Evolutionary dynamics of Chinese tourism market extremely low-priced strategies based on wright-fisher processes

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Abstract. Extremely low-priced of package tours is an important cause of Chinese tourism market price disorder. Regulating the price of package tours in Chinese tourism market, can solve the problem of Chinese tourism market price disorder. In order to research the reason of extremely low package tours price, consider the stochastic dynamics of N homogeneous mixed travel agency pricing strategies, and each travel agency could choose Extremely low-pricing or regular pricing. Based on Wright-Fisher processes, we obtain the dominant strategy of Extremely low-pricing and regular pricing under the weak selectivity in the package tours price setting, when the travel agency groups are finite. And then further verify these conditions by numerical simulation.The simulation shows that the Price elasticity of tourism demand, the transparency of the tourism market and the degree of government supervision strength have important effects on the stochastic evolution of package tours price setting. Reducing the demand elasticity of tourism market, increasing the transparency of the tourism market and the degree of government supervision strength can make travel agency choose regular pricing and solve chaotic of Chinese tourism market further. Therefore, this paper puts the suggestion of "two increases and one decrease" for the development of Chinese tourism market.

1. Introduction

Extremely low-priced of package tours is a chronic disease of Chinese tourism industry, which first appeared in the 1990s. In recently, with the occurrence of "compulsive shopping" and "abusive tourist" and other tourism complaints due to extremely low-priced of tours market [1]. The public is starting to concerned about the tourism market price disorder caused by extremely low-priced of package tours. For a time, extremely low-priced of package tours were pushed to the forefront of public opinion and led to declining the credibility of China's tourism market. Therefore, extremely low-priced of package tours has seriously affected the image of Chinese tourism market and inhibited the development of Chinese tourism industry.

Extremely low-priced of package tours is a tourism market price disorder, which violated the objective economic law. Pricing strategies of tourist product providers is an important factor that caused tourism market price disorder. In the mass tourism market, travel agencies usually are the main suppliers of the package tours products. The pricing strategy of travel agencies has a direct impact on the price of products in the tourism market. Thus, the travel agency is the liability subject of Chinese tourism market price disorder, and the low-priced strategy of travel agency is the important factor which led to Chinese tourism market price disorder. So, researching the pricing strategies of travel agencies is significant to solve tourism market price disorder and keep the Chinese tourism industrial consistent developing.

2. Literature review

Nowadays, most of the research on travel agency pricing strategy game in academia is based on the infinite overall and completely rational object model. Long Yong and others studied the pricing strategies of travel agencies when they cooperated with online tourism platforms based on Stackelberg game. Long Yong believed that the pricing of tourism products by travel agencies was mainly affected by the Commission threshold and marginal service cost. In the cooperation between them, online tourism platforms always wanted to keep the prices of tourism products low. Therefore, Online Tourism Platform will be more inclined to choose travel agency cooperation with lower service cost. According to Picazo P [2] and Estrella Díaz [3], the pricing strategy of travel agency is mainly influenced by the marketing strategy of travel agency. The brand image and marketing content of travel agency will affect the final pricing decision of travel agency. [3,4] Furthermore, Joaqun Alegre found that the tourism market environment also has a certain impact on the pricing strategy of travel agencies through comparative study of the tourism market prices in Germany and Britain. When the tourism market is oligopoly, travel agencies tend to implement the low-price strategy because of fierce intra-industry competition.[5] The result is similar, Guanhua studied the pricing strategy of Chinese travel agencies based on Bertrand model, and found that the travel agency industry in China is in an oligopoly competition state.[6] Because of the high homogeneity of Chinese tourism commodities, there exists intense price competition among travel agencies. It is based on the principle that market price equals marginal cost to price tourism commodities. Meanwhile, based on fair preference Lin Qiang analyzed the pricing strategy of travel agency in game with other players in tourism commodity supply chain. Lin believed that the pricing strategy of travel agency in game with other players in tourism commodity supply chain was related to whether the information of game system was symmetrical or not. When the information of game system was asymmetrical, the game system will be a zero-sum game, the travel society adopts a low-price strategy to compete with other main bodies in the tourism commodity supply chain because of its complete rationality.[7] For further explore price competition among the Chinese travel agencies, NingzeQun analyzed the development trend of Chinese travel agency industry from 1997 to 2000. Though the research on the Profit and Loss Statements of Chinese travel agency, Ning found a paradox of Chinese tourism industrial that the number of Chinese travel agencies' entry and their profitability show a reverse trend. For this paradox, Ning put forward a theory of "tourism black box pricing". It is meaning in Chinese tourism market, the process of tourism consumption is a black box, so that travel agencies can make up for their losses due

to intense price competition by forcing them to make extra consumption in the process of providing tourism services [8].

Through the analysis of the above literature, we can see that the current studies on the pricing strategy of travel agencies is usually carried out under the scenario of competition and cooperation between travel agencies and other main bodies in the tourism commodity supply chain, and the theoretical model is mainly based on the object model of infinite totality and complete rationality. However, due to the existence of external factors such as national policy, corporate responsibility and market threshold, the number of travel agencies is always limited. Therefore, the basic hypothesis of infinite totality is a common defect in the study of travel agency pricing strategy in the current academic circles. And meanwhile, as the literature shows, the intense price competition of Chinese travel agencies is the main reason of extremely low-priced tourism products. According to Bertrand's price competition model, the excessive competition within the industry has a more significant impact on the emergence of very low prices than excessive competition within other stakeholder in the industrial chains.[9] Compared with other tourism-related acts, competition and game among different travel agents will have more significant impact on the pricing strategy of travel agencies. However, reviewing the literature, we can see that there are many studies on pricing competition between travel agencies and other tourism-related subjects in the academic circles, but there are few studies on pricing competition between different travel agencies.

Under the actual situation, however, the number of travel agencies is limited, and pricing decisions are limited and rational. The final pricing strategy of travel agencies always needs several dynamic games to converge to a stable state. Therefore, the evolutionary game theory has better applicability in the analysis of travel agency pricing decision-making process. So, in this paper, we based on the assumption of limited rationality and limited aggregate, studies the price competition and pricing game among different travel agencies under the scenario of intra-species competition and cooperation, analyzing and describing the evolution process of pricing strategy of travel agencies.

The evolutionary game with finite population has been discussed extensively in the field of biology and behavioral economics [10]. Schaffer analyzed the economic meaning of evolutionary learning from the viewpoint of evolution [11], and extended Smith's concept of infinite population evolutionary stability to finite population [12]. Based on the research of Schaffer, Tanaka and Ania further discussed the evolutionary game characteristics of finite population ,and believed that the evolutionary game dynamics of finite population is a stochastic process [13,14]. Nowadays, The evolutionary game dynamics of a finite population is mainly studied by means of the frequency-dependent Moran and Wright-Fisher processes [15-21]. The former is an asynchronous update process, in which, at each time step, an individual in a population is selected to produce a descendant proportional to its fitness and its offspring replaces a randomly selected individual [22]. The Wright-Fisher evolutionary process is also a stochastic process, but unlike the Moran process, it is synchronous. In each generation, individuals produce offspring proportional to their payoff. The next generation is sampled randomly from this pool of offspring. The total population size is constant. Therefore, every time step in the Wright-Fisher process corresponds to an entire generation of N time steps in the Moran process[23]. In 2006, for the first time, Imhof and Nowak pro-posed that the dynamic evolution of a finite population can be studied by a frequency-dependent Wright-Fisher process and studied the fixation probability in

a 2×2 game model [24]. Traulsen pointed out that, in an infinite population, strict Nash equilibrium evolution is always stable, but in a limited population, random effects can cause the system to deviate from strict Nash equilibrium. For the reason [25], Traulsen produced a new evolutionary stability concept and proved that the two equilibrium concepts can be gained from both the frequency-dependent Moran and Wright-Fisher processes.

Analogical ecology shows that price competition among different travel agencies is essentially an intraspecific competition and intraspecific game phenomenon. In this phenomenon, the learning and replacement process of travel agency's population strategy will be displayed, so the Moran process and Wright-Fisher process have better applicability to the research of the evolution of pricing strategy in travel agency's population. In fact, the evolution of strategies among different travel agencies is usually simultaneous and synchronous. Therefore, based on the actual situation, this paper uses frequency-dependent Wright-Fisher process to study the evolution of intraspecies pricing strategy of Chinese travel agencies, in order to explore the evolution mechanism of extremely low-priced of package tours in Chinese tourism market, and solving the problem of tourism market price disorder.

3. Model

3.1. Evolutionary Game Theory

Ever since Smith, Price and Taylor put forward the basic concepts of evolutionary stability strategy and replicating dynamic equation[26], evolutionary game theory has been widely used in various fields. Evolutionary game theory, as the main theory to analyze the evolution process of group strategy, has good applicability to the study of decision evolution in group game. In recent years, evolutionary game theory has been used in the study of ecotourism development and tourism conflict, which involves the interests conflict of multi-party tourism subjects.

In evolutionary game theory, the stable convergence evolution of game process is mainly described by replication dynamic equation. The replication dynamic equation is:

$$\frac{dx_i(t)}{dt} = [u(e^i, x) - \sum_{i=1}^{k} x_i u(e^i, x)] x_i$$

In this equation, each individual can choice strategies i or other strategies, the probability of strategies i is x_i, while the $u(e^i, x)$ refers to the expected payoff of strategies i in the game.

From the replication dynamic equation of evolutionary game, can be found the game population in evolutionary game analysis needs to be assumed as an infinite population, so that the replication dynamic equation can be expressed in differential form. For this reason, when study evolutionary game of finite population, the stochastic process should be introduced to.

3.2. Wright-fisher process with different selection intensities

Studied the evolutionary game dynamic in a mixed homogeneous finite population. Suppose a population that consists of a fixed number of N individuals, each individual can be of one of two types, A or B, where A -type individuals refer to those who adopt strategy A in the game, do B type individuals, and every individual can interact with any other. The state of the population is fully characterized by the numbers i of individuals of using strategy A and N − i of individuals using strategy B. The payoffmatrix for the game is:

$$\begin{array}{cc} & \begin{array}{cc} A & B \end{array} \\ \begin{array}{c} A \\ B \end{array} & \begin{bmatrix} a & b \\ c & d \end{bmatrix} \end{array}$$

In this game, the average payoffs of individuals using strategies A and B are given by:

$$F = \frac{a(i-1) + b(N-i)}{N-1} \;, G = \frac{ci + d(N-i-1)}{N-1}$$

Under a classical evolutionary game dynamic framework, the expected payoff represents the fitness. However, from the perspective of heredity transmission, the individual reproduction rate is proportional to the corresponding game revenue. Therefore we should consider the difference in selection intensities ω of the two types of individuals are introduced.[27] The fitness of an A and B individual is given by:

$$f = 1 - w + wF \;, g = 1 - w + wG$$

Suppose that in the current generation i individuals use strategy A. Then, the composition of the next generation is determined through N independent binomial trials. So, the Wright-Fisher evolutionary process is a discrete-time Markov chain with the state space $\{0, 1 \cdots\cdots N\}$ and transition probabilities

$$P_{ij} = \binom{N}{j} \left(\frac{if_i}{if_i + (N-i)g_i} \right)^j \left(1 - \frac{if_i}{if_i + (N-i)g_i} \right)^{N-j}$$

Where $\binom{N}{j} = C_N^j$.

3.3. Parametric Hypothesis

In actual market, different travel agencies have many strategic choices in pricing game. In order to highlight the evolution of extremely low-priced and simplify the analysis process, this paper assumes that the travel agency population is a limited and homogeneous single population mixed with multiple travel agencies, and that there are only two kinds of pricing strategies within the population, namely " extremely low-priced strategy" and "normal pricing strategy". The following are specific parameter assumptions.

Hypothesis 1. In a travel agency market (M), there are N travel agencies that provide the same goods. These travel agencies have the same market position and are all bounded rational individuals. In this market, the expected payoff of travel agencies just effected by their strategy, instead of their market position. Therefore, the pricing strategy game between each travel agency is symmetrical game.

Hypothesis 2. In M market, the pricing strategy of each travel agency can be of one of two types, T_y (y = 1,2). In here, T_1 strategy denotes the set of extremely low-price pricing strategies and T_2 strategy denotes the set of normal pricing strategies. Among them, we assume the number of travel agencies who select strategy T_1 is i, and the number of travel agencies who select strategy T_2 is j, and i + j = N.

Hypothesis 3. In M market, the total tourism demand is L, the demand elasticity is θ . In T_1 strategy, Travel agencies will set the price of tourism products is P_1.While in strategy T_2, Travel agencies will set the price of tourism products is P_2.Where $P_2 \gg P_1$.

Hypothesis 4. Based on the research of Andrea[28] ,this paper supposes that when the pricing strategy in M market is the same, the tourism demand will be digested by all travel agencies on average. When there are different pricing strategies in M market, part of the tourism demand of the higher-priced side will flow to the lower-priced side. Based on Alfred Marshall's demand elasticity theory, this paper assumes that the change of tourism demand flow is ΔQ. Where ΔQ is a function of θ, $\Delta Q = (1 - \frac{P_1}{P_2}) \frac{L\theta}{2}$, and $(0 \le \Delta Q \le \frac{L}{2})$.

Hypothesis 5. Review the research of Chinese tourism Market, when the travel agencies choose extremely low-price pricing strategies, with information dominance, they usually compensate for the loss of extremely low-price pricing strategies by forcing tourists to shop and increasing additional tourism consumption in the process of providing tourism services[29].   For this reason, it is assumed that the travel agencies with strategy T_1 have additional Grey Income (G), and that the additional Grey Income (G) is a function of the pricing difference , $G = k\ (P_2 - P_1)$, where k as a compensation coefficient, which is negatively correlated with the transparency of tourism market.

Hypothesis 6. As well known, the Chinese government's behavior has a great Impact on Chinese tourism market. In order to analyze the influence of government behavior on travel agency pricing game, this paper introduces the parameter of government punishment behavior(F).It is assumed that, in order to ensure market price order, when there are travel agencies in M market that are far below the average market price, they will be punished economically by government(F).

Based on the above hypothesis, the symmetric game payment matrix is obtained as shown in Table 1. Because of the symmetry, this paper only gives the payment matrix of a single entity.

Table 1. Symmetric game payment matrix.

	T_1	T_2
T_1	$\frac{L}{2}P_1 + G$	$\left(\frac{L}{2} + \Delta Q\right)P_1 + G - F$
T_2	$\left(\frac{L}{2} - \Delta Q\right)P_2$	$\frac{L}{2}P_2$

3.4. Stochastic game Model

3.4.1. Fitness calculation

According to the parameter hypothesis and the payment matrix, the expected payoff of travel agencies chooses T_1 and T_2 strategies without considering the individual's own game are

$$F_i = \frac{(\frac{L}{2}P_1 + G)\ (i - 1) + [\ (\frac{L}{2} + \Delta Q)\ P_1 + G - F\ ](N - i)}{N - 1}$$

$$G_i = \frac{P_2(\frac{L}{2} - \Delta Q)\ i + \frac{L}{2}P_2(N - i - 1)}{N - 1}$$

(1)

consider the difference in selection intensities ω .Then the fitness of T_1 and T_2 strategies are

$$f_i = 1-\omega+\omega F_i = 1-\omega+\omega\frac{(\frac{L}{2}P_1+G)\,(i-1)+[\,(\frac{L}{2}+\Delta Q)P_1+G-F](N-i)}{N-1}$$

$$g_i = 1-\omega+\omega G_i = 1-\omega+\omega\frac{P_2(\frac{L}{2}-\Delta Q)\,i+\frac{L}{2}P_2(N-i-1)}{N-1} \tag{2}$$

Selective intensity ω is a description of the contribution of expected payoff to actual fitness. For a finite population model, however, the parameters ω have an impact on the long-term behavior. If $\omega = 0$, then $f_i = g_i = 1$,for all states i and covers the case of neutral selection. If $\omega = 1$, then $f_i = F_i, g_i = G_i$,the game will be in a state of complete rationality. This case is the so-called strong selection. If $\omega \in \{\omega | 0 < \omega < 1\}$ then the payoffs from the game have only a marginal influence on fitness f_i and g_i, the game will be in a state of bounded rationality. This case is the so-called weak selection. [30] Realistic, the pricing strategies of travel agencies are bounded rationality. Thus, this paper assumes $\omega \in \{\omega | 0 < \omega < 1\}$.

Due to the requirement of non-negative fitness in genetic algorithm, based on the formula (2), the fitness function is modified by adding $\propto$ correction coefficient. The corrected fitness is

$$f_i = 1-\omega+\omega F_i = 1-\omega+\omega\frac{(\alpha+\frac{L}{2}P_1+G)\,(i-1)+[\alpha+(\frac{L}{2}+\Delta Q)P_1+G-F](N-i)}{N-1}$$

$$g_i = 1-\omega+\omega G_i = 1-\omega+\omega\frac{[\alpha+P_2(\frac{L}{2}-\Delta Q)]\,i+(\alpha+\frac{L}{2}P_2)(N-i-1)}{N-1} \tag{3}$$

$$\left(\omega\in(0,1);\ f_i>0;\ g_i>0\right)$$

3.4.2. Dynamic Equation

Based on the independent binomial distribution characteristics of policy update in Wright-Fisher process.[31] Formula (3) shows that the probability of generating T_1 strategy in each experiment is as follows:

$$P_i = \frac{if_i}{if_i+(N-i)g_i}\ ,\quad i\in(0,N) \tag{4}$$

Therefore, the process of generation of T_1 strategy individuals is a N-weight Bernoulli experiment with probability of $P_i = \frac{if_i}{if_i+(N-i)g_i}$. So, the Proportion evolution of T_1 strategy from I to Δi is a discrete-time Markov chain with the state space $\{0,1\cdots\cdots N\}$ and transition probabilities:

$$P_{i\Delta i} = \binom{N}{\Delta i}\left(\frac{if_i}{if_i+(N-i)g_i}\right)^{\Delta i}\left(1-\frac{if_i}{if_i+(N-i)g_i}\right)^{N-\Delta i} \tag{5}$$

Since the individual strategy updating is synchronized in Wright-Fisher process, it is assumed that the individual strategy updating step is $\Delta t(\Delta t > 0)$. The frequency of T_1 strategy at t-Time is x(x =

$\frac{i}{N}$).Thus, When the total number of N is large and finite, the evolution relationship between frequency

X and time t of T1 strategy in Wright-Fisher process can be described by Langevin equation[32].

$$\frac{dx}{dt} = m(x) + \sqrt{v(x)}\xi \tag{6}$$

Where, $m(x) = \frac{E(\Delta x)}{\Delta t}$ is drift term, $v(x) = \frac{E[(\Delta x)^2]}{\Delta t}$ is diffusion term, ξ is gauss noise and Δx is

the unit step of T_1's increment. Substitute $x = \frac{i}{N}$ into $m(x)$ and $v(x)$, we can obtain the result:

$$m(x) = m(\frac{i}{N}) = \frac{E(\Delta(\frac{i}{N}))}{\Delta t} = \frac{1}{N}\frac{1}{\Delta t}\sum_{\Delta i=0}^{N}(\Delta i - i)\binom{N}{\Delta i}(P_i)^{\Delta i}(1-P_i)^{N-\Delta i}$$

$$= \frac{1}{\Delta t}[(\frac{if_i}{if_i + (N-i)g_i}) - \frac{i}{N}] \tag{7}$$

$$v(x) = v(\frac{i}{N}) = \frac{E(\Delta(\frac{i}{N})^2)}{\Delta t} = \frac{1}{N}\frac{1}{\Delta t}\frac{if_i(N-i)g_i}{[if_i + (N-i)g_i]^2}$$

When the total number of N is large and finite, namely $N \to \infty$,

$$\lim_{N\to\infty} m(x) = \lim_{N\to\infty} m(\frac{i}{N}) = \frac{1}{\Delta t}[(\frac{\frac{i}{N}f}{\frac{i}{N}f + (1-\frac{i}{N})g}) - \frac{i}{N}] = \frac{1}{\Delta t}[(\frac{xf}{xf + (1-x)g}) - x] \tag{8}$$

$$\lim_{N\to\infty} v(x) = \lim_{N\to\infty} v(\frac{i}{N}) = 0$$

Where $f = 1 - \omega + \omega\left(x\left(\alpha + \frac{L}{2}P_1 + G\right) + (1-x)\left(\alpha + \left(\frac{L}{2} + \Delta Q\right)P_1 + G - F\right)\right)$, $g = 1 - \omega +$

$\omega\left(x\left(\alpha + P_2\left(\frac{L}{2} - \Delta Q\right)\right) + (1-x)\left(\alpha + \frac{L}{2}P_2\right)\right)$.

So, form the dynamic equation of frequency-dependent Wright-Fisher process based on equation (8) is obtained as follows:

$$F(x) = \frac{dx}{dt} = m(x) + \sqrt{v(x)}\xi = \frac{1}{\Delta t}[(\frac{xf}{xf + (1-x)g}) - x]$$

$$= \frac{1}{\Delta t}\frac{x(1-x)(f-g)}{x(f-g) + g} \tag{9}$$

4. Strategic stability analysis

4.1. Stability Point discussion

If there is a stable strategy in Wright-Fisher process, the dynamic equation needs to be

satisfied $F(x) = 0$,Substitute $f = 1 - \omega + \omega \left(x \left(\alpha + \frac{L}{2} P_1 + G \right) + (1 - x) \left(\alpha + \left(\frac{L}{2} + \Delta Q \right) P_1 + G - F \right) \right)$, $g = 1 - \omega + \omega \left(x \left(\alpha + P_2 \left(\frac{L}{2} - \Delta Q \right) \right) + (1 - x) \left(\alpha + \frac{L}{2} P_2 \right) \right)$ into equation(8):

Thus,

$$F(x) = \frac{1}{\Delta t} \frac{x(1-x)\omega \left(x(F + P_2\Delta Q - P_1\Delta Q) + \frac{L}{2}P_1 - \frac{L}{2}P_2 + P_1\Delta Q + G - F \right)}{x\omega \left(x(F + P_2\Delta Q - P_1\Delta Q) + \frac{L}{2}P_1 - \frac{L}{2}P_2 + P_1\Delta Q + G - F \right) + 1 - \omega + \omega \left(x(\alpha + P_2(\frac{L}{2} - \Delta Q)) + (1-x)(\alpha + \frac{L}{2}P_2) \right)} \quad (10)$$

Let $\sigma = \omega \left(x(F + P_2\Delta Q - P_1\Delta Q) + \frac{L}{2} P_1 - \frac{L}{2} P_2 + P_1\Delta Q + G - F \right)$, $\eta = x\omega(x(F + P_2\Delta Q - P_1\Delta Q) + \frac{L}{2} P_1 - \frac{L}{2} P_2 + P_1\Delta Q + G - F) + 1 - \omega + \omega(x(\alpha + P_2 \left(\frac{L}{2} - \Delta Q \right) + (1 - x)(\alpha + \frac{L}{2} P_2))$.

Thus, Formula (10) can be reduced to

$$F(x) = \frac{1}{\Delta t} \frac{x(1-x)\delta}{\eta} \quad (11)$$

Let $F(x) = \frac{dx}{dt} = 0$, there are two solutions can be obtained, $x_1 = 0$, $x_2 = 1$.

If the evolution stable state $x_i (i = 1,2)$ is stable, then x_i is robust to small fluctuation disturbance. Therefore, based on the stability theorem of differential equation, the stability point $x_i (i = 1,2)$ needs to satisfy the conditions $F(x)' = 0$ before it can evolve to a stable state, which was introduced by Richard Bellman (1980).Thus, this paper gets definitions as follows.

Definition 1. When $x_1 = 0$ is a stable point of intra-species pricing game for travel agencies, the parameters need to satisfy condition $S_1 = \left\{ G + P_2\Delta Q < \frac{L}{2}(P_2 - P_1) \right\}$.

Definition 2. When $x_2 = 1$ is a stable point of intra-species pricing game for travel agencies, the parameters need to satisfy condition $S_2 = \left\{ P_1\Delta Q + G - F > \frac{L}{2}(P_2 - P_1) \right\}$.

Proof.: Derivation of formula (11), thus

$$F(x)' = \frac{1}{\Delta t} \frac{((1-x)\delta - x\delta + x(1-x)\delta')\eta - x(1-x)\delta\eta'}{\eta^2} \quad (12)$$

Substitute $x_1 = 0$ and $x_2 = 1$ into equation (12), we obtain

$$F(0)' = \frac{\delta(0)}{\eta(0)} = \frac{1}{\Delta t} \frac{\omega\left(\frac{L}{2}P_1 - \frac{L}{2}P_2 + P_1\Delta Q + G - F\right)}{1 - \omega + \omega\left(\alpha + \frac{L}{2}P_2\right)}$$

$$\text{(13)}$$

$$F(1)' = -\frac{\delta(1)}{\eta(1)} = \frac{1}{\Delta t} \frac{-\omega\left(\frac{L}{2}P_1 - \frac{L}{2}P_2 + G + P_2\Delta Q\right)}{1 - \omega + \omega\left(\alpha + \frac{L}{2}P_1 + G\right)}$$

If $F(0)' < 0$,then $\dfrac{1}{\Delta t}\dfrac{\omega\left(\frac{L}{2}P_1 - \frac{L}{2}P_2 + P_1\Delta Q + G - F\right)}{1 - \omega + \omega\left(\alpha + \frac{L}{2}P_2\right)} < 0$. From equation （3）, we can see 0<ω<1 and $1 -$

$\omega + \omega\left(\alpha + \frac{L}{2}P_2\right)$ >0.Beacuse of $\Delta t > 0$,to make $\dfrac{1}{\Delta t}\dfrac{\omega\left(\frac{L}{2}P_1 - \frac{L}{2}P_2 + P_1\Delta Q + G - F\right)}{1 - \omega + \omega\left(\alpha + \frac{L}{2}P_2\right)} < 0$, just let $\frac{L}{2}(P_1 - P_2) +$

$P_1\Delta Q + G - F < 0$,namely $P_1\Delta Q + G - F < \frac{L}{2}(P_2 - P_1)$.

If $F(1)' < 0$ then $\dfrac{1}{\Delta t}\dfrac{-\omega\left(\frac{L}{2}P_1 - \frac{L}{2}P_2 + G + P_2\Delta Q\right)}{1 - \omega + \omega\left(\alpha + \frac{L}{2}P_1 + G\right)} < 0$. From equation (3) , we can see 0<ω<1 and $1 - \omega +$

$\omega\left(\alpha + \frac{L}{2}P_1 + G\right)$ >0.Beacuse of $\Delta t > 0$,to make $\dfrac{1}{\Delta t}\dfrac{-\omega\left(\frac{L}{2}P_1 - \frac{L}{2}P_2 + G + P_2\Delta Q\right)}{1 - \omega + \omega\left(\alpha + \frac{L}{2}P_1 + G\right)} < 0$, just let $-\left(\frac{L}{2}(P_1 -\right.$

$P_2) + P_2\Delta Q + G) < 0$,namely $G + P_2\Delta Q > \frac{L}{2}(P_2 - P_1)$.

Assume $S_\epsilon(\epsilon = 1,2)$ is the set of conditions, when $x_1 = 0$ or $x_2 = 1$ is the stable point. And $U_\gamma(\gamma = 1,2)$ is the set of values, when $x_1 = 0$ or $x_2 = 1$ is the stable point. Then $\overline{U_\gamma}(\gamma = 1,2)$ is the set of values, when $x_1 = 0$ or $x_2 = 1$ is not the stable point. Where $U_1 = \{P_1\Delta Q + G - F <$ $\frac{L}{2}(P_2 - P_1)\}$;$U_2 = \left\{G + P_2\Delta Q > \frac{L}{2}(P_2 - P_1)\right\}$;$\overline{U_1} = \left\{P_1\Delta Q + G - F > \frac{L}{2}(P_2 - P_1)\right\}$;$\overline{U_2} = \{G +$ $P_2\Delta Q > \frac{L}{2}(P_2 - P_1)\}$.

Thus, when the function satisfies the condition that $S_1 = U_1 \cap \overline{U_2} = \left\{P_1\Delta Q + G - F < \frac{L}{2}(P_2 - P_1)\right\} \cap$ $\left\{G + P_2\Delta Q < \frac{L}{2}(P_2 - P_1)\right\}$, $x_1 = 0$ is the stable point. While, when the function satisfies the condition that $S_2 = U_2 \cap \overline{U_1} = \left\{G + P_2\Delta Q > \frac{L}{2}(P_2 - P_1)\right\} \cap \left\{P_1\Delta Q + G - F > \frac{L}{2}(P_2 - P_1)\right\}$, $x_2 = 1$ is the

stable point.

From the Hypothesis 3., we can see $P_1 \ll P_2$. And from Hypothesis 6., we can see $F > 0$. Thus, there is $G + P_1 \Delta Q - F < G + P_2 \Delta Q$. Further, we can get $S_1 = U_1 \cap \overline{U_2} = \left\{ P_1 \Delta Q + G - F < \frac{L}{2}(P_2 - P_1) \right\} \cap \left\{ G + P_2 \Delta Q < \frac{L}{2}(P_2 - P_1) \right\} = \overline{U_2}$, and then, Definition 1. has been proofed.

Similarly, we can get $S_2 = U_2 \cap \overline{U_1} = \left\{ G + P_2 \Delta Q > \frac{L}{2}(P_2 - P_1) \right\} \cap \left\{ P_1 \Delta Q + G - F > \frac{L}{2}(P_2 - P_1) \right\} = \overline{U_1}$, and then , Definition 2. has been proofed.

4.2 Analysis of Stability Conditions

When the Definition 1. is true, that is the expected payoff function satisfies $S_1 = \left\{ G + P_2 \Delta Q < \frac{L}{2}(P_2 - P_1) \right\}$, then $x_1 = 0$ will be The Stability Strategy of Intra-species Pricing Game for Travel Agencies. In this case, the selection ratio $(\frac{i}{N})$ of T_1 strategy in the evolution game system will be 0.

From the Hypothesis 2, where $i + j = N$. So in this case, the selection ratio $(\frac{j}{N})$ of T_2 strategy in the evolution game system will be 1. Thus, When the Definition 1. is true, normal pricing strategies will be the Stability Strategy of Travel Agency Industry in M Market.

From the Hypothesis 3, compared with adopting extremely low-price pricing strategy, when travel agencies adopt normal pricing strategies, the price of package tours will be higher, namely $P_2 \gg P_1$. Thus, when P_1 is small enough to be $P_1 \to 0$, there is $\lim\limits_{P_1 \to 0} S_1 = \left\{ \frac{G}{P_2} + \Delta Q < \frac{L}{2} \right\}$. And from the Hypothesis 4 and Hypothesis 5, there are $\lim\limits_{P_1 \to 0} \Delta Q = \frac{L\theta}{2}$, $\lim\limits_{P_1 \to 0} G = k$. Thus, when the Definition 1 is true, under the Hypothesis 3, The evolution and stability of normal pricing strategies of travel agencies are mainly affected by demand elasticity θ and compensation coefficient k.

When the demand elasticity θ is small, tourists are not sensitive to the price of tourism commodities. In the case, Higher pricing strategies of tourism commodities will help travel agencies to obtain more revenue. When the compensation coefficient (k) is low, the transparency of the tourism market is high, tourism market information is symmetrical. Thus, in this case, travel agencies will find it difficult to cross-subsidize extremely low prices by forcing tourists to shop and increasing additional tourism consumption. Therefore, When the Definition 1 is true, the normal pricing strategy is strictly dominant and stable in evolution.

When the Definition 2 is true, that is the expected payoff function satisfies $S_2 = \left\{ P_1 \Delta Q + G - F > \frac{L}{2}(P_2 - P_1) \right\}$. then $x_2 = 1$ will be The Stability Strategy of Intra-species Pricing Game for Travel Agencies. In this case, the selection ratio $(\frac{i}{N})$ of T_1 strategy in the evolution game system will be 1.

From the Hypothesis 2., where $i + j = N$. So in this case, the selection ratio $(\frac{j}{N})$ of T_2 strategy in the

evolution game system will be 0. Thus, When the Definition 2 is true, extremely low-price pricing strategies will be the stability strategy of travel agency industry in M market.

Similarly, from the Hypothesis 3, when P_1 is small enough to be $P_1 \to 0$, there is $\lim_{P_1 \to 0} S_2 = \left\{ G - F > \frac{L}{2} P_2 \right\}$. Thus, when the Definition 2 is true, under the Hypothesis 3, The evolution and stability of extremely low-price pricing strategies of travel agencies are mainly affected by government penalties F and additional grey income G. When grey tourism income (G) is higher and government penalty (F) is lower, travel agencies can not only seize the market through extreme low prices, but also cross-subsidize extreme low prices through grey tourism income (G). Meanwhile, because of the low punishment (F) of the government, the illegal cost of tourism enterprises is low, extremely low-price pricing strategy can bring more benefits to travel agencies. Thus, when the Definition 2 is true, the extremely low-price pricing strategy is strictly dominant and stable in evolution.
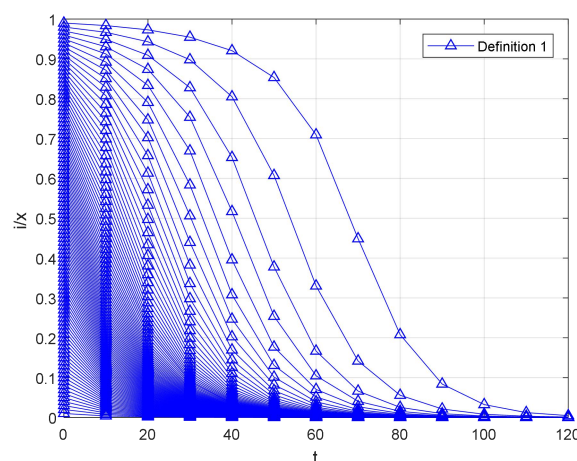
5. Simulation analysis

To further verify stable conditions, in this section, we will analyze the influence of main parameters on the evolution of travel agency pricing strategy.

5.1. Simulation of Definition 1

For verifying Definition 1, with the condition of $S_1 = \left\{ G + P_2 \Delta Q < \frac{L}{2} (P_2 - P_1) \right\}$, this paper sets the parameters as follow: $L = 100, \Delta t = 10, \omega = 0.5, P_2 = 30, P_1 = 1, F = 60, \theta = 0.5, k = 5, \alpha = 60$. And then, Simulate the evolutionary game with initial strategy T_1 ratio is $x\left(\frac{i}{N}\right)$, where $x\left(\frac{i}{N}\right) \in [0.01, 0.99]$. Fig. 1 shows the result.
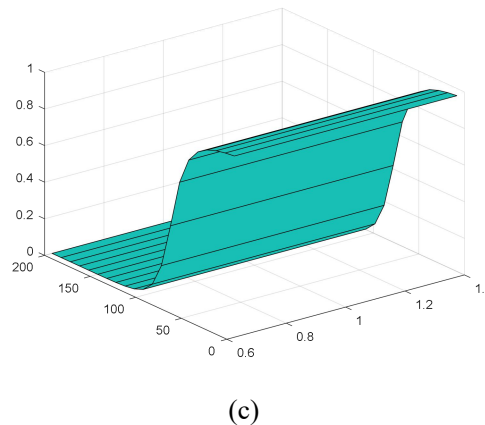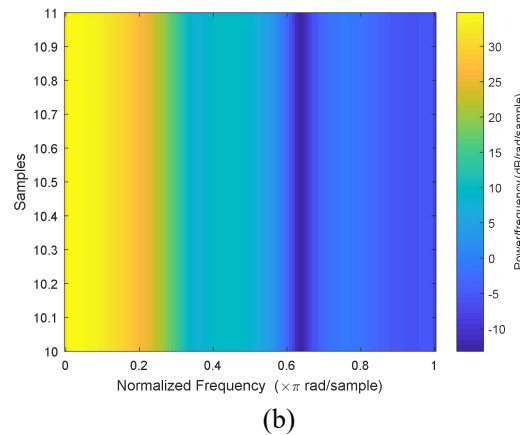

(a)

(b)

(c)

Figure 1. Simulation of Definition 1.

Fig. 1 (a)–(c) shows that, when Definition 1 is true, the demand elasticity (θ) of tourism market and the compensation coefficient (k) of travel agencies will be lower. The market with low demand elasticity is the market with low demand elasticity, under the circumstances, the rate of price change will be greater than the rate of demand change, so it will be difficult for travel agencies to gain more benefits by low-price competition. Because the compensation coefficient (k) is inversely proportional to the transparency of tourism market, when the compensation coefficient (k) is low, the transparency of travel agency market will be higher, tourists have easier access to tourism market and tourism commodity information. Thus, it is difficulty for travel agencies obtain additional grey tourism income through compulsory shopping and additional tourism consumption.

Therefore, when Definition 1 is true, the fitness of the extremely low-price pricing strategy of travel agencies will be lower than that of the normal pricing strategy, and the normal pricing strategy will strictly dominate in the game. Whatever the initial proportion of T_1 strategy is set, the final selection of the system will evolve to a stable state of $x_1 = 0$. At this time, the selection proportion of T_1 strategy will be 0, and that of T_2 strategy will be 1. Therefore, normal pricing strategy will become a stable pricing strategy for travel agencies in M market.

Although the initial proportion setting has no effect on the result of strategy evolution, it can be seen from Figure 1 that the initial proportion setting has a great influence on the speed of evolution stability. When Definition 1 is true, the rate of stability of M market strategy evolution is inversely

proportional to the initial proportion setting, and the longer it takes for M market strategy evolution to be stable when the initial proportion setting is higher.

5.2. Simulation of Definition 2

For verifying Definition 2, with the condition of $S_2 = \left\{ P_1 \Delta Q + G - F > \frac{L}{2}(P_2 - P_1) \right\}$, this paper sets the parameters. To ensure the comparability of experiments, comparing with the simulation of Definition 1, only the parameters F, θ and K are changed in the simulation of Definition 2. The parameters of Definition 2 are set as follows: $L = 100, \Delta t = 10, \omega = 0.5, P_2 = 30, P_1 = 1, F = 30, \theta = 1.5, k = 60, \alpha = 60$. Similarly, we Simulate the evolutionary game with initial strategy T_1 ratio is $x\left(\frac{i}{N}\right)$, where $x\left(\frac{i}{N}\right) \in [0.01, 0.99]$. And Fig. 2 shows the result.
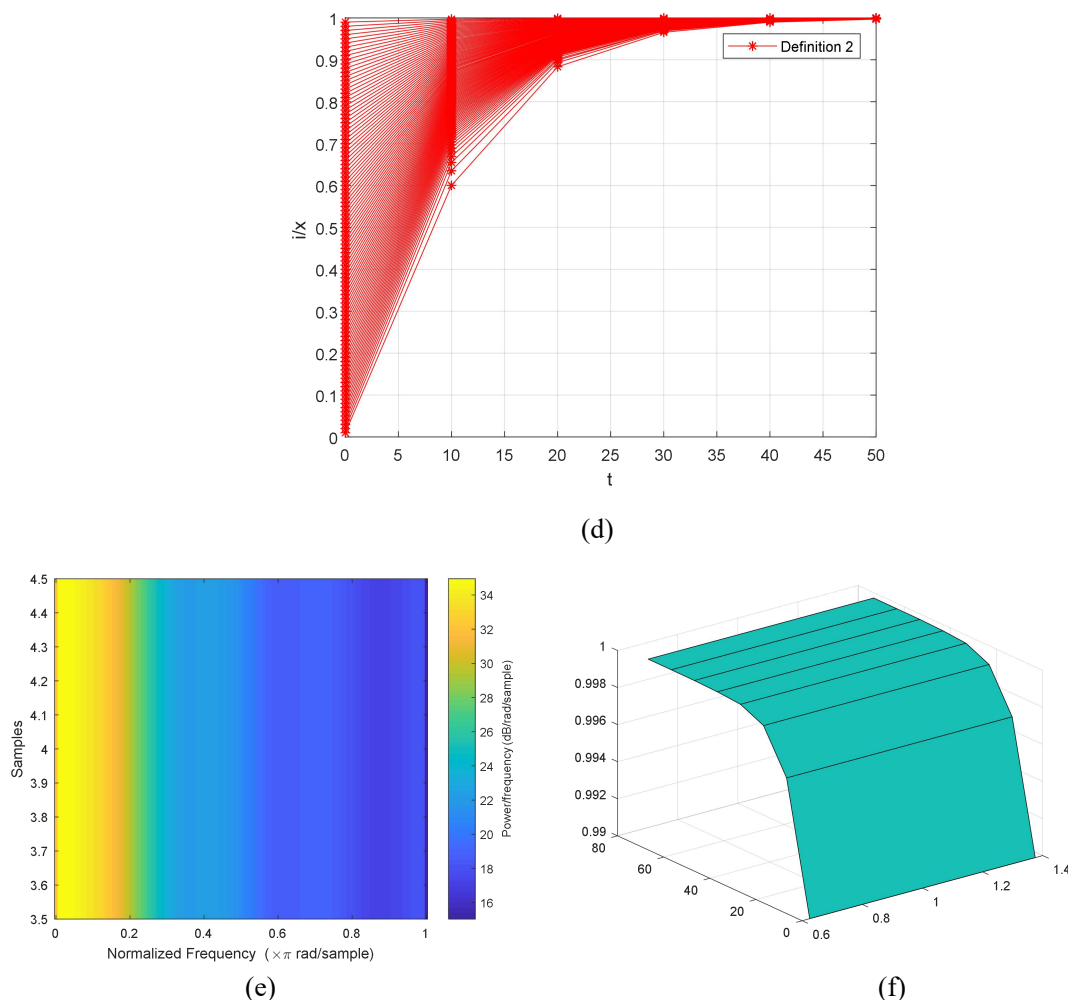

(d)

(e)

(f)

Figure 2. Simulation of Definition 2.

Fig. 2 (d)–(f) shows that, when Definition 2 is true, the demand elasticity (θ) of tourism market and the compensation coefficient (k) of travel agencies will be higher and the government penalties F is lower. The market with high demand elasticity is the market with high demand elasticity,

under the circumstances, the rate of demand change will be greater than the rate of price change. From the Hypothesis 4, $0 \leq \Delta Q \leq \frac{L}{2}$. Thus, when the demand elasticity (θ) is 1.5, there is

$\Delta Q = (1 - \frac{P_1}{P_2}) \frac{L\theta}{2} \approx 72.5 > \frac{L}{2}$. Therefore, under the Definition 2 condition, the change of tourism demand flow ΔQ is 50, namely the demand of travel agencies that make normal pricing strategies will all flow to the travel agencies with extremely low-price strategies. At this time, travel agencies can seize the whole market by making extremely low-price pricing. Meanwhile, due to the compensation coefficient (k) is inversely proportional to the transparency of tourism market, when the compensation coefficient (k) is high, the transparency of travel agency market will be lower. In this case, the tourism market is a black box market, it is easy for travel agencies to obtain grey tourism income by compulsory shopping and increasing additional tourism consumption.

Therefore, when Definition 2 is true, extremely low-price pricing strategy will bring more benefit to travel agency, and because the lower government punishment (F), the illegal cost of travel agencies is low. So, the fitness of the extremely low-price pricing strategy of travel agencies will be higher than that of the normal pricing strategy, and the extremely low-price pricing strategy will strictly dominate in the game. Whatever the initial proportion of T_1 strategy is set, the final selection of the system will evolve to a stable state of $x_1 = 1$. At this time, the selection proportion of T_2 strategy will be 0, and that of T_1 strategy will be 1. Therefore, extremely low-price pricing strategy will become a stable pricing strategy for travel agencies in M market.

Same as the simulation of Definition 1, although the initial proportion setting has no effect on the result of strategy evolution, while the initial proportion setting has a great influence on the speed of evolution stability. When Definition 2 is true, the rate of stability of M market strategy evolution is directly proportional to the initial proportion setting, and the shorter it takes for M market strategy evolution to be stable when the initial proportion setting is higher.

5.3. Simulation of different selective intensity

For further analyze the influence of selectivity intensity ω on the evolution of travel agency pricing strategy under the circumstance of limited rationality. Based on the parameters setting of Definition 2, this paper analyses the evolution of grouped 1 and 2 with different selectivity intensity ω. Where, the parameters   setting   of   grouped   1   are   : $L = 100, \Delta t = 10$, $\omega_1 = 0.01$, $P_2 = 30$, $P_1 = 1$, $F = 30$, $\theta = 1.5$, $k = 60, \alpha = 60$; the parameters setting of grouped 2 are: $L = 100, \Delta t = 10$, $\omega_2 = 0.99$, $P_2 = 30$, $P_1 = 1$, $F = 30$, $\theta = 1.5$, $k = 60, \alpha = 60$。Simulate the evolutionary game with initial strategy T_1 ratio is 0.1, 0.5 and 0.9. The Fig. 3 shows the result.
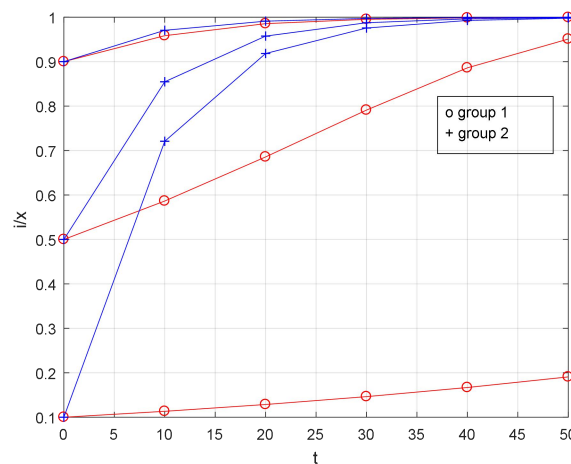
Figure 3. Simulation of different selective intensity.

From Figure 3, the selectivity intensity ω has no effect on the ultimate outcome of evolution game when the game is a bounded rational game, but has a significant effect on the speed of evolution game. The selectivity intensity ω of group 1 is 0.01 and the selectivity intensity ω of group 2 is 0.99. While in Figure 3, the speed of evolution stability in group 2 is always faster than that in group 1, Therefore, it can be concluded that the selectivity intensity ω has a significant influence on the evolution speed of the game in the limited rational game, and the selectivity intensity ω has a positive correlation with the evolution speed of the game.

6. Conclusion

Extremely low-priced of package tours is an important cause of Chinese tourism market price disorder. In this paper, we considered the Chinese tourism market extremely low-priced strategies evolutionary dynamic process of Wright-Fisher in a finite population under weak selection. And found that the change of tourism demand flow (ΔQ), grey additional tourism income (G) and government penalties (F) have direct effects on the evolution of travel agency pricing strategy. The demand elasticity (θ), compensation coefficient (k) and government penalties (F) are the fundamental reasons that affect the choice of travel agency pricing strategy. Therefore, based on the conclusion of the study, this paper proposes a solution to the price disorder in Chinese tourism market as follow.

I. Strengthen the Government's Penalty and Increase the Low Competition Cost of Travel Agencies

In the intraspecific pricing game of travel agencies, the government plays the role of supervisor. Chinese government punishment (F) can effectively increase the cost of vicious price competition and enhance the potential benefits of normal competition. It can be seen from the establishment conditions

of Definition 2 that, once the punishment intensity of the government is $F < P_1 \Delta Q + G + \frac{L}{2}(P_1 - P_2)$,

the extremely low-price pricing strategy of will become the stable pricing strategy of travel agencies. Therefore, strengthening the Chinese government's punishment to maintain the implementation cost of the extremely low-price strategy at a high level will play a positive role in preventing and improving Chinese tourism market price disorder.

However, it should be noted that the supervision and incentive effect of government punishment (F) has a significant effect only when the proportion of travel agencies choose extremely low-price

strategy is small. From the proof of Definition 1, the stability of normal pricing strategy of travel agencies is only affected by these parameters G, P_2 and ΔQ, because there is always $P_1 \Delta Q + G - F < G + P_2 \Delta Q$. Only when $G + P_2 \Delta Q < \frac{L}{2}(P_2 - P_1)$, the pricing strategy of travel agency will be stability at normal pricing. Therefore, once the extremely low-price pricing strategy has been the stable pricing strategy in the tourism market, it will be difficult for the government to make normal pricing become a stable pricing strategy in the tourism market again by means of government penalty (F).

II. Strengthen market transparency and reduce the difficulty of obtaining tourism market information

The grey additional tourism income (G) is an important profitable means, when travel agencies to implement extremely low-price pricing strategy. It is also one of the main case for tourism complaints and chaos in the Chinese tourism market. Reducing the grey tourism additional income (G) of travel agencies can effectively control extremely low-cost travel disorder and reduce the occurrence of complaints and chaos in Chinese market. From the actual situation and related literature, the dominant information of travel agencies is the fundamental reason why travel agencies can obtain tourism grey income (G). Thus, the Chinese government and relevant agencies can further enhance the transparency of the tourism market, make the information between tourists and travel agencies symmetrical, eliminating the driving force of the grey tourism additional income (G) of travel agencies, further reduce the occurrence of travel agencies choosing extremely low-price strategy.

III. Promoting the resident's Tourism consumption concept and Reducing the Elasticity of Chinese tourism Market Demand

From the fitness of T_1 and T_2 strategies, we can find that the fitness of T_1 strategies f_i is positively correlated with tourism demand elasticity θ, while the fitness of T_2 strategies g_i is negatively correlated with tourism demand elasticity θ. Therefore, the higher the demand elasticity θ, the more likely the pricing strategy of travel agencies will be stable in the extremely low-price pricing strategy. Thus, reducing the elasticity of tourism demand θ is of great significance for solving the problem of unreasonable low-price pricing of travel agencies.

From the theory of elasticity, demand elasticity is related to consumption concept. While, in Chinese tourists' consumption concept, tourism product are often non-necessities or even luxury goods, and meanwhile most of Chinese tourists' consumption behavior is uncertain consumption, lack of long-term planning of tourism consumption, short time to adjust tourism demand, tourists are very sensitive to the price of tourism commodities. In addition, because China's tourism market is a typical off-peak season market and the demand for tourism is concentrated, the elasticity of tourism demand in China's tourism market is high. Thus, extremely low-price pricing strategy has a high fitness in China's tourism market.

Therefore, through the promotion of tourists' consumption concept, guiding tourists' consumption habits, making tourism commodities a necessity, making the residents form the habit of long-term planning consumption and off-season travel, can effectively reduce the elasticity of Chinese tourism market demand θ. Further alleviating and solving the price disorder in Chinese tourism market.

7. Discussion

This paper discusses the stability conditions of normal pricing strategy and extremely low-price pricing strategy of Chinese travel agencies, and based on game Analysis and simulation experiments,

discusses the main factors affecting the pricing of Chinese travel agencies, and puts forward some suggestions to alleviate the price disorder in Chinese tourism market. The research has certain practical significance and practical value. However, in order to highlight the evolution process of extremely low-price strategy, this paper does not fully reflect the evolution of all pricing strategies of travel agencies. It only focuses on the evolution of normal pricing and extremely low-price pricing of travel agencies, which has some limitations. Therefore, based on the Wright-Fisher process to explore the evolution of intra-species pricing strategy in multi-strategy scenarios is the next research focus of this paper.

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