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Multi-players dynamic game with visitor education intervention

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ABSTRACT

Multi-players dynamic game between government, parks managers and visitors is proposed in this paper to find out which party should invest money to visitor education and their optimal investment strategies. The game reveals that government should invest a lot of fund to helping the park managers to develop proper visitor education programmes when the visitor education the visitor education market is still on the initial or immature stage. A positive interaction mechanism between government, parks managers and visitors can be created finally when the three parties choose their own optimal investment strategies of visitor education.

KEYWORDS

Visitor education intervention; Multi-players dynamic games.

INTRODUCTION

The fast expanding visitation to some protected areas in China severely challenges the protection of the environment and precious natural resource, cultural resource and social conditions[1]. The dynamic property of the ecological tourism system with the visitor educational intervention is very complicated. Wei, D. and Wen, S. proposed a stochastic Dynamics to study the efficacy of the visitor education intervention[1]. They also showed that visitor education intervention is necessary factor to maintain sustain the opportunities for high quality visitor experiences while avoiding or minimizing associated negative impacts to protected area resources and neighbors communities[2]. However, they didn't study the cost sharing and distribution of visitor education programme. The problem is significant to carry out the visitor education programme effectively. It is easy to find that some tourism resources are not pure public goods, so governments are unwilling to sharing the visitor education programme cost solely[4]. Parks managements are not willing pay all the cost of visitor education either. In fact, the cost of visitor education should be shared by all the stakeholders including visitors and park managers and governments. Hence, it is necessary to study the dynamic game between visitors, parks managers and governments with the cost of visitor education. Wei, D. and Wen, S. started to study the multi-players dynamic game between visitors, parks managers and local governments about the cost of visitor education[4]. It is useful to figure out which party should invest money to visitor education and their optimal investment strategies.

NOTATIONS

e_1:The unit cost of behavior intervening
e_2:The unit cost of knowledge services
e:The total cost of visitor education
x_1: The visitors participation level of behaviors intervention
x_2:The visitors' participation level
$u_1(x_1 e_1)$:The utility function of visitor satisfaction
$u_2(x_2 e_2)$:The visitors' satisfaction increment due to knowledge services
$g(x_1 e_1)$:The negative utility function
c:The cost of basic services providing by parks
$u(c)$:The visitors' satisfaction of the basic services
a:The ticket price of park
$U(x_1, x_2)$:The utility function of visitors
t: Taxes per ticket collected by Government
α : The sharing cost ratio of goverment in visitor education programme
$1-\alpha$: The sharing cost ratio of the park in visitor education programme
N:The function of tourist quantity
R_G: The earnings of government
$\varphi(x_1 e_1)$: Resource maintenance and clean-keeping cost saving by the behavior intervention
$\phi(x_2 e_2)$: The market promotion cost saving by the knowledge services
R:The total income of the park
S_g :The visitor education input strategy of government
S_p :The strategy of parks
S_v :the strategy of visitors

MULTI-PLAYERS DYNAMIC GAME OF GOVERNMENT-PARK-VISITOR

Wei, D. and Wen, S. proposed that the primary missions of visitor education including intervening the visitors' behaviors (referred as "behaviors intervening") and spreading or sharing knowledge of parks to visitors (referred as knowledge services)[5]. e_1 is the unit cost of behavior intervening of the park. And $e_2$is the unit cost of knowledge services. Hence, the total visitor education cost can be calculated as $e = \sum_{i=1}^{2} e_i$. Visitors can enjoy the beautiful scene and its high standard service in tourism destination. Visitors' satisfaction includes enjoying the beautiful scenes and sharing the knowledge of the park and so on. The net utility function of satisfaction by behaviors intervening is denoted as u_1^n. And it's easy to get $u_1^n(x_1e_1) = u_1(x_1e_1) - g(x_1e_1)$. The utility function of visitors behaviors intervening can be denoted as following.

$$U(x_1, x_2) = u(c) + u_1^n(x_1e_1) + u_2^n(x_2e_2) \quad \textbf{(1)}$$

where $u_2^n(x_2e_2) = u_2\ (x_2e_2)$ is the net utility function of satisfaction by knowledge services. When visitors' satisfaction increases, the tourist quantity is increases meanwhile. The tourist quantity can be described as following.

$$N = N(U(x_1, x_2)) \quad \textbf{(2)}$$

Visitor education is a kind of public good, so government should share a part of the total cost of visitor education programme. Hence, the return of government should include the tax collecting by the tickets and getting rid of visitor education cost. The tax income of government is $T_G = tN\big(U(x_1, x_2)\big)$. The visitor education cost of government is $C_G = \alpha eN\big(U(x_1, x_2)\big)$. R_G is denoted as the earnings of government. R_G can be calculated by following.

$$R_G = T_G - C_G \quad \textbf{(3)}$$

The parks can save a part of clean-keeping cost and resource maintenance cost by the behavior intervention. $C_b = \varphi(x_1e_1)N\big(U(x_1, x_2)\big)$ is the cost saving by behavior intervention. Parks can also save a part of market promotion cost by the knowledge services. The cost saving by knowledge services is denoted as $C_k = \phi(x_2e_2)N\big(U(x_1, x_2)\big)$. The total incomes of park can be calculated as following.

$$R_P = (a - t)N\big(U(x_1, x_2)\big) + C_b + C_k - C_v + \varepsilon \quad \textbf{(4)}$$

where $C_v = ((1 - \alpha)e + c)N\big(U(x_1, x_2)\big)$ is the total cost of park including the cost of basic services providing by parks and visitor education. Generally, the stakeholders including government, parks and visitors should play important role in visitor education. The investment of visitor education is a game between the three parties. In fact, the interaction between the three parties can be considered as a Multi-players Dynamic Game typically. The government, parks and visitors are assumed as rational economic man. The game of visitor education can be divided to three different stages. The government should choose the optimal taxes ratio t in each ticket and investment ratio of visitor education programme in the first stage. The second stage is that the park mangers should decide the optimal visitor education input including behavior intervention cost e_1 and knowledge services cost e_2 according to the government's taxes ratio and visitor education investment ratio. Visitors should choose the optimal visitor education participation level (x_1, x_2) according to the park's visitor education investment in order to obtain the maximum satisfaction in the third stage. The dynamic game of visitor education between the three parties is denoted as $G(S_g\ , S_p\ , S_v\ , R_G, R_P, U_V)$. $G(S_g\ , S_p\ , S_v\ , R_G, R_P, U_V)$ is complete and perfect information three stage multi-players dynamic game. S_g ,S_p and S_v is the strategy of government, the parks and visitors. Governments should choose the best strategies $(\alpha, t) \in S_g$ in order to obtain the maximization value R_G in the first stage of game $G(S_g\ , S_p\ , S_v\ , R_G, R_P, U_V)$. Park managers should choose the optimal education investment strategies $(e_1, e_2) \in S_p$ in order to obtain the maximization value R according to the investment strategies of governments in the second stage of the game $G(S_g, S_p, S_v, R_G, R_P, U_V)$. Visitors should choose the optimal participation strategy $(x_1, x_2) \in S_v$ maximizing U according to the visitor education strategy of governments and parks' managers in the third stage of game $G(S_g, S_p, S_v, R_G, R_P, U_V)$. Government-Park-Visitor three Stage Multi-players Dynamic Game can be transformed as the following optimization problem:

$$Max\{R_G(\alpha, t, e_1, e_2, x_1, x_2), R_P(\alpha, t, e_1, e_2, x_1, x_2), U_V(\alpha, t, e_1, e_2, x_1, x_2)\} \quad \textbf{(5)}$$

$s.t.$

$S_g = \{(\alpha, t) \in R^2\}$

$S_p = \{(e_1, e_2) \in R^2\}$

$S_v = \{(x_1, x_{2)} \in R^2, 0 \leq x_1, x_2 \leq 1\}$

RESULTS AND DISCUSSIONS

Game theory shows that Backwards Induction is the best method to solve the problem[4]. In the third stage of $G(S_g, S_p, S_v, R_G, R_P, U_V)$, visitors should choose their optimal strategies (x_1^*, x_2^*) according to the park's investment strategy. In the second stage of $G(S_g, S_p, S_v, R_G, R_P, U_V)$, parks' managers should try to choose thier optimal strategies of visitor education investment $(e_{1,}^* e_2^*)$ in order to obtain the maximum earnings. When the equilibrium state of the game is arrived, the optimal investment strategies of park managers should let the visitors being willing to participate in the visitor education programme. It is so-called basic participation constraints of visitors$U(x_1^*, x_2^*, e_1^*, e_2^*) = U_0$. In the first stage of $G(S_g, S_p, S_v, R_G, R_P, U_V)$, the government should choose the optimal taxes rate and visitor education investment strategies to make the parks' managers being willing to pay money to develop visitor education programme. In the other words, the government should choose optimal (α^*, t^*) to make the expectation return of parks' managers is great than or equal to the normal market return rate. It can be defined as the parks' minimum participation constraints. The constrains can be denoted as $ER(\alpha^*, t^*, x_1^*, x_2^*, e_1^*, e_2^*) \geq R_0$. The maximization problem (5) can be transformed as the following problems including LP1, LP2, and LP3.

(LP1) $max \ \{u(c) + u_1^n(x_1 e_1) + u_2^n(x_2 e_2)\}$ **(6)**

$s.t.$

$(x_1, x_2) \in S_v$

(LP2) $max\,\{(a-t)N\big(U(x_1, x_2)\big) + C_b(x_1^*, x_2^*, e_1^*, e_2^*) + C_k(x_1^*, x_2^*, e_1^*, e_2^*) - C_v\}$ **(7)**

$s.t$

$(x_1^*, x_2^*) \in S_v$

$(e_1^*, e_2^*) \in S_p$

(LP3) $max\,\{T_G(x_1^*, x_2^*, e_1^*, e_2^*) - C_G(x_1^*, x_2^*, e_1^*, e_2^*)\}$

$$= \max_{e_1^*, e_2^*}\{N\big(U(x_1^*, x_2^*)\big)(a - c - e + \varphi(x_1^* e_1^*) + \phi(x_2^* e_2^*)) - R_0 \} \quad \textbf{(8)}$$

$s.t$

$(t^*, \alpha^*) \in S_g$

$(x_1^*, x_2^*) \in S_v$

$(e_1^*, e_2^*) \in S_p$

The optimization first order condition[7] of LP1 is

$$u_1^{'}(x_1^* e_1^*) = g^{'}(x_1^* e_1^*) \quad \textbf{(9)}$$

$$u_2^{'}(x_2^* e_2^*) = 0 \quad \textbf{(10)}$$

Eq.(9) shows that visitors should choose their optimal visitor education participation level x_1^* when the positive marginal utilities of the behavior intervention are equal to its' negative utilities. Eq.(10) shows that visitors should choose the optimal knowledge services participation level x_2^* when the maximum satisfaction level $u_2(x_2^* e_2^*)$ is achieved.

It can obtain following equations from LP1 and LP2

$$\frac{\partial \varphi(x_1^* e_1^*)}{\partial e_1^*} = (1 - \alpha) \quad \textbf{(11)}$$

$$\frac{\partial U(x_1^*, x_2^*)}{\partial e_2^*} = \frac{\partial u_2(x_2^* e_2^*)}{\partial e_2^*} \quad \textbf{(12)}$$

$$\frac{\partial \phi(x_2^* e_2^*)}{\partial e_2^*} = (1 - \alpha) \quad \textbf{(13)}$$

The optimal parks' visitor education investment strategies of behavior intervention can be obtained by Eq.(11). It can easy to see from Eq.(11) that the optimal park investment strategy is achieved when the marginal return of investment e_1^* equals to the investment rate of the park. It is easy to see that $\frac{\partial \varphi(x_1^* e_1^*)}{\partial e_1^*} = \frac{\partial \phi(x_2^* e_2^*)}{\partial e_2^*} = (1 - \alpha)$. The parks' optimal investment strategies on visitor education programme is achieved when the marginal returns of investment of the parks on the knowledge services and the behavior intervention are equal.

It can derive from LP3 that $\frac{\partial \varphi(x_1^* e_1^*)}{\partial e_1^*} = \frac{\partial \phi(x_2^* e_2^*)}{\partial e_2^*} = (1 - \alpha) = 1$ and $\alpha = 0$. It means that the ratio of visitor education cost paid by goverment equal to zero. In that case, the government can obtain the maximum returns. When $\alpha > 0$, the government should set up funds to inducing and supporting the park to develop visitor education in order to obtain equilibrium state of the game $G(S_g, S_p, S_v, R_G, R_P, U_V)$. So α is a government visitor education induction coefficient actually. The government should input more investment ($\alpha \gg 0$) to help the park to develop proper visitor education programme, when the visitor education market is still on the immature stages. It can see from Figure 1 that the utilities of visitors can be changed by the sharing cost ratio of goverment in visitor education programme α. In the initial stage, the dynamic game $G(S_g, S_p, S_v, R_G, R_P, U_V)$ can achieve equilibrium state when $e = e_0^*$, but the utility function of visitor U_0 is under lower equilibrium state. The government intervention coefficient α can decrease gradually when investment enthusiasm of the park is getting higher. The equilibrium spot of the game is growing slowly and the return of the park is increasing at the same time. Then the game $G(S_g, S_p, S_v, R_G, R_P, U_V)$ can achieve higher the equilibrium state. When α diminishs to zero finally, the park's visitor education investment achieves maximum and the utilities of the visitors can also obtain biggest state $U = U_{max}$.

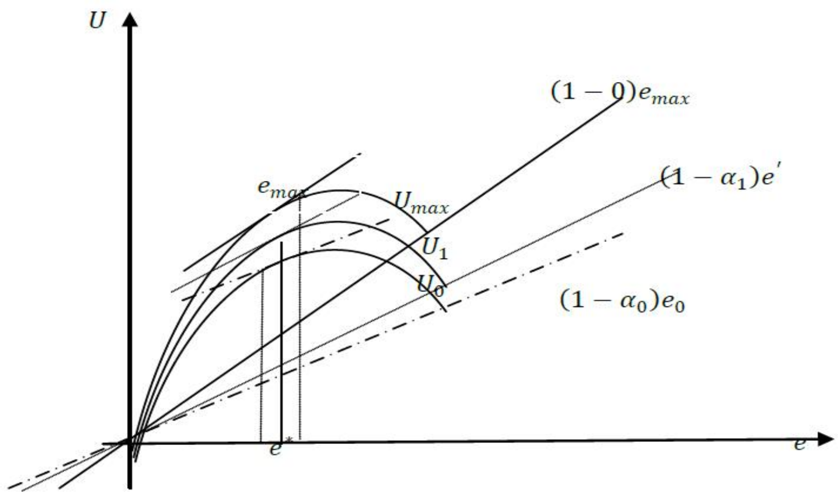

Figure 1: The induction coefficient of Government visitor education, the utility function of visitors and the park's visitor education investment

CONCLUSIONS

This paper proposes multi-players dynamic game between government, parks managers and visitors to find out which party should invest money to visitor education and their optimal investment strategies. The multi-players dynamic game is transformed to three maximization problems by the Backwards Induction method. The solution of the multi-players dynamic game shows that the government should invest inducing fund to support the park to develop visitor education. The park's optimal investment strategy on visitor education is obtained when the marginal returns of investment on the behavior intervention and the knowledge services are equal. The optimal strategies of the visitors are obtained choosing the participation level when marginal positive of behavior intervention equals to its negative utility.

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