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Original Research Article

Modeling a green supply chain in the hotel industry: An evolutionary game theory approach

Ming-Hsiang Chen [a,b,c], Haixiang Wei [d], Min Wei [d], Haiyu Huang [d,*], Ching-Hui (Joan) Su [e]

[a] *School of Business and Tourism Management, Yunnan University, Kunming 650091, China*
[b] *School of Hospitality Business Management, Carson College of Business, Washington State University, Pullman, WA 99164-4742, USA*
[c] *Tourism and Social Administration College, Nanjing Xiaozhuang University, Nanjing 211171, China*
[d] *School of Management, Xiamen University, Xiamen 361005, China*
[e] *Department of Apparel, Events, and Hospitality Management, College of Human Sciences, Iowa State University, Ames, IA 50011-1078, USA*

A R T I C L E I N F O

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A B S T R A C T

Despite extensive discussion of environmental management for hotels, little research has been done on the hotel industry's green supply chain management. This study uses the evolutionary game approach to examine the generation of green behaviors and a green supply chain by hotels. Results show that most hotels do have an incentive mechanism for green growth; hotels with green behaviors are more profitable than those that are not. Furthermore, governments and hotel customers are critical in the "greening" of traditional hotel supply chains. The findings can assist governments in formulating effective environmental policies, provide a theoretical avenue in governing green practice, and guide stakeholders to understand the formation and evolution of green development in the hotel industry.

1. Introduction

Environmental sustainability has become a vital guide to the development of a code of sustainable organizational practices (Wang et al., 2013). The hotel industry is a people industry. In such a dynamic industry, collaboration with stakeholders can lead a hotel to a more sustainable future (Xu and Gursoy, 2015). A stakeholder is defined as "any group (or individual) who can affect or be affected by the achievement of the objectives of an organization" (Freeman, 2010). The key stakeholder groups in a hotel are internal (e.g., employees and managers) and external (e.g., customers, competitors, suppliers). The suppliers-inputs-process- outputs-customers (SIPOC) diagram was used to explain the hotel supply chain from the beginning (suppliers) to end (customers) (Al-Aomar and Hussain, 2017) (Fig. 1).

The greening of an industry through its supply chain management is a way for organizations to attain sustainable economic growth while protecting the environment (Zhu et al., 2008). A green supply chain incorporates environmental practices and combines economic development with environmental protection (Al-Aomar and Hussain, 2017). A green supply chain is vital to the hotel industry's sustainability and also helps ensure the healthy development of tourism. Research on the green hotel supply chain and the development of an evolutionary model can help governments better understand the issues at play in hotel development and status, which will, in turn, help the government formulate more effective green and sustainable development policies for the hotel industry.

Previous studies have noted that a green supply chain can be manifested through different forms of green practices. Zhu and Sarkis (2004) analyzed the relationship between internal environmental management, external green tourism supply chain management, and ecological benefits, finding that green tourism supply chain management is conducive to promoting ecological benefits. Al-Aomar and Hussain (2018) noted that for the past few years, hotels have been under pressure to be more efficient and sustainable, as being green is imperative to a hotel supply chain. Some empirical studies have even evaluated the performance of supply chains. Al-Aomar and Hussain (2017) developed an assessment framework for a hotel supply chain to adopt green practices, noting that "going green" comes from the perspective of waste reduction and resource protection. In the hotel supply chain, the analysis of these and other relationships is crucial.

The green supply chain can provide a theoretical basis for the analysis of green practices in the hotel supply chain. Most of the

* Corresponding author.
E-mail addresses: ming-hsiang.chen@wsu.edu (M.-H. Chen), weihaixiang@stu.xmu.edu.cn (H. Wei), xiada2000@126.com (M. Wei), huanghaiyu@xmu.edu.cn (H. Huang), joansu@iastate.edu (C.-H.(J. Su).

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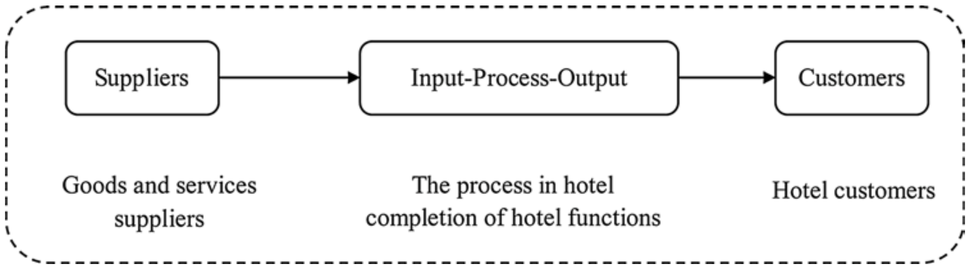

Fig. 1. The platform for the SIPOC chart of a hotel supply chain.

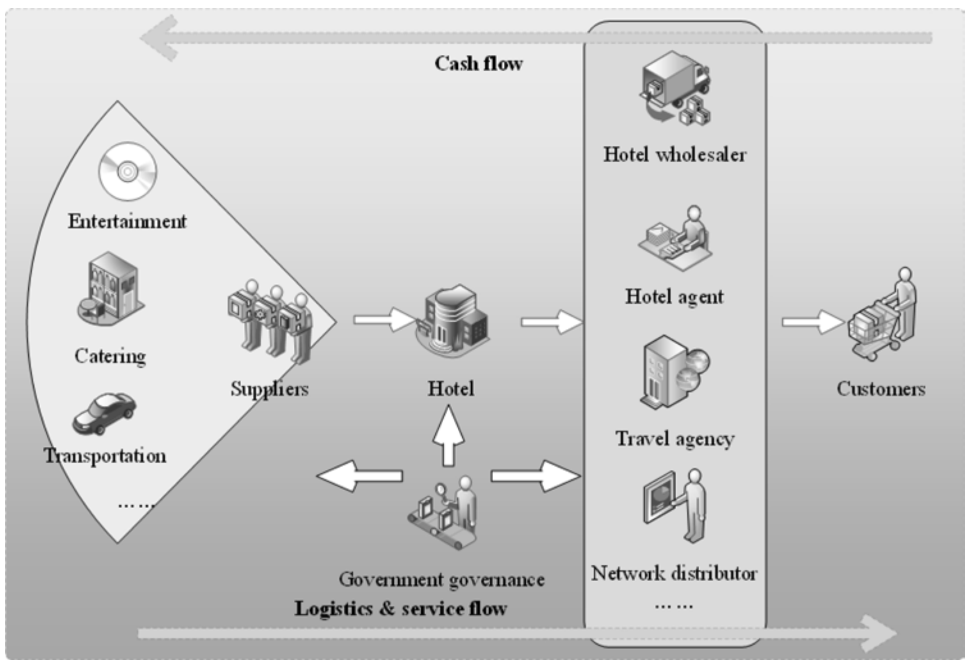

Fig. 2. The green hotel supply chain (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

sustainability research in the hospitality industry has examined organizations' operational and strategic measures (Kim et al., 2017) that were built on the premise of the green hotel supply chain. The formation of a green supply chain is a dynamic process, and each entity in the supply chain may select a different action (e.g., entrance or exit). Each individual or entity in a supply chain compares its choices to others, to arrive at the most favorable decisions. Additionally, traditional supply chain sustainability focuses on environmental dimensions, but its integration with social and economic dimensions has been studied only in terms of optimization (Babu and Mohan, 2018). There is a body of literature that views sustainability in economic or social terms. However, in studying the sustainability of supply chains, the analysis reveals a lack of integration across the social, economic and environmental dimensions. Most of the scant literature on holistic, sustainable supply chain models concentrates on industrial sectors and rarely on microscopic analysis. External factors should be considered in the analysis of a green hotel supply chain (Fig. 2).

This study applies evolutionary game theory to the analysis of the formation and evolution of a green hotel supply chain. Evolutionary game theory has been used in management, economics, sociology, and other disciplines (Friedman, 1991). It allows a hotel to identify each participant's strategy when influenced by the choices of others. Evolutionary game is derived from biological evolution theory and classical game theory, but differs from the traditional game theory in that it abandons the "completely rational" hypothesis and unites with the dynamic evolution of the process (Yi and Liu, 2005). Considering "limited rationality," players adjust their strategies through continuous learning, imitation, and mutation. The attainment of equilibrium is not the result of one game, but the result of constant adjustment and improvement.

This study focuses primarily on (1) the establishment process of the green hotel supply chain to explore the goals of the empirical green hotel supply chain as well as key factors influencing the adoption of the green hotel strategy, and (2) evolutionary processes and future trends in greening. The objectives of this study are to identify the conditions necessary to create and support a green and sustainable hotel supply chain in real situations, and to analyze the results produced under different conditions. As a green hotel supply chain functions as a virtuous circle, its effectiveness depends on the actions of its stakeholders. While hotel stakeholders tend to base their decisions upon the maximization of benefits, governments (supervisors) and consumers (hotel customers) also shape those decisions. The key contributions of this work are the two proposed evolutionary game models (one between the hotel and the government; the other between the hotel and its customers) to explain the dynamic evolution of a green hotel supply chain. Both models have practical advantages in understanding the government, hotel, and hotel customers whose roles and functions affect a hotel's green supply chain.

The remainder of this paper is organized as follows. Section 2 presents a literature review of the green hotel supply chain and of evolutionary game theory. Section 3 introduces the formation and evolutionary models of a green hotel supply chain. Section 4 reports the study's findings from the analysis of the model's parameters. Section 5 offers a discussion and implications for a sustainable green hotel supply chain. Section 6 concludes the study and proposes directions for future research.

2. Literature review

2.1. Green hotel

The environmentally responsible management of hotels has received more attention in recent years, and green hotels are believed to be one of the most efficient patterns of sustainable development in the hospitality industry (Chan and Hsu, 2016; Han et al., 2018). Green hotels exhibit an environmentally friendly pattern that follows ecologically sound practices (e.g., water conservation, energy management, environmental protection, waste management, green rooms, green catering) to sustainable development (Han and Kim, 2010; Green Hotels Association, 2014). Naturally, green hotels tend to be actively supportive of actions that protect the planet from further damage, which means they are environmentally friendly (Lee and Cheng, 2018). The future development of green hotels has excellent potential, despite the associated higher cost that is short term (e.g., the increased cost of green technology and products).

This "green" praxis follows customer demand. The term "green hotel" was coined in order to gain commercial success and not to minimize its environmental effects (Jones et al., 2014; Pizam, 2009). Some studies have shown that hotels' embedded sustainability efforts or green marketing strategies clearly increase profit margins (Dodds and Holmes, 2016) and improve brand recognition (Davari and Strutton, 2014). Rahman and Reynolds (2016) developed a behavioral decision model to examine customers' willingness to support environmental protection; the results show that customers are willing to spend more to stay in a green hotel. Lee et al. (2010) found that awareness of environmental protection and conservation is a motivation for customers to do so. Verma and Chandra (2018) studied consumers' attitudes toward green hotels and found that young consumers' willingness to visit green hotels reflects a self-orientation and motivation to engage in pro-environmental activities.

Going green poses challenges for hotels. There is a noticeable disconnect between hotel customers' pro-environmental attitude and their actual consumption behaviors. While customers with green attitude and behavior are motivated and willing to pay extra to stay at a green-certified hotel (Prud'homme and Raymond, 2013), those are not as environmentally conscious may complain about the inconvenience of some campaigns aimed at reducing unnecessary waste. In addition, Lynes and Dredge (2006) have found that the fear of legal penalties may be a reason for a hotel to commit to green practices. A hotel may hesitate to adopt green actions if the legal penalties for not doing so are ineffective (Tzschentke et al., 2008). Hence, understanding he hidden power and influence of stakeholders is critical in developing green hotels. When greening a hotel, not only environmental protection but also the hotel's stakeholders and their interactions need to be concerns.

2.2. Green supply chain management in the hotel industry

The supply chain in the hotel industry is a network of organizations committed to providing customers with different hotel products and services (Al-Aomar and Hussain, 2017). The literature on the green supply chain concentrates on manufacturing and production, for example, green product design, product recovery, and network design logistics (Gungor and Grupta, 1999; Sheu et al., 2005; Zhang et al., 2009). In a hotel supply chain, the "green" in a service supply chain means the delivery of profitable long-term services and sustainability. However, this is a relatively new and little-studied area of sustainability research (Al- Aomar and Hussain, 2017). The waste produced in a hotel supply chain is similar to that in other sectors of the service industry, and environmental protection means water and energy savings, resource recycling, and products with green or environmentally friendly labels (Lee and Cheng, 2018).

Green supply chain management originates from the concepts of environmental and supply chain management (Wang et al., 2013). Adding the "green" element to supply chain management (SCM), the green supply chain is defined by the connection between environmental protection and SCM, including product design, selection of materials, manufacturing technology, the delivery of products, and recycle management (Srivastava, 2007). A green element is essential to the supply chain because it helps increase revenues and cut costs. In addition, companies should integrate green elements with SCM, which can serve to meet regulatory requirements, improve the public image, and gain stakeholders' reputation (Malik et al., 2016). A green element is essential to the supply chain and is appropriate for the hotel supply chain.

The interaction of stakeholders in a hotel supply chain is vital for the hotel's future green development. A supply chain is susceptible to elements, such as government regulation, technology evolution, and market reaction; it is thus essential to analyze the influence factors before constructing an evolutionary game model (Babu and Mohan, 2018). The conversion of a traditional service supply chain to become "green" has attracted much attention, bringing an awareness of issues such as the relationship between tourism management and stakeholders, advances in recycling, and helping the tourism industry recognize the value of sustainable practices (Anton et al., 2004; Huang et al., 2012). By considering the stakeholders and analyzing the formation and evolution of a green hotel supply chain, we will be closer to fully understanding the sustainable development of the hospitality industry.

Unlike a traditional hotel supply chain, a green hotel supply chain combines environmental protection and SCM with external factors such as government regulations and hotel customers' preferences affecting the evolution process in the formation of the chain due to the interaction between stakeholders and the characteristics of the hotel industry. As the popularity of environmental protection and sustainability grows, the consumer's desire to be "green" has been a driver in the development of green hotels (Singjai et al., 2018; Su and Swanson, 2017; Wang et al., 2013), which is an indication that hotel operators are also concerned about environmental issues (Choi et al., 2015). In other words, their behavior can help promote the formulation of environmental management regulations, such as the electronic equipment directive in the European Union, China's star rating standards for green hotels. These regulations force the supply chain to transform itself into a type of environmental protection (Rao and Holt, 2013). As an essential link in the hotel supply chain, hotel customers now have an increased awareness of environmental protection and prefer green goods and services that meet sustainable development, thus providing opportunities for the development of a green hotel supply chain (Han and Kim, 2010; Ji et al., 2015).

2.3. The application of the evolutionary game theory

The supply chain management model connecting with sustainable indices has been discussed (Dubey et al., 2017; Esfahbodi et al., 2016), but sustainability must also be considered in all interactions between stakeholders (Ashby et al., 2012). One way for researchers to explain a green hotel's strategy is to build upon evolutionary theory from biology — for example, evolutionary game theory (Araujo and Souza, 2010; Babu and Mohan, 2018). Evidence shows that stakeholders in the supply chain have a significant influence on the development of a green hotel (Abdel-Maksoud et al., 2016); thus, interactions between stakeholders should be considered in the investigation of the green hotel supply chain. Evolutionary game theory is a game-theoretic analysis designed to analyze the game players' behaviors that contribute to developing the best green hotel supply chain strategies.

Evolutionary game theory is derived from biological evolution, which is widely used in disciplines such as economics and social sciences (Smith and Price, 1973; Cai and Kock, 2009). In contrast to traditional game theory, evolutionary game theory compensates for the drawback of the perfect rational hypothesis. The hypothesis of limited rationality makes the dynamic complex system of behaviors that change over time more appropriate for predicting the behavior of the game players. The evolutionary game has been introduced as a model for anonymous strategic interaction — that is, each player interacts with others over a period of time and the payoff (fitness) is affected by the selection of others (Friedman, 1991).

In economics, evolutionary game theory provides many findings from the perspective of stakeholders (Barari et al., 2012). These findings have been used to analyze the behaviors of players in the tourism industry. He et al. (2018) explored an incentive mechanism for the government to develop sustainable tourism by constructing an evolutionary game model and offered some suggestions to the government. Blanco et al. (2009) adopted the evolutionary game model to tourism firms to find the relationship between green firms and regulation. In other words, evolutionary game theory can be applied to the analysis of stakeholders' relationships. In addition, the theory can help distinguish different equilibria and assist in understanding the dynamics of players over the long term.

Mailath (1998) discussed the distinction between game theory and evolutionary game theory, with the latter being a particularly attractive way of learning. Action is divided among different potential strategies; if one agent is able to optimize and know the situation, the best action can be taken, which often implies higher payoffs. Because of the linkage to stakeholders, evolutionary game theory is often adopted in the discussion of stakeholders' relationships. Liu et al. (2018) used an evolutionary game dynamic to facilitate and analyze the evolution of cooperation. Tian et al. (2014) developed a system dynamic model to describe the diffusion of green supply chain management by manufacturers and examined the relationships between producers, consumers and the government in the sense of green supply chain management. Babu and Mohan (2018) used an integrated approach to evaluate the supply chain from the perspective of payers and providers.

Because a supply chain is dynamic and complex, it is impossible to make recommendations for different stakeholders based solely on green practices or a performance analysis. The evolutionary game approach offers an analytical framework for a hotel supply chain's evolution; effective measures to discourage or inhibit non- green development are also provided. Based on evolutionary game theory, the model considers the role of government, hotels, and hotel customers in the analysis of a green hotel supply chain's formation and evolution. The effect of green development on the success of a hotel is also discussed.

3. Model description

This section introduces the evolutionary stable strategy (ESS) and the evolution method to analyze hotels' green behavior and to see if it remains stable through natural selection. We then analyze the formation and evolutionary stability of a green hotel supply chain by a two-strategy selection dynamic model among stakeholders.

3.1. Evolutionary stability model of hotels' green behavior

Hotels in a green hotel supply chain enter into or exit the chain based upon internal and external factors. In the course of long-term evolution, a participant will continue to learn and mutate, choosing strategies that produce the most benefits. In a green hotel supply chain, a hotel can choose green or non-green strategies. Over time, if hotels that choose a green strategy survive, while those that do not are eliminated, the inference is to attribute success to the formation mechanism of a green hotel supply chain. To better understand the process, this study analyzes the hotel's preference for green activity and whether it is stable through natural selection while pursuing profitability. We utilized *i* and *j* to symbolize any two categories of entities which make up a hotel supply chain (e.g., hotel, supplier, distributor) to examine the evolution of hotel green behavior. Table 1 shows the definition of model variables.

Table 1
Definition of the variables of the model.

Variable	Definition
q_i	The output of green products of entity i,($q\geq 0$).
p_i	The price of green products of entity i, $p_i = a - q_i + kq_j$.
c	Constant term associated with the green technology level of the entity, ($c>0$).
$C_{(qi)}$	The total cost of green operation, $C(q_i) = cq_i^2$.
π_i	The profit of entity i, $\pi_i\left(q_i, q_j\right) = q_i\left(a - q_i + kq_j\right) - cq_i^2$.
G_i	The green willingness of entity i, $G_i\in[0,1]$. The larger the G_i, the higher the green willingness of entity i is.
$\boldsymbol{\Pi_i}$	The objective function of entity i's green willingness. In order to improve competitiveness, entities will consider not only their operating profits but also the profits of other entities in the system, which makes the objective function of entity i have a specific correlation with entity j.

Note: We use supply chain entity i as an example to describe its model variables, the same concept applies to entity j.

In light of the variance of cost behaviors, the total cost of the entity does not always vary in a linear fashion with the production of service, the nonlinear quadratic function model as the cost function was employed (Hayes, 1987; Kaserman and Mayo, 1991), and the cost function of entity i is:

$$C(q_i) = cq_i^2 (q \geq 0) \tag{1}$$

Where q_i is the green production volume of the entity i, and c is a constant related to the entity's green technology ($c>0$). The higher the entity's adoption of green technology, the lower c is, assuming that the levels of green technology in the hotel supply chain are equal (Yi, 2010). The inverse demand function of the entity (Bárcena-Ruiz and Espinosa, 1999) is then:

$$p_i = a - q_i + kq_j \tag{2}$$

Additionally, the demand function is hypothesized to be a linear function, that is, the price of a good will decrease when the quantity of that good increases, where $i \neq j$, constant $a>0$, $-1<k<1$, and k is the correlation of different entities in the hotel supply chain. For example, when an entity j provides substitute goods for i, the increase of the goods of j will make the price of i decrease, then $k<0$, and when an entity j provides complementary goods, the increase of the goods of j will make the price of i increase, then $k>0$. The cost and inverse demand of entity j can be computed in the same way as entity i does. Based on these assumptions, the profit functions of entities i and j are:

$$\pi_i(q_i, q_j) = q_i(a - q_i + kq_j) - cq_i^2 \tag{3a}$$

and

$$\pi_j(q_i, q_j) = q_j(a - q_j + kq_i) - cq_j^2 \tag{3b}$$

In the hotel supply chain, the interests of entities i and j are related. Thus, their willingness to adopt green practices is closely related to achieving a win-win situation in the evolution process — that is, there is a correlation in the objective function of green intention between entities i and j. Based on the willingness model (Yi, 2010), assume that G_i and G_j are the green preference (willingness) parameters of entities i and j, respectively, and G_i, $G_j\in[0, 1]$. Here, $G_i=G_j = 1$ denotes that both entities with strong green preferences produce a win-win result, and $G_i=G_j = 0$ denotes both entities that consider only their own vested interests and adopt a non-green plan of development.

The overall objective profit functions of a green preference by entities i and j are:

$$\prod\nolimits_i (q_i, q_j) = G_i[\pi_i(q_i, q_j) + \pi_j(q_i, q_j)] + (1 - G_i)\pi_i(q_i, q_j) \tag{4a}$$

and

$$\prod_j(q_i, q_j) = G_j[\pi_i(q_i, q_j) + \pi_j(q_i, q_j)] + (1 - G_j)\pi_j(q_i, q_j) \tag{4b}$$

A mingling of competitive and cooperative relationships exists in entities in the hotel supply chain. Entities that are willing to adopt green strategies could enjoy the externalities of collaboration, which makes the objective function of the entity i has a specific correlation with the entity j. The first term of Eqs. (4a) and (4b) indicates that if both entities are willing to adopt green strategies, entities i and *j* could both benefit from their collaboration; the second term of equations 4(a) and 4 (b) indicates that they are reluctant to do much about green development.

Considering the objective maximization functions of a green preference by entities *i* and *j*, the first derivative of the objective functions of two entities with their respective values were calculated as given in Eq. (5), and the second derivative can be deducted as Eq. (6). Similarly, the first and second derivatives of the objective functions of entity *j* can be computed. The result shows that the second derivative is less than 0, proving that a maximum value in the function and the condition of profit maximization are satisfied.

$$\prod_i^{'} = \frac{\partial \prod_i}{\partial q_i} = a - 2q_i + kq_j - 2cq_i + kG_i q_j \tag{5}$$

and

$$\prod_i^{''} = \frac{\partial \prod_i^{'}}{\partial q_i} = -2 - 2c < 0 \tag{6}$$

The equilibrium solution of output decision was obtained as:

$$q_i = \frac{ak(1 + G_i) + 2a(1 + c)}{4(1 + c)^2 - k^2(1 + G_i)(1 + G_j)} \tag{7a}$$

and

$$q_j = \frac{ak(1 + G_j) + 2a(1 + c)}{4(1 + c)^2 - k^2(1 + G_i)(1 + G_j)} \tag{7b}$$

Assuming that the entities have the same green preference (G_i=G_j=G), the outcome of the entity game is calculated. Because parameters G_i, G_j and k have such assumptions as G_i, G_j∈[0, 1] and $-1<k<1$, then $k+G<2$, the result of Eq. (8) is more than 0.

$$\begin{aligned}\pi(G, G) - \pi(0, 0) &= \frac{a^2(1 + c - kG)}{[2(1 + c) - k(1 + G)]^2} - \frac{a^2(1 + c)}{[2(1 + c) - k]^2} \\ &= \frac{a^2k^2G[(2 - k - G) + c(2 - G)]}{[2(1 + c) - k(1 + G)]^2[2(1 + c) - k]^2} > 0\end{aligned} \tag{8}$$

The results demonstrate that a green preference entity will generate higher profits versus a non-green entity in the hotel supply chain, which testifies to the benefits of adopting green and sustainable initiatives that lend support of going green to respond to today's dynamic competitive environment. For hotel companies (hotels) in the supply chain, if a green hotel remains viable throughout the process of natural selection, that is indicative of the hotels' willingness to "go green" and of the need for a green hotel supply chain. The analysis of a hotel's adoption of green behavior is local and does not represent the relationship between a global equilibrium and the dynamic selection process. All stakeholders are considered in the generation of a green hotel supply chain. For further insight into green behavior in the evolution of a green supply chain, an evolutionary model of game theory is used.

3.2. The evolution model of stakeholders in a green hotel supply chain

Hotel supply chain transformation into green development is a long-term process. In complex environments, relevant stakeholders must always weigh green input and output benefits. Because of the limited rationality, it is hard for stakeholders first to decide what is best for long-term development. Therefore, the government may invest resources in overseeing green development or choosing not to guide the development priority arrangement. Hotels may adopt a green development strategy or stick to the original pattern of development, and consumer decisions are more volatile. Evolutionary game model construction helps analyze the behavioral characteristics of internal and mutual strategic choice of stakeholders, dynamic evolution, and stable status. Then it describes the dynamic development process of strategic stakeholder selection in the hotel supply chain.

Clarifying the major stakeholders in a green hotel supply chain is the first step in building an evolutionary model. While maximum benefit is the goal of hotels, the selection of a green strategy is affected by internal and external factors, such as horizontal competition, government regulation, and hotel customer preferences. Considering the evolution of stakeholders in a hotel supply chain, this study constructs evolutionary game models among governments, hotels, and hotel customers. Primary stakeholders in the green hotel supply chain consist of customers, suppliers, employees, government, local communities, and competitors. As a result of the statistical complexity of the dynamics of evolutionary stable strategies, we have chosen consumers to represent market forces (the invisible hand) and the government to exemplify non-market forces (the visible hand); both have invented powers in the free market (Tan et al., 2007).

The evolutionary stable strategy and replicator dynamics (RD) are two concepts of evolutionary game theory (Smith, 1974). ESS means that if everyone in a population chooses the same strategy, no mutation counter-measures will impact the strategy under the control of natural selection. In other words, if variation cannot affect the original form, then the original form illustrates a stable existence (Smith, 1974; Taylor and Jonker, 1978) that can be expressed by the following mathematical equations. If the members of the group have the same set of pure strategy S_k ={s_1, s_2, s_3,... s_m}, the mixed strategy set can be defined as:

$$S = \left\{ \left(x_1, x_2, x_3, \ldots x_m \right) \middle| \sum x_i = 1, x_i \geq 0 \right\} \tag{9}$$

where x_i denotes the probability of the adoption of strategy *i* at one time, if strategy $s \in S$ satisfies: (i) $\forall s \neq s$' and $s' \in S$, then $f(s, s) \geq f(s', s)$, and (ii) when $f(s, s) = f(s', s)$, also $f(s, s') > f(s', s')$. Thus, strategy *s* is ESS.

RD refers to the constant adjustment of the entity's by ways of learning imitation and the choice of the current situation. If there is an occasional error deviation in the game, then the replication dynamics can restore it (Taylor and Jonker, 1978; Zeeman, 1981). This can be expressed by the mathematical equation:

$$d_{x(t)} \Big/ d_t = x(U_s - \overline{U}) \tag{10}$$

where *x* denotes the proportion of strategy *s*, U_s denotes the expected fitness of strategy *s*, $\overline{U}$ denotes the average fitness of all strategies, and $d_{x(t)}$ /d_t denotes the change of strategies' proportion by time.

3.2.1. Model description between government and hotels

For further insight into the evolution of a green hotel supply chain, this section considers the stakeholders of government and hotels. We list the model assumption of ESS analysis between the two as follows.

3.2.1.1. Government. We denote *x* as the probability of government regulatory action, and (1- *x*) is the probability of no government regulatory action. When government regulation is enacted, a corresponding regulation cost C_1 will be generated. In addition, *pm* (punishment) arises when a hotel selects a non-green strategy. When a hotel selects a non-green strategy, the government pays the corresponding pollution treatment cost C_2.

3.2.1.2. Hotels. We denote *y* as the probability of a hotel selecting a green strategy, and (1-*y*) is the probability that a hotel selects a non-green strategy. When a hotel selects a green strategy, a corresponding cost C_3 will be generated, for example, an investment in green

Table 2
The payoff values of model 1.

Game agents and their strategies		Hotels	
		Green	Non-green
Government	Regulation	$-C_1-R_2$, $-C_3+R_1+R_2$	$-C_1+pm- C_2$, $-pm$
	Non-regulation	0, $-C_3+R_1$	$-C_2$, 0

technology, and R_1 represents the benefit as a result of choosing a green strategy. Moreover, R_2 (benefit from a government reward) will appear when the government enacts regulation and hotels are punished if a non-green strategy is chosen. Table 2 explains the payoff values.

Let π_{11}, π_{12} denote the government's expected fitness of the different selections (regulation, non-regulation), and $\overline{\pi}_1$ denote the average fitness of the government. Moreover, π_{21}, π_{22} denotes a hotel's expected fitness of different selections (green, non-green), and $\overline{\pi}_2$ denotes the average fitness of hotels. We calculate the fitness of the government as:

$$\pi_{11} = y(-C_1 - R_2) + (1-y)(-C_1 + pm - C_2) \tag{11a}$$

$$\pi_{12} = y \cdot 0 + (1-y)(-C_2) \tag{11b}$$

and

$$\overline{\pi}_1 = x\pi_{11} + (1-x)\pi_{12} \tag{11c}$$

From Eq. (11a) to (11c), the replicator dynamic equation of the government's selection can be expressed as:

$$F(x) = \frac{d_{x(t)}}{d_t} = x(\pi_{11} - \overline{\pi}_1) = x(1-x)(pm - ypm - R_2y - C_1) \tag{12}$$

Similar to the evolution process for the dynamic equation of the government, we calculate the fitness of hotels as:

$$\pi_{21} = x(-C_3 + R_1 + R_2) + (1-x)(-C_3 + R_1) \tag{13a}$$

$$\pi_{22} = x(-pm) + (1-x) \cdot 0 \tag{13b}$$

and

$$\overline{\pi}_2 = y\pi_{21} + (1-y)\pi_{22} \tag{13c}$$

From Eq.s (13a) to (13c), the replicator dynamic equation of the hotels' selection can be expressed as:

$$F(y) = \frac{d_{y(t)}}{d_t} = y(\pi_{21} - \overline{\pi}_2) = y(1-y)(xR_2 + R_1 - C_3 + xpm) \tag{14}$$

By observing Eq.s (12) and (14), the strategies of the participants in the chain interact, and the consequential benefits are affected due to other stakeholders' decisions. From Eq.s (12) and (14), we extract a finding that the participant's decision can affect other participant's strategies.

3.2.2. Model description between hotels and hotel customers

3.2.2.1. Hotels. We denote y as the proportion of hotels selecting a green strategy, and (1- y) is the proportion that selects a non-green strategy. When a hotel chooses a green strategy, the corresponding cost (e.g., the expense of investing in green technology) c_1 will be generated and r_1 (benefit) will appear when a hotel chooses a green strategy. Here, r_2 represents extra benefit due to fulfilling hotel customers' preferences, and p represents hotels' invisible loss for no added value to hotel customers, due to the choice of a non-green strategy.

3.2.2.2. Hotel customers. We denote z as the proportion of hotel customers who prefer to use green products, and (1-z) is the proportion who do not. When hotel customers are provided with green products, a corresponding cost c_2 (a higher price than that of a comparable non-green product) will be generated; in addition, r_3 will be generated for hotel customers who will have a more enjoyable experience because the hotel provided green products. Hotel customers will pay e (environmental loss) when the two players — hotels and hotel customers — do not support green concepts (Table 3).

Table 3
The payoff values of model 2.

Game agents and their strategies II		Hotel Customers	
		Accept	Reject
Hotels	Green	$-c_1+r_1+r_2$, $-c_2+r_3$	$-c_1+r_1-p$, 0
	Non-green	$-r_2$, $-r_3$	0, $-e$

Let π^{11}, π^{12} denote hotels' expected fitness of different selections (green and non-green, respectively), and $\overline{\pi}^1$ denotes the average fitness of a hotel. Moreover, π^{21}, π^{22} denote hotel customers' expected fitness with different selections (acceptance and rejection, respectively), and $\overline{\pi}^2$ denotes the average fitness of hotel customers. We calculate the fitness of hotels as:

$$\pi^{11} = z(-c_1 + r_1 + r_2) + (1-z)(-c_1 + r_1 - p) \tag{15a}$$

$$\pi^{12} = z(-r_2) + (1-z) \cdot 0 \tag{15b}$$

and

$$\overline{\pi}^1 = y\pi^{11} + (1-y)\pi^{12} \tag{15c}$$

From Eq.s (15a) to (15c), the replicator dynamic equation of a hotel selection is:

$$F(y) = \frac{d_{y(t)}}{d_t} = y(\pi^{11} - \overline{\pi}^1) = y(1-y)(r_1 + zp + 2zr_2 - c_1 - p) \tag{16}$$

Similar to the evolution process for the dynamic equation of hotels, the fitness of hotel customers can be calculated as:

$$\pi^{21} = y(-c_2 + r_3) + (1-y)(-r_3) \tag{17a}$$

$$\pi^{22} = y \cdot 0 + (1-y)(-e) \tag{17b}$$

$$\overline{\pi}^2 = z\pi^{21} + (1-z)\pi^{22} \tag{17c}$$

and

$$F(z) = \frac{d_{z(t)}}{d_t} = z(\pi^{21} - \overline{\pi}^2) = z(1-z)(2yr_3 + e - c_2y - r_3 - ye) \tag{18}$$

Eq.s (16) and (18) deduce that the hotel and hotel customers' benefits and strategy choices highly correlate.

4. Model solutions

4.1. ESS analysis among stakeholders

By analyzing the differential equations, we obtain five local equilibrium points. Let differential Eqs. (12) and (14) equal 0, and the equilibrium points of the system are:

(0,0), (0,1), (1,0), (1,1) and $(\frac{C_3-R_1}{R_2+pm}, \frac{pm-C_1}{pm+R_2})$

Taking the partial derivative of x and y based on differential Eq.s (12) and (14) in turn, we can express the Jacobian as:

$$J = \begin{bmatrix} (1-2x)(pm - ypm - R_2y - C_1), -x(1-x)(pm + R_2) \\ y(1-y)(R_2 + pm), (1-2y)(xR_2 + R_1 - C_3 + xpm) \end{bmatrix} \tag{19}$$

Local stability analysis is then used to determine the local stability of the five- equilibrium points (Friedman, 1991).

As for the evolution analysis between hotels and hotel customers, let Eq.s (16) and (18) equal 0, and the equilibrium points of the system are:

(0,0), (0,1), (1,0), (1,1) and $(\frac{r_3-e}{2r_3-e-c_2}, \frac{c_1+p-r_1}{2r_2+p})$

Taking the partial derivative of y and z based on differential Eq.s (16) and (18) in turn, we express the Jacobian as:

Table 4
Local stability analysis of the equilibrium points (I).

Equilibrium point	Determinant of J	Sign	Trace symbol	Sign	Local stability	Conditions
(0, 0)	$(pm-C_1)(R_1-C_3)$	+	$pm-C_1+R_1-C_3$	−	ESS	$A>0, C<0$
(0, 1)	$(C_1+R_2)(R_1-C_3)$	+	$-C_1-R_2-R_1+C_3$	−	ESS	$A<0$
(1, 0)	$(C_1-pm)(R_2+R_1-C_3+pm)$		$C_1+R_2+R_1-C_3$		Instability	Any condition
(1, 1)	$(R_2+C_1)(C_3-R_1-R_2-pm)$		$C_1+C_3-R_1-pm$		Instability	Any condition
$\left(\frac{C_3-R_1}{R_2+pm}, \frac{pm-C_1}{pm+R_2}\right)(y^*, z^*)$	$(A^2/B-A)(C^2/B-C)$		0		Saddle point	Any condition

Note: $A = C_3-R_1$, $B = R_2+pm$, $C = pm-C_1$.

Table 5
Local stability analysis of the equilibrium points (II).

Equilibrium point	Determinant of J	Sign	Trace symbol	Sign	Local stability	Conditions
(0,0)	$(r_1-c_1-p)(e-r_3)$	+	$r_1-c_1-p+e-r_3$	−	ESS	$D>0, F>0$
(0,1)	$(r_1+2r_2-c_1)(r_3-e)$	+	$r_1+2r_2-c_1+r_3-e$	−	ESS	$r_1+2r_2<c_1, r_3<e$
(1,0)	$(c_1+p-r_1)(r_3-c_2)$	+	$c_1+p-r_1+r_3-c_2$	−	ESS	$F<0, r_3<c_2$
(1,1)	$(c_1-r_1-2r_2)(c_2-r_3)$	+	$c_1-r_1-2r_2+c_2-r_3$	−	ESS	$c_1<r_1+2r_2, c_2<r_3$
$\left(\frac{r_3-e}{2r_3-e-c_2}, \frac{c_1+p-r_1}{2r_2+p}\right)$ (y^*, z^*)	H		0		Saddle point	Any condition

Note: $D = r_3-e$, $E=2r_3-e-c_2$, $F = c_1+p-r_1$, $G=2r_2+p$.

$$H = \frac{(E-2D)(G-2F)(D^2E-DE)(r_1+G+FG^2-FG-r_1G)-DEFG(E-D)(G-F)}{E^2G^2}$$

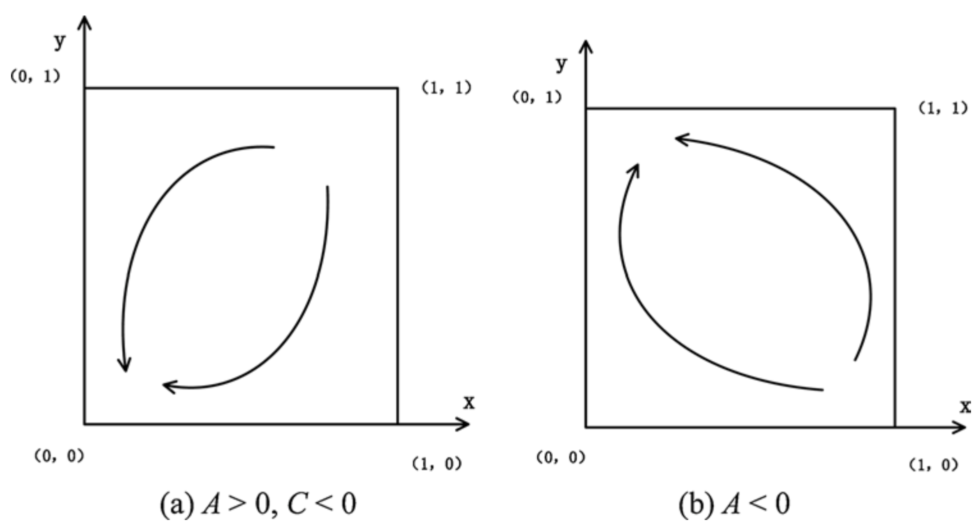

Fig. 3. Phase diagram of ESS I.
Note: $A = C_3-R_1$, $B = R_2+pm$, $C = pm-C_1$.

$$J = \begin{bmatrix} (1-2y)(r_1+zp+2zr_2-c_1-p), y(1-y)(p+2r_2) \\ z(1-z)(2r_3-c_2-e), (1-2z)(2yr_3+e-c_2y-r_3-ye) \end{bmatrix} \tag{20}$$

4.2. Strategy stability analysis

We also analyze the stability of the Jacobian matrix's equilibrium points to demonstrate whether a dynamic evolutionary system is stable. When the Jacobian matrix satisfies the condition that the determinant (J) is greater than 0 and the trace (J) is less than 0, the method achieves evolutionary system stability (Friedman, 1991), that is, convergence has local stability characteristics. According to the analysis ESS among stakeholders, the stable strategy changes with the circumstances. When $0<x^*<1$, $0<y^*<1$, and $0<z^*<1$, both (x^*,y^*) and (y^*,z^*) are a possible stable strategy. Thus, the determinant of J and trace of J can be calculated as described in Tables 4 and 5.

First, we consider the dynamic game model between the government and hotels, where (0,0) and (0,1) are ESS — in which these two stakeholders will choose (non-regulation, non-green) or (non-regulation, green) under different conditions to reach a point of stability. When $C_3>R_1$, $pm<C_1$ (Fig. 3a), or in other words, if the cost of a green strategy is greater than the benefit, and the cost to regulate is more than the benefit gained (for example, public good or revenue from fees or fines) then hotels and the government will not choose (green, regulation).

To facilitate the development of a green hotel supply chain, the government should impose or increase penalties to pressure hotels to institute green practices, because R_2 (government incentives to hotels) do not work in this situation. Another ESS is (0,1) — that is, when $C_3<R_1$ (Fig. 3b), the cost of a green strategy is less than the benefit. If the benefit gained by imposing penalties is less than the cost of regulation, then a limited rational government would choose non-regulation, and the system converges to the point of (non-regulation, green) in this situation, which is also the most ideal state. As a result, no government action

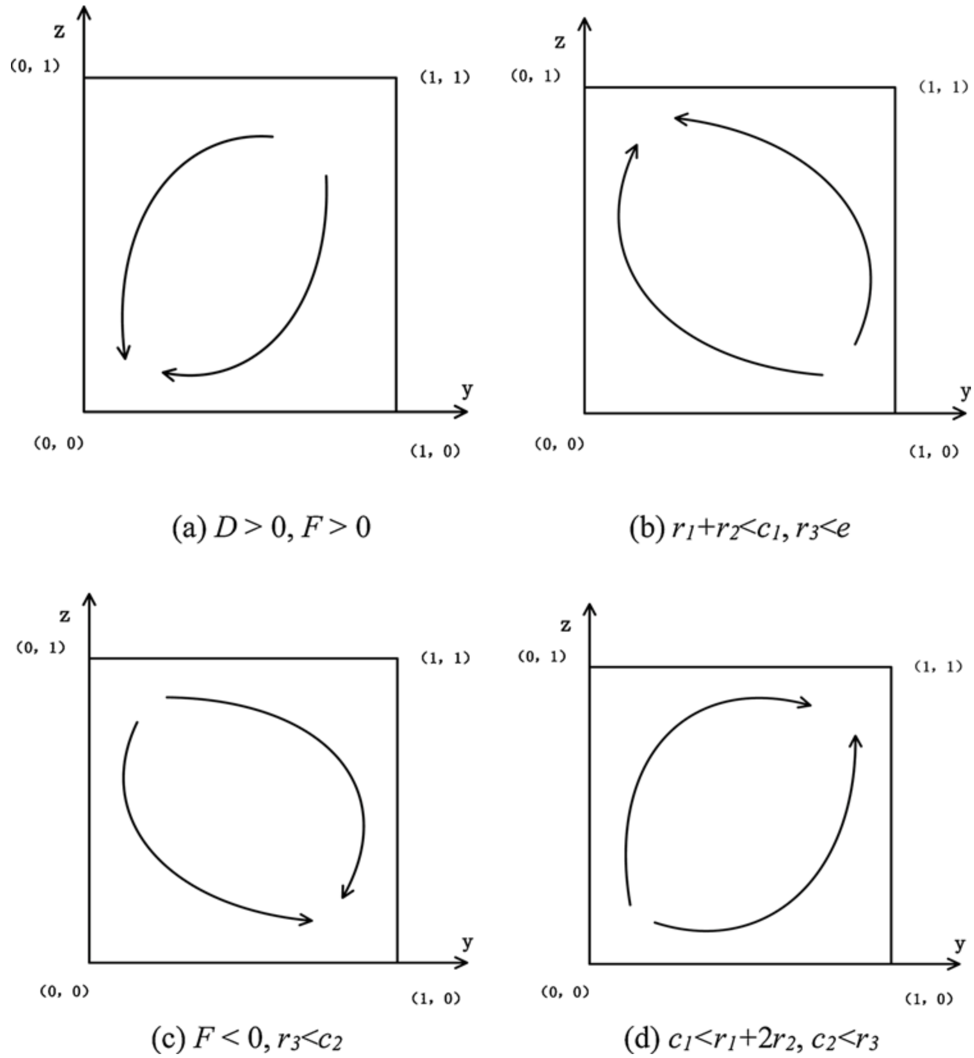

Fig. 4. Phase diagram of ESS II.
Note: $D = r_3-e$, $E=2r_3-e-c_2$, $F = c_1 +p-r_1$, $G=2r_2 +p$.

is required and hotels will consciously adopt a green strategy. Government regulation does act as an incentive for green development; however, over time, government will recognize that there is no need for continued regulation; after that, both the government and hotels will achieve a win-win situation, maximizing their respective interests.

Second, the development of the hotel supply chain is influenced by the hotel customers' interest in and use of green products and services. In the dynamic model between hotels and hotel customers, (0,0), (0,1), (1,0) and (1,1) will be ESS under different conditions. Hotels will not choose a green strategy if the cost is more than the benefit, and *e* (the loss of green products due to a non-green strategy) will influence the hotel customers' selection of a hotel according to the cost-benefit principle. A green hotel supply chain cannot survive without the joint effort of both hotels and hotel customers. The production and operations of a hotel are affected by an ever-changing market, and hotel customers must support the use of green products. Thus, the decisions made by hotel customers are important.

In this evolution model, the ideal state of ESS is (1,1) — that is, hotels will choose a green strategy, and hotel customers will welcome green services. Under the conditions of $c_1<r_1 +2r_2$, $c_2<r_3$ (Fig. 4d), which means that the two parties' respective profits have been maximized, the roles of *e* and *p* will continue to decrease or even disappear.

5. Discussion of results and implications

Extending green hotel literature to the area of dynamic supply chain management, this study uses evolutionary game theory to explain the formation of hotels' green behaviors and the dynamic process of a green hotel supply chain. The green behavior of the single group (hotels) and the green contribution of multistakeholder groups (government and hotel customers) are incorporated into this evolutionary game model. Below, we discuss the major findings and implications.

5.1. Discussion of model results

The present study confirms that our findings are in line with Al-Aomar and Hussain's (2017) value creation framework if hotels adopt lean-green practices. Our results show that green willingness is a significant factor in hotels' revenue. More specifically, hotels with green behaviors are more successful than those without them (Eq. (8), $\pi(G, G)-\pi(0, 0) > 0$). As demonstrated, hotels' green willingness will affect the result of their strategy, and the parameters in the model of hotels' green behavior consider the hotels' self-benefit (profit maximization). Hotels that go green are more profitable than hotels that do not. The result also reveals over the long process of evolution that hotels that are not green, will be driven out of the market because they are less profitable. Sections 5.1.1. and 5.1.2 provide detailed discussions to the

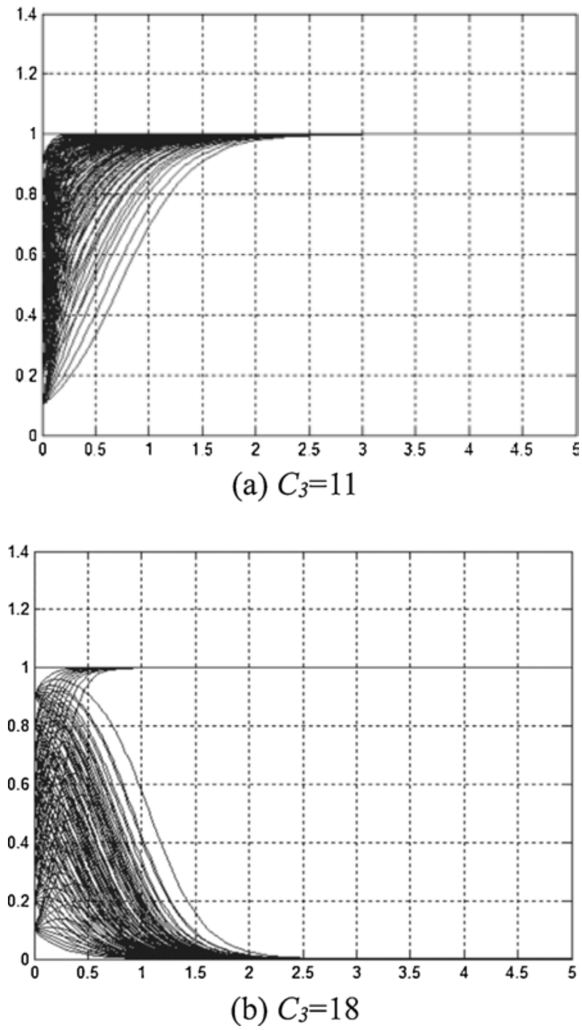

Fig. 5. The dynamic evolution diagram of hotels with changes in C_3.

two proposed evolutionary game models.

5.1.1. Model results between government and hotels

The formation of a thriving green hotel supply chain requires benign interaction among the government, hotels and hotel customers. Optimal equilibrium is reached when all participants adopt and support green behaviors. Through evolutionary game theory, the optimal path toward the creation of a hotel supply chain is established. Notice that the results of the evolutionary game are related to the hotel supply chain's initial state and the payoff to game players (the parameters). We used the Matlab R2016b to describe the evolutionary dynamics among the parameters (government, hotels, and hotel customers) (He et al., 2018).

The values of the parameters affect the payoffs of different individuals. In the game between government and hotels, the results show a different strategy under changes in the parameters. Fig. 5 shows the values of $R_1 = 14$, $R_2 = 6$, $C_1 = 10$, $C_3 = 11$, $pm = 8$ satisfying the condition of $R_1 > C_3$. For then when C_3 is changed from 11 to18 ($C_3 = 18$), the variation trend of hotels is clear; hotel's strategy selection tends to 1, a green strategy (Fig. 5a), but converges to 0 (non-green strategy, Fig. 5b) with increased cost of green C_3. This finding confirms that the initial purpose of green hotel development was commercial, not environmental (Jones et al., 2014; Pizam, 2009). Accordingly, the formation and evolution of the green hotel supply chain need government supervision and consumers' support for green consumption behaviors.

In addition, it is interesting to find that in the model's results, the government strategy always converges to 0 (Table 4). This means that the government's participation (in the form of regulation) acts as a booster for the green development of hotels. In the course of time, the government will eventually discontinue regulation. However, because at the early stage of development, the irrational factors such as a relevant system, talent, and allocation of technology resources will limit the government's ability to develop management measures, green convergence in hotels will appear complicated.

The development of sustainable hotels depends upon whether a viable green hotel supply chain can be formed. As the government and hotels are constantly adjusting their strategies according to the condition of others, there may be a long period of co- existence between "regulation and non-regulation" and "green and non-green." Finally, as the development of green hotels transforms into a virtuous cycle, dropping hotel costs along with increasing incomes would allow the hotel to move to the green spontaneously leading the government to adjust its position in the green hotel supply chain from a regulator to a third party observer providing a guarantee of green service offerings.

5.1.2. Model results between hotels and hotel customers

The game model between hotels and hotel customers is more complex. Figs. 6 and 7 show the dynamic evolution of hotels and hotel customers for changes to r_1, r_3 and e. The initial parameters are $c_1 = 20$, $c_2 = 6$, $r_1 = 16$, $r_2 = 6$, $r_3 = 10$, $p = 12$, $e = 15$. According to Fig. 6, when the initial cost value (c_1) of the hotel choosing a green strategy remains unchanged, the rate of hotel's convergence to green will slow as income decreases (Figs. 6c to 6d). When the benefit (r_1) falls below a certain value, the hotel will choose a non-green strategy (Fig. 6b). In addition, the evolutionary game model's results show that hotel customers' attitudes and behaviors have a strong influence on hotels' green behavior (the parameters of r_3 and e). Fig. 7 illustrates the changes with numerical simulation. As the loss (e) of choosing a non-green product increases, consumers will support green development. Moreover, when hotel customers use green products, the continuous increasing extra benefit r_3, such as the consumption experiences, will drive consumers to choose green hotels.

5.2. Theoretical implications

This study discusses the formation and evolution of a green hotel supply chain. Evolutionary game theory combines classic game theory analyzing the dynamic evolutionary process. Our results go beyond previous reports, showing that a process of dynamic equilibrium development did exist in the green supply chain. This section summarizes the theoretical contributions made by this study.

Our results cast a new light on the understanding of game group selection and stakeholders' behavior in the green hotel supply chain. When comparing our results to those of older studies (He et al., 2018; Huang et al., 2010), it must be pointed out that we incorporated internal factors, such as willingness to go green, which give better results than previous research that is limited to consideration of external factors (e.g., behavioral game analysis of stakeholders) to reflect the actual state of the modeling process. The formation of a green supply chain is an evolutionary process. The government's regulations (reward or punishment) and the cultivation of customers' green consumption behavior are indispensable for entities involved in the supply chain to consider adopting a green strategy. Moreover, an integrated supply chain to optimize entities' collective performance is also advantageous to the formation of the green supply chain.

The result of the game analysis is then compared with the results of investigations of customers' sustainable behavior. Contrarily to the results of substantial studies, it has been confirmed that hotels' environmentally friendly behavior can increase customer satisfaction and loyalty (Prud'homme and Raymond, 2013; Merli et al., 2019). Our analysis found evidence that consumers' pro-environmental and

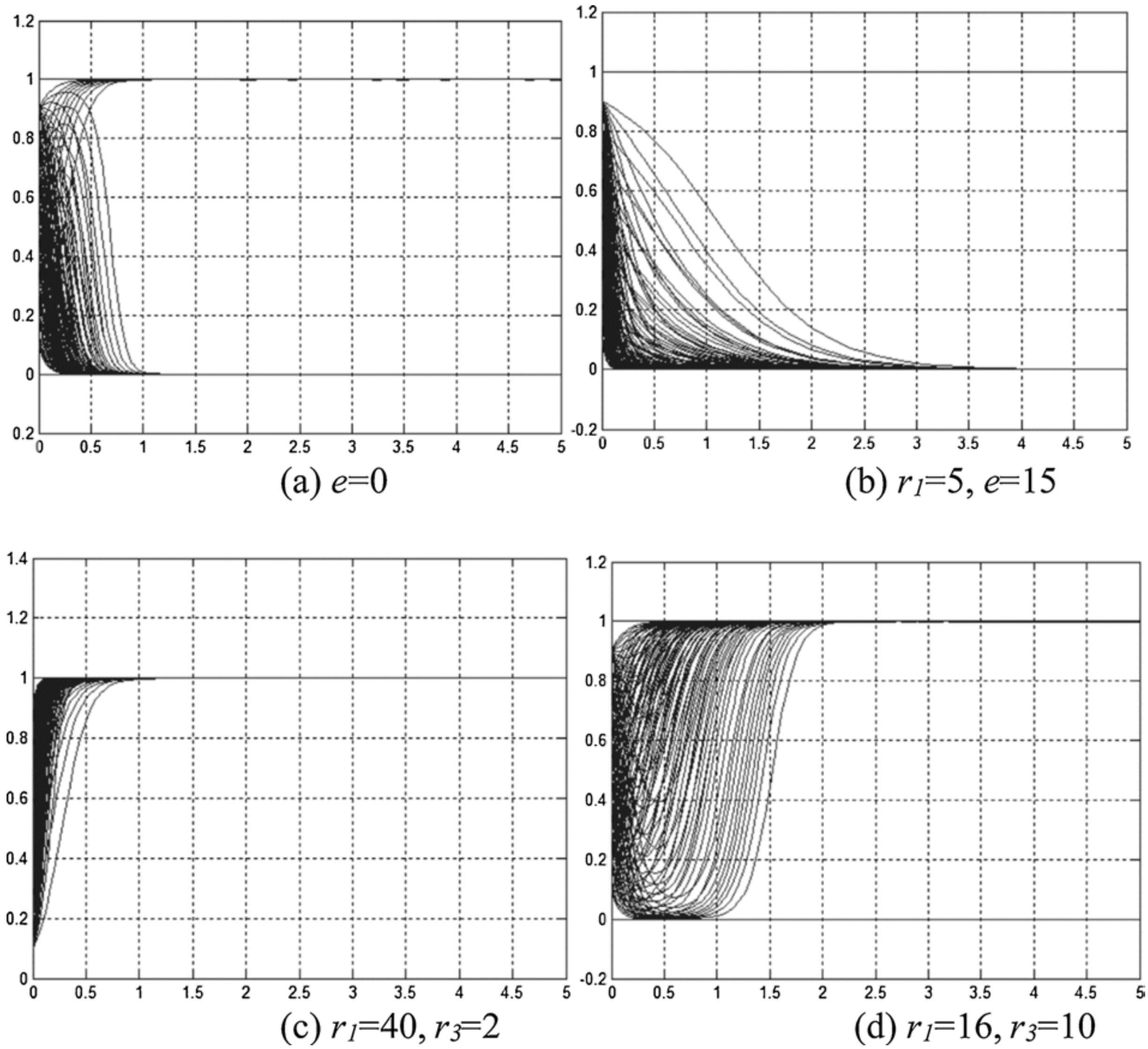

Fig. 6. The dynamic evolution diagram of hotels with changes in r_1, r_3 and e.

anti-environmental behaviors can converge (evolutionary stability strategy). This indicates that some hotel customers are less supportive of green products. Overall, this study complements previous findings by providing a much more detailed examination of game theory.

5.3. Managerial implications

Several managerial implications can be drawn from this study. Hotel customers' preferences have a significant role in creating a green hotel supply chain. From the evolutionary game model between hotels and hotel customers, we can find that the value orientation of consumers is difficult to change in a short time. This indicates that their influence always exists, and is verified by our results. The role of consumers in the green development of the hotel supply chain must be emphasized. Customers' values and beliefs should be considered as factors that affect purchasing decisions (Hoyer et al., 2016). Our findings stress the changeability of customers' green consumption behaviors and attitudes (Baker et al., 2014; Rahman et al., 2012). Hotel managers should train consumers on sustainable habits and cultivate loyal hotel customers to reduce the environmental impact, as age, education, and other characteristics are evidently having a meaningful effect on going green (Verma and Chandra, 2018).

Our research has also verified that government oversight is essential early in the development of a green hotel supply chain because it can alleviate fluctuations in hotels' strategy in the evolutionary game model between hotels and hotel customers. From the result of the evolutionary game model, government strategy always converges to 0, that is, as supporting the green hotel supply chain, the government's role changes with each stage and finally it chooses non-regulation. To guide the transformation of the traditional hotel supply chain into a green hotel supply chain, government needs to change its reward-penalty mechanism.

The results from this study lead us to believe that the construction of the green hotel supply chain needs all stakeholders' joint efforts and will bring long-term benefits to integrated entities in the green hotel supply chain. These findings imply that supply chain integration strategies can achieve a win-win result in green hotel development.

6. Conclusion, limitations and directions for future research

Our findings lead to two conclusions. Green supply chain management is an efficient way to improve an entity's competitiveness (Zhu and Sarkis, 2004), especially in the hotel industry. A dynamic analysis demonstrates that a hotel's attitude toward "green" has a significant effect on its revenue; in other words, hotels that adopt green behaviors reap higher benefits than hotels that do not.

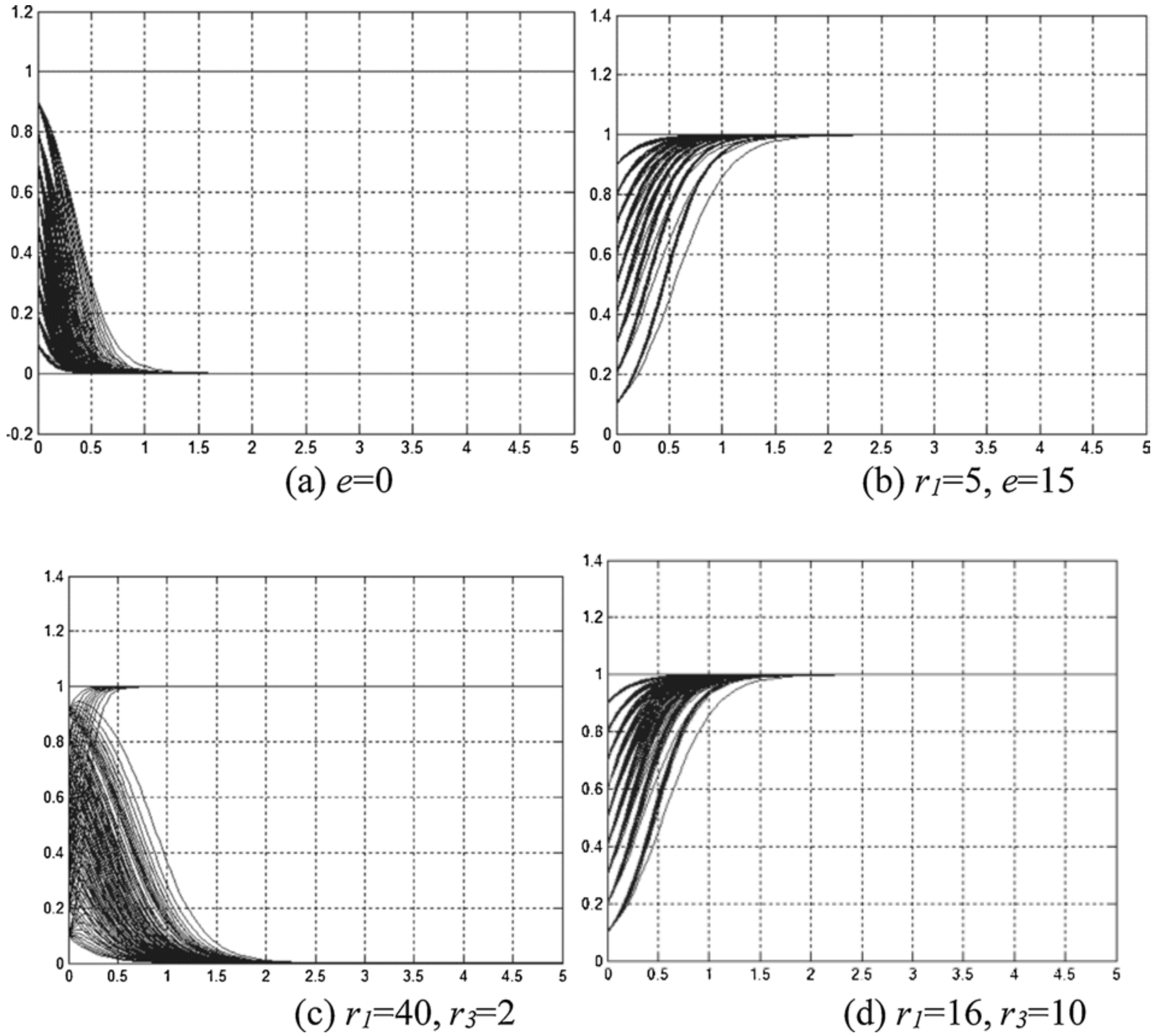

Fig. 7. The dynamic evolution diagram of hotel customers with changes in r_1, r_3 and e.

Additionally, the transformation from the traditional to a green supply chain requires the efforts of all stakeholders. Regulatory supervision and consumers' preference for green products are indispensable factors in the formation of the green hotel supply chain. In the absence of regulation and the lack of green consumption awareness, some hotels would not invest in adopting a non-green strategy based on short- term benefits. On these grounds, we have concluded that government should cultivate consumers' environmental awareness, encourage green consumption behavior, and regulate entities in supply chains to run more environmentally friendly business. The cost and benefit-sharing mechanism should be established in the supply chain system, which could elicit a higher willingness among hotels to participate in the construction of the green supply chain.

This study has the following limitations. First, a green hotel supply chain's existence and evolution are only proven hypothetically through mathematical game model analysis and simulation analysis. The parameter assumptions of the model setting in this study are from the stakeholder interaction perspective and focus on considering the cost-benefit of supply chain. Future work should utilize statistical data from authoritative institutions or other methods (interviews or surveys) for additional research to verify the proposed model's findings for the practical application. Second, while there are differences intrinsic to each stakeholder in the hotel supply chain, this study is a macroscopic analysis of the formation and evolution of a green hotel supply chain. Future research may examine the influence upon the evolutionary game model results based upon the intrinsic differences among stakeholders, for example, a customer's education, the hotel's star rating and the government's influence on the economy. As the development of the hotel industry is closely related to the regional economy, further analysis could consider regional differences, such as corporate culture and regulatory strength.

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