green products, the enterprises pay for Q_{P1} ($P_1 - C_1 + t'$), and the consumer pays for Q_{P1} ($V_{g1} - P_1 + t$). If enterprises produce green and consumers consume traditional products, the enterprises pay for rQ_{P1} ($p_1 - C_1 + t'$), and the consumer pays for rQ_{P1} ($V_{g2} - P_1 + t - L_1$). If enterprises use traditional production and consumers consume green products, the enterprises pay for (1 – r) ($P_2 - C_2$) Q_{P2}, and the consumer pays for (1 – r) ($V_{g1} - P_2 - L_2$) Q_{P2}. If enterprises use traditional production and consumers consume traditional products, the enterprises pay for (1 – r) ($P_2 - C_2$) Q_{P2}, and the consumer pays for (1 – r) ($V_{g1} - P_2 - L_2$) Q_{P2}.

Derivation Calculations for Evolutionary Game Models

Taking the expected return of the enterprise's production as the measurement basis, let the expected return of the firm to carry out green production be u_1, the expected return of the traditional production be u_2, and the average expected value be, which can be known according to the assumptions.

$$u_1 = \beta Q_{P1}(P_1 - C_1 + t') + (1 - \beta)\gamma Q_{P1}(P_1 - C_1 + t')$$

$$u_2 = \beta(1 - \gamma)Q_{P2}(P_2 - C_2) + (1 - \beta)Q_{P2}(P_2 - C_2)$$

$$\bar{u} = \alpha u_1 + (1 - \alpha)u_2$$

$$F(\alpha) = (1 - \alpha)\alpha\{\beta[Q_{P1}(P_1 - C_1 + t') - (1 - \gamma)Q_{P2}(P_2 - C_2)] + (1 - \beta)$$

$$[\gamma Q_{P1}(P_1 - C_1 + t') - Q_{P2}(P_2 - C_2)]\}$$

Take the expected return of consumer consumption as the measurement basis, so that the expected return of consumer green consumption E_1, the expected return of purchasing traditional products E_2. is the average return according to the assumption conditions.

$$E_1 = \alpha Q_{P1}(V_{g1} - P_1 + t) + (1 - \alpha)(1 - \gamma)Q_{P2}(V_{g1} - P_1 - L_2)$$

$$E_2 = \alpha\gamma Q_{P1}(V_{g2} - P_1 + t - L_1) + (1 - \alpha)Q_{P2}(V_{g2} - P_2)$$

$$\bar{E} = \beta E_1 + (1 - \beta)E_2$$

$$F(\beta) = (1 - \beta)\beta\{Q_{P1}\alpha[(V_{g1} - P_1 + t) - \gamma(V_{g2} - P_1 + t - L_1)] + (1 - \alpha)Q_{P2}$$

$$[(1 - \gamma)(V_{g1} - P_2 - L_2) - (V_{g2} - P_2)]\}$$

Let F(α) = 0 and F(β) = 0. At this point, 5 equilibrium points (0, 0) (0, 1) (1, 0) (1, 1), (α^*, β^*) are obtained.

$$\alpha^* = \frac{Q_{P2}[(V_{g2} - P_2) - (1 - \gamma)(V_{g1} - P_2 - L_2)]}{Q_{P1}[(V_{g1} - P_1 + t) - \gamma(V_{g2} - P_1 + t - L_1)] - Q_{P2}[(1 - \gamma)(V_{g1} - P_2 - L_2) - (V_{g2} - P_2)]}$$

$$\beta^* = \frac{Q_{P2}(P_2 - C_2) - \gamma Q_{P1}(P_1 - C_1 - t')}{(1 - \gamma)\, Q_{P1}(P_1 - C_1 - t') + \gamma Q_{P2}\,(P_2 - C_2)}$$

Where $\alpha^* \in (0, 1)$ and $\beta^* \in (0, 1)$.

The replication dynamic equation is listed according to equations (1) and (2), and the Jacobi matrix is constructed from this equation.

$$\frac{dF(\alpha)}{d\alpha} = (1 - 2\alpha)\{\beta[Q_{P1}(P_1 - C_1 + t') - (1 - \gamma)Q_{P2}(P_2 - C_2)] + (1 - \beta)[\gamma Q_{P1}(P_1 - C_1 + t') - Q_{P2}(P_2 - C_2)]\}$$

$$\frac{dF(\alpha)}{d\beta} = (1 - \alpha)\alpha[Q_{P1}(P_1 - C_1 + t') - (1 - \gamma)Q_{P2}(P_2 - C_2)] - [\gamma Q_{P1}(P_1 - C_1 + t') - Q_{P2}(P_2 - C_2)] = (1 - \alpha)\alpha[(1 - \gamma)Q_{P1}(P_1 - C_1 + t') + \gamma Q_{P2}(P_2 - C_2)]$$

$$\frac{dF(\beta)}{d\alpha} = (1 - \beta)\beta\{Q_{P1}[(V_{g1} - P_1 + t) - \gamma(V_{g2} - P_1 + t - L_1)] - Q_{P2}[(1 - \gamma)\,(V_{g1} - P_2 - L_2) - (V_{g2} - P_2)]$$

$$\frac{dF(\beta)}{d\beta} = (1 - 2\beta)\{\alpha Q_{P1}[(V_{g1} - P_1 + t) - \gamma(V_{g2} - P_1 + t - L_1)] + (1 - \alpha)Q_{P2}[(1 - \gamma)\,(V_{g1} - P_2 - L_2) - (V_{g2} - P_2)]\}$$

The Jacobi matrix expression is:

$$\begin{bmatrix} (1 - 2\alpha)\left\{\begin{matrix}\beta[Q_{P1}(P_1 - C_1 + t') - (1 - \gamma)Q_{P2}\,(P_2 - C_2)] \\ + (1 - \beta)[\gamma Q_{P1}(P_1 - C_1 + t') - Q_{P2}(P_2 - C_2)]\end{matrix}\right\} \\ (1 - \beta)\,\beta\left\{\begin{matrix}Q_{P1}[(V_{g1} - P_1 + t) - \gamma(V_{g2} - P_1 + t - L_1)] \\ - Q_{P2}[(1 - \gamma)\,(V_{g1} - P_2 - L_2) - (V_{g2} - P_2)]\end{matrix}\right\} \end{bmatrix}$$

$$\begin{bmatrix} (1 - \alpha)\alpha[(1 - \gamma)Q_{P1}(P_1 - C_1 + t') + \gamma Q_{P2}(P_2 - C_2)] \\ (1 - 2\beta)\left\{\begin{matrix}\alpha Q_{P1}[(V_{g1} - P_1 + t) - \gamma(V_{g2} - P_1 + t - L_1)] \\ + (1 - \alpha)Q_{P2}[(1 - \gamma)\,(V_{g1} - P_2 - L_2) - (V_{g2} - P_2)]\end{matrix}\right\} \end{bmatrix}$$

In 1991, Friedman D. pointed out that the equilibrium points of the two sides of the evolutionary game model can be deduced from the local equilibrium of the Jacobi matrix, and whether the local equilibrium point is the equilibrium stabilization point of the two sides involved in the game can be judged according to the rank of the Jacobi matrix and the positivity or negativity of the determinant.

To determine the stability of the system, the determinant must be positive and the trace value must be negative under

two conditions. If both values are positive, then this system is in an unstable state. If the Jacobi matrix trace value is 0, then the point is a saddle point. There are two stable strategies in the evolutionary game of production and consumption. (0, 0) indicates that enterprises choose traditional production and consumers choose traditional consumption. (1,1) indicates that enterprises choose green production and consumers choose green consumption. The saddle point indicates that the enterprises and consumers may eventually evolve into the strategy of green production and green consumption or the strategy of traditional production and traditional consumption in the process of the game [7–11, 21, 22].

Results and Discussion

In order to more intuitively show the impact of different original parameters on the final choice of evolutionary game strategy, we chose MATLAB programming software to carry out different parameter settings under the enterprise and consumer final evolutionary game path selection simulation. The specific case is Haier, one of the leading refrigerator brand enterprises in China. In 2023, Haier's refrigerator market share exceeded 40%, ranking first in the industry. In recent years, Haier has increased investment in refrigerator carbon reduction, committed to reducing the refrigerator energy consumption of green refrigerator production, to fully realize the scene instead of products, and ecological coverage of the industry vision. At the same time, in order to save energy and reduce emissions, benefit people's livelihood, and expand domestic demand, the government subsidizes production enterprises and consumer terminals through financial subsidies to further expand the market share of energy-saving and emission-reduction green refrigerators. Based on the actual production of Haier refrigerators, combined with the six assumptions of the evolutionary game model, the parameters are as follows.

Q_{p1} represents the market demand for green refrigerators with a value of 10 million units. Q_{p2} represents the market demand for traditional refrigerators, also with a value of 10 million units. P_1 indicates the price of green refrigerators, which is 6,000 yuan per unit. P_2 is the price

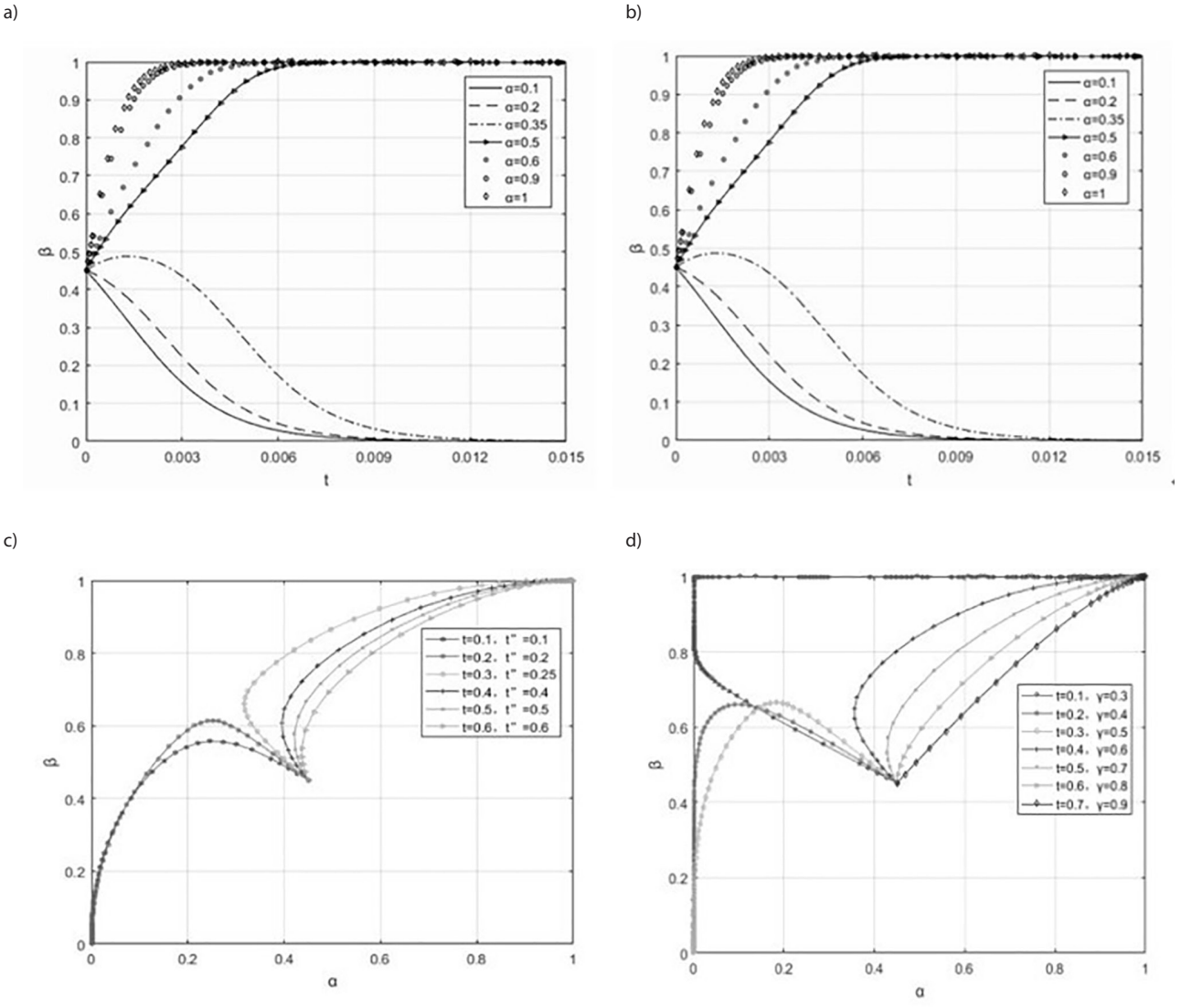

Fig. 1. Game evolution diagram.

of traditional refrigerators, which is 4,000 yuan per unit. C_1 is the production cost of green refrigerators, which is 5,000 yuan per unit. C_2 is the production cost of traditional refrigerators, which is 2,000 yuan per unit. V_{g1} is the consumers' estimated value of green refrigerators, which is 7,000 yuan per unit. V_{g2} is the consumers' estimated value of traditional refrigerators, which is 5,000 yuan per unit. t is the amount of subsidy given by the government for purchasing green refrigerators, which is 3000 yuan per unit. t' is the amount of subsidy given by the government to companies that produce green refrigerators, which is 4000 yuan per unit. L_1 is the perceived loss when a consumer buys a green refrigerator, and L_2 is the perceived loss when a consumer buys a conventional refrigerator for the same 6000 yuan. r is the consumer acceptance of green refrigerators, with a value of 0.4. α is the probability of firms producing green refrigerators, with a value of 0.45. β is the probability of consumers purchasing green refrigerators, which is 0.4. The setting of these parameters reflects the actual situation of the current refrigerator market and provides basic data for subsequent research and analysis.

The Effect of Raw Probabilities on the Final Outcome of Evolutionary Games

Different initial probabilities of enterprises and consumers will have different impacts on the final evolutionary game results. According to the MATLAB simulation results, the probability critical value of enterprises to produce green refrigerators is located between 0.25~0.45, as shown in Fig. 1. When the probability of the enterprise carrying out green production is lower than the critical value, the final evolution results in the production of traditional refrigerators. On the contrary, when the probability is higher than the critical value, the final evolution result is the production of green refrigerators. Fig. 1 (b) reflects the evolution of consumers purchasing green refrigerators with different initial probabilities, whose critical values are located between 0.35 and 0.50. When the probability of consumers purchasing green refrigerators is less than the critical value, the evolution results in traditional production. Conversely, when it is higher than the critical value, the final evolution result is green production. With the increasing probability of green production by enterprises and green consumption by consumers, the evolution speed of enterprises producing green refrigerators is accelerated. Combined with Fig. 1 (a) and (b), it can be seen that when both enterprises' green production and consumers' green consumption willingness are high, it will accelerate the emergence of the evolutionary outcome of enterprises' production of green refrigerators.

The Effect of the Government's Purchase Subsidy t for Green Refrigerators and the Subsidy t' for Enterprises' Production of Green Refrigerators on the Final Evolutionary Outcomes

Consider the impact of the joint effect of the government's purchase subsidy t to consumers and the government's subsidy t' to production enterprises on the final evolutionary game outcome. Fig. 1 (c) intuitively shows that the critical value of the government purchase subsidy is 0.20 thousand yuan to 0.30 thousand yuan, and the critical value of the government production subsidy is 0.20 thousand yuan to 0.25 thousand yuan. When both government subsidies to consumers and enterprises are below the critical value, the final evolutionary game result is (0, 0). (i.e. production of traditional refrigerators, consumption of traditional refrigerators). When the government subsidies to both sides are higher than the critical, the final evolution result is (1,1). (i.e. production of green refrigerators, consumption of green refrigerators). Combined with the simulation results, the government subsidy to the producer reduces the speed of the evolution result to (0,0), while accelerating the process to (1,1). The government subsidy to both sides produces a more obvious evolutionary effect.

The Joint Effect of Government Subsidy t and Consumer Acceptance r on the Final Evolution of Green Refrigerators

Fig. 1 (d) incorporates the consumer acceptance of green refrigerators r into the analysis, and it can be seen that the critical value of the government subsidy t to consumers is 0.30 thousand yuan to 0.40 thousand yuan, and the critical value of γ is 0.50 to 0.60. If both the government subsidy and consumer acceptance are lower than the critical value, the result of the evolutionary game is (0,0). If both government subsidies and consumer acceptance are higher than the critical value, the final evolutionary strategy of the system is (1,1). From the simulation results, the system will quickly converge to (1,1) when the government subsidy and consumer acceptance are at a high level and gradually increase. At the same time, the government's subsidy to consumers slows down the convergence of the system to (0,0) to a certain extent.

The Effect of Government Subsidy t on the Final Evolution of Green Refrigerators and the Prices of Green Refrigerators P_1 and Traditional Refrigerators P_2

Fig. 2 (e) intuitively reflects the final evolution of the system when the government's purchase subsidy t and the price of green refrigerators P_1 work together. It can be seen that the critical value of t is 0.25 thousand yuan to 0.30 thousand yuan, and the critical value of P_1 is 5 thousand yuan to 6 thousand yuan. When the values of the two parameters are lower than their respective critical values at the same time, the final evolution strategy of the enterprise and the consumer is (0, 0). At this time, the price of green refrigerators plays a decisive role in the system evolution results, with the increasing price, the system converges to (0, 0) speed up. When the values of the two parameters are higher than the critical value at the same time, the final evolution strategy of the system is (1,1). At this point, the government subsidy to consumers plays a decisive role in the evolution of the system, as the government subsidy t continues to increase, offsetting the result of the increase

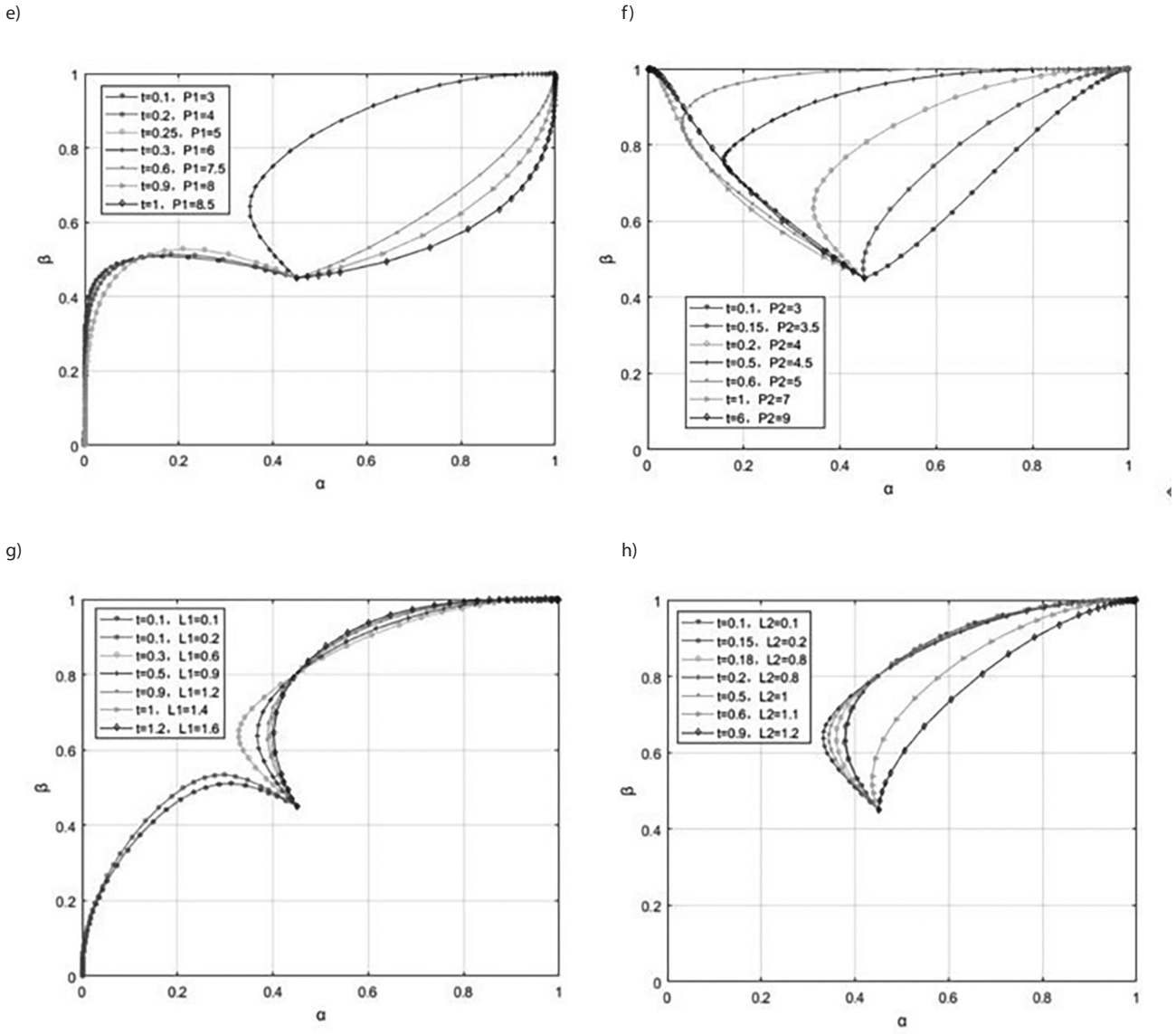

Fig. 2. Plot of evolutionary game results.

in the price of green refrigerators to the increase in consumer spending, where the increase in the price of green refrigerators will slow down the efficiency of the transformation of the strategy to a certain extent to (1,1).

Fig. 2 (f) considers the impact of the government's purchase subsidy t for green refrigerators and the traditional high refrigerator price P_2, and the critical values of the two parameters are 0.20 thousand yuan ~ 0.50 thousand yuan and 4 thousand yuan ~ 4.5 thousand yuan respectively. If both t and P_2 are less than the critical values, the system evolution strategy will converge to (1,1). When both t and P_2 are larger than the critical value, the consumer and producer evolutionary game system cannot reach a steady state. On the one hand, with the increasing price of traditional refrigerators, the tendency for producers to produce traditional refrigerators is increasing. On the other hand, the government's subsidy for consumers to buy green refrigerators is increasing, and in the context of the increasing price of traditional refrigerators, the consumer's choice gradually evolves into buying green refrigerators. Therefore, under the joint action of the two, the final system evolution strategy becomes (0,1), and the system is unstable.

The Effect of Government Subsidies for Buying Green Refrigerators t in Conjunction with the Perceived Loss of Buying a Green Refrigerator L_1 and the Perceived Loss of Buying a Conventional Refrigerator L_2 on the Final Evolutionary Outcome

Consumers expect to buy a specific type of refrigerator, but do not buy it in the end, which will result in psychological loss. Figure 2 (g) shows the results of the government subsidy t and the perceived loss of buying a green refrigerator L_1 together. The critical values of t and L_1 are 0.10 thousand yuan to 0.30 thousand yuan and 0.20 thousand yuan to 0.60 thousand yuan, respectively. When both parameter values are lower than the critical value, the evolutionary strategies of enterprises and consumers are (1,1). When

both t and L_1 are higher than the critical value, the evolution strategy of the system is (0,0). From the results, when consumers consider buying traditional refrigerators but buy green refrigerators, their perceived loss is low, at this time. The government subsidy for green refrigerators plays a decisive role in the results, and the government subsidy motivates consumers to buy green refrigerators. When the perceived loss is high, consumers prefer to choose traditional refrigerators, so the final evolution strategy of the system will prompt manufacturers to produce traditional refrigerators, and the system finally forms a steady state of (0, 0).

Fig. 2 (h) is the result of the combined effect of government subsidies t and the perceived loss of L_2 in the purchase of conventional refrigerators. The critical values of t and L_2 are 0.15 to 0.20 thousand yuan and 0.20 to 0.80 thousand yuan, respectively. From the results, it can be seen that the perceived loss of buying a traditional refrigerator plays a decisive role in the evolution of the system at this point, and as the value of L_2 keeps increasing, the system converges to (0,0) at a gradually slower rate. When the values of t and L_2 are both lower than the critical value, the evolution strategy of enterprises and consumers is (0,0). This means that it plays a decisive role in the evolution of the system, and as the value of L_2 increases, the system gradually slows down to (0,0). When t and L_2 are both higher than the critical value, the evolution strategy of the system is (1,1). Meanwhile, when the perceived loss of consumers buying traditional refrigerators is large, the government subsidy and perceived loss together motivate consumers to buy green refrigerators. With the increasing government subsidy and perceived loss, the system converges to (1,1) at an accelerating rate.

Conclusions

This paper pays special attention to the government's purchase subsidy, the consumer's subsidy, the consumer's acceptance, and the consumer's heart expectation in establishing the evolutionary game model. The research includes three main aspects:

(1) The impact of different initial probability evolutionary game results.

(2) The impact of individual variables on the final strategies of enterprises and consumers.

(3) The impact of bivariate variables on the final evolutionary strategy.

The conclusions of the study show that: Firstly, government subsidies have a greater impact on the final evolutionary outcome, and further research shows that the strength of unilateral government subsidies to enterprises or consumers on the final steady-state evolution is weaker than that of the realization of a double subsidy policy. Secondly, modern marketing concepts believe that enterprises should focus on consumer demand, but the products produced by enterprises will also affect consumers' purchasing decisions to a certain extent. Therefore, the price of a product becomes an important consideration for both corporate production and consumer consumption. Thirdly, consumers' subjective cognitive factors play an important role in the evolution of system strategies. When government subsidies and consumers' acceptance of green products increase, the value of green products and the perceived loss of not purchasing the desired products will increase the speed of the system's steady state evolution, which will have an important impact on the final evolution of the game results.

Suggestions

Based on the conclusions of the above analysis, it is possible to make separate recommendations for the government, enterprises, and consumers.

1. The government can formulate relevant environmental regulatory policies to provide incentives and penalties to enterprises and consumers, and give subsidies for technological innovation to enterprises that adopt green technological innovation and green production, while imposing certain penalties on enterprises that fail to adopt green technological innovation and green production. Enterprises can only choose their own behavioral patterns after they have constructed the bottom line of environmental compliance and made it clear that they must internalize the external diseconomies.

2. For products produced by enterprises, flexible pricing strategies can be realized in different regional markets. In the context of green and high-quality development, the transformation of enterprise green production benefits include not only direct economic benefits, but also brand benefits and the resulting business opportunities, the power of the market is much greater than the power of the government. So companies should actively research and develop innovation, reduce the price of new products, benefit the people, and give certain discount concessions, in order to stimulate consumers to buy green and reduce air pollution.

3. Observing consumers buying products helps fully understand the different needs of consumers and constantly optimize the customer experience. In the dual-carbon background, the state has repeatedly advocated that society as a whole practice the concept of green consumption, to enhance consumer awareness of green environmental protection. As for consumers, it is important to raise their awareness of environmental protection in their daily lives, let them take the initiative to change their consumption patterns, respond to the call of the State and the Government, and actively participate in green consumption.

Research Limitations

This paper explores the green strategy choice and behavior of consumers and producers under the double subsidy policy by conducting an evolutionary study and considering consumer behavior in order to construct a game model of the evolution of production behavior and consumption behavior, but there are some limitations.

(1) Limitations of theoretical assumptions. The theoretical basis of game evolution in this paper is often based on some simplified assumptions, such as the complete rationality of the participants and the complete symmetry

of information. However, in reality, these assumptions are often difficult to establish.

(2) Adaptability to a dynamic environment. Game evolution models are usually designed for static or relatively stable environments. However, many situations in the real world are dynamically changing, including the market environment, technological advances, policy adjustments, etc., and these changes may lead to the original equilibrium state being broken.

(3) Neglect of social and cultural factors. Game evolution models tend to focus on the analysis of economic and technical factors while neglecting the impact of social and cultural factors on strategy selection. However, in real life, factors such as social norms, cultural traditions, and values often have a significant impact on participants' decisions.

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Conflict of Interest

The authors declare no conflict of interest.

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