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*Published in:*  
Journal of Intelligent and Fuzzy Systems

*Link to article, DOI:*  
[10.3233/JIFS-179087](https://doi.org/10.3233/JIFS-179087)

*Publication date:*  
2019

*Document Version*  
Peer reviewed version

[Link back to DTU Orbit](#)

*Citation (APA):*  
Chen, Z. (2019). Economic benefit analysis of green building based on fuzzy logic and bilateral game model. *Journal of Intelligent and Fuzzy Systems*, 37(1), 301-313. <https://doi.org/10.3233/JIFS-179087>

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# Economic benefit analysis of green building based on fuzzy logic and bilateral game model

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**Abstract.** Green building is the development of sustainable development concept in architectural field. While the construction industry has brought great benefits to the development of national economy, its high investment, high pollution and inefficient development mode has also produced a huge energy load. Therefore, from the perspective of environmental and economic sustainability, the development of green buildings is particularly important. In this paper, the author makes economic benefit analysis of green building based on fuzzy logic and bilateral game model. By introducing such factors as economic benefits, cognition and government policies, this paper construct an evolutionary game model, which provides a basis for improving the economic benefits of green buildings. The results show that the first factor affecting enterprise decision-making is the incremental profit of green building developers, followed by the government's incentive policy. After the evolution of the market, the final strategic choice will be stabilized to higher economic benefits. Generally speaking, green buildings need to effectively control incremental costs and consider scale benefits. Through management efficiency innovation and policy stimulation, the problems of huge investment cost and long payback period can be solved, so as to improve the economic benefits of green building development.

Keywords: Green building, game theory, incentive mechanism, benefit analysis

## 1. Introduction

In January 2015, the Central Economic Work Conference fully explained the characteristics of the "new normal economy". In December the same year, the Central Economic Work Conference proposed to focus on strengthening the structural reform, in the moderate expansion of aggregate demand at the same time, to capacity, to inventory, to leverage, reduce costs, and make short board[1]. Economic development mode from extensive to intensive growth, low efficiency, high pollution shift to high efficiency, low emission development, driven by factor-driven shift to innovation-driven development model [2,3]. The face of supply-side reform of the new normal, China's green building development must take the road

of innovation, overall innovation needs of the whole industrial chain innovation[4,5]. However, the development process of green building involves many participants, including government, owners, developers, contractors, suppliers, consumers, the public and other stakeholders, for different subjects to pursue their own interests[6]. Different subjects for the pursuit of their own interests, their behavior choices vary, their behavior will greatly affect the development of green building process. Zheng introduced the value chain theory, and they pointed out that the green building supply chain management is characterized by large scale and long duration[7]. The lack of common benefit basis among the multi - stakeholder involved in the green building, and the lack of effective coopera-

tion innovation incentive mechanism seriously hampered the development of green building in China[8].

The main contribution of this paper is to make economic benefit analysis of green building based on fuzzy logic and bilateral game model. By introducing such factors as economic benefits, cognition and government policies, this paper constructs an evolutionary game model, which provides a basis for improving the economic benefits of green buildings. The results show that the first factor affecting enterprise decision-making is the incremental profit of green building developers, followed by the government's incentive policy. After the evolution of the market, the final strategic choice will be stabilized to higher economic benefits. Generally speaking, green buildings need to effectively control incremental costs and consider scale benefits.

This paper is organized as follows: The related work is introduced in Section II. Model hypothesis and Green building developer - home buyers evolutionary game analysis is described in Section III. Green Building Developer - Government Evolutionary Game Analysis is presented in Section IV and Construction of Green Building Evaluation System is presented in Section V. Countermeasures and Suggestions in Section VI. Finally, Conclusions are given in Section VII.

## 2. Related work

In the process of promoting green building, incentive is an effective means to improve the performance of the project. Motivation mechanism can be divided into three types: incentive based on cost, monetary and non-monetary incentive, contract and external contract incentive[9]. Revenue incentive is one of the key issues in the project incentive. As a long-term dynamic incentive model, emotional incentive has a lasting incentive and constraint effect on project-oriented organizations[10]. Many scholars use the external theory of economics to analyze the external economy of green building[11,12]. Vyas (2017) analyzed the cost-effectiveness of green building[13]. Asadullah (2016) analyzed the method of building intellectualization[14]. Zuo (2017) Evaluates Green Buildings from the Life Cycle Perspective[15]. MacNaughton (2016) analyses the environmental perception and health of green buildings[16]. Jones (2016) analyzed the development of green strategy[17]. Tam (2017) Analysis of Life Cycle Cost of Green Building Implementation[18]. In

order to solve the problem of "market failure" in green building, the author puts forward the design of incentive mechanism of green building by setting up the market allocation model of green building.

In the incentive mechanism design research, the green building related cooperation between enterprises is to implement the basis of innovation. Cui Fang Zhang has studied the quality decision under asymmetric information, quality evaluation decision-making, payment transfer decision-making and coordination mechanism of rewards and punishments. Hong-bo WANG according to the theory of incentive mechanism, qualitative analysis is carried out on incentive objectives, incentive objects and incentives of green building, and established the government and the developer community evolutionary game model, proposed that the government should lock the far-sighted incentive policy[19]. Jian-gang SHI based on the fairness preference, this paper constructs a cross-organizational two-way incentive model, and analyzes the impact of project effort, fairness preference, payment cost and distribution system on project value increment[20]. Based on the above research results, domestic and foreign scholars do not consider the influence of interaction decision among the stakeholders in the coordination of interests of green building propulsion mechanism[21,22,23]. In the selection of incentive subjects, the driving factors of green building promotion mechanism are not clear.

From the supply side perspective, real estate developers in the green building development path by the "economic interests", "emotional awareness", "policy-oriented" three conditions of the constraints. Specifically, the internal factors of green building developers mainly include their own economic interests, external factors mainly lie in the constraints of policies and regulations, as well as consumer market awareness of the competitive pressure[24]. The promotion mechanism of green building is to take the real estate developer as the center, explore its game with the government and buyers of both the innovative mechanism, to form an innovative, harmonious, green, open, sharing social benefits, economic benefits, environmental benefits of the common development of the path mechanism.

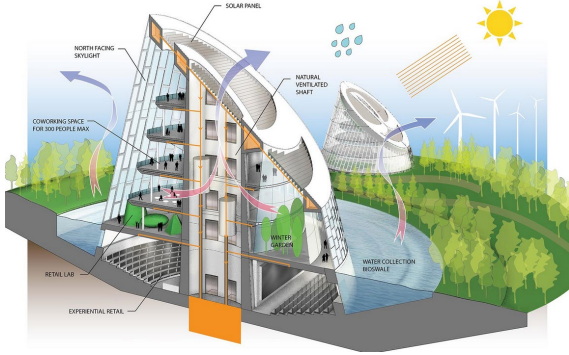


Fig.1. green building

### 3. Model establishment

#### 3.1. Model hypothesis

This paper takes the green building supply side as the breakthrough point, through the construction of the developers and buyers, government "bilateral" game to examine the green building industry chain innovation relationship[25]. It is assumed that the green building's strategy choice for home buyers has two: development and non development [26,27]. Home buyers to deal with green building developers also have two behavioral strategies to choose: participate or not participate in the purchase of green building products[28]. Governments have two strategies for green building developers: the implementation of incentive policies and the implementation of policy in the form of mere formality. Therefore, the probability of green building developers to develop green buildings is  $x$  and the probability of not building green buildings is  $1-x$ . The probability of buyers to participate in green building is  $y$ , buyers do not participate in the probability of green building is  $1-y$ . The probability for the government to implement the incentive policy is  $z$ , and the implementation of the policy is  $1-z$ . Then this paper carries out the model hypothesis with three dimensions: "economic interest", "emotional cognition" and "policy orientation".

Economic interest--Assuming that the game model,  $\lambda_1$  are direct revenue of green building developers, and  $\lambda_2$  are direct revenue of green building buyers.  $\varphi_1$  is the cost of developers to develop ordinary con-

struction, and  $\varphi_2$  is the purchase of ordinary buildings need to pay the cost of construction[29].

Emotion cognition--For more intuitive expression of the impact of consumer sentiment on the supply side, the game model is introduced to the concept of green building developers and home buyers to participate in the incremental revenue and incremental cost of green building.  $\rho_1$  and  $\rho_2$  are green building developers and home buyers to participate in green building incremental benefits.  $\varphi_1$  is the additional cost to the development of green buildings and  $\varphi_2$  is the additional cost of purchasing green buildings.

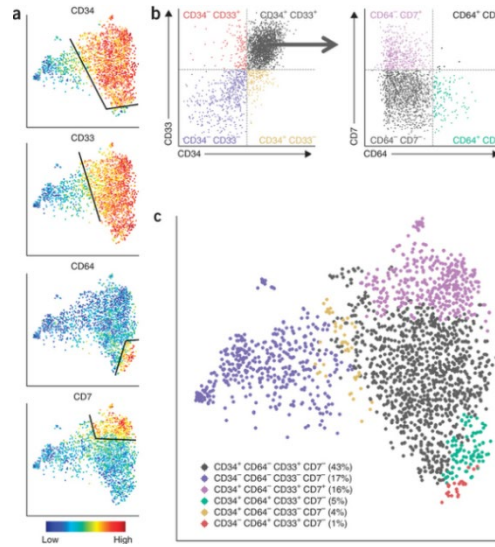


Fig.2. The High Dimensional Data Pattern

Policy Guidance--  $\lambda_3$  is the government social benefits from green building popularity.  $-\lambda_3$  is the government loss because of the developer did not develop green building. When the government adopts the incentive policy, if the green building developers actively respond to the development of green building will get the government's incentive  $\pi_1$ . If green building developers still do not invest in the development of green building when the government to take incentive policies, then the government will take punitive measures  $-\pi_2$  against green building developers.

The core participants in the supply side of green building: green building developers, home buyers

and government. Without considering the impact of policy factors on the construction market, the game group is bounded rational, limited information role of economic man. According to the model hypothesis,

the game model of developers - home buyers, developers - government is constructed. The game matrix is shown in Table 1

Table 1  
the game model of the supply side of green building

		Home buyers		Government	
		participate(y)	Not participate(1-y)	Incentive policy(z)	A mere formality policy(1-z)
developers	Development (x)	$\lambda_1 - \varphi_1 + \rho_1 - \varphi_1'$ $\lambda_2 - \varphi_2 + \rho_2 - \varphi_2'$	$\lambda_1 - \varphi_1 - \varphi_1'$ $\lambda_2 - \varphi_2$	$\rho_1 - \varphi_1' + \pi_1$ $\rho_3 - \pi_1$	$\rho_1 - \varphi_1'$ $\rho_3$
	Not develop (1-x)	$-\varphi_2, 0$	$\lambda_1 - \varphi_1$ $\lambda_2 - \varphi_2$	$-\pi_2$ $-\rho_3 + \pi_2$	0,0

Based on this, this paper takes the green building supply side of the main interests as the starting point, construct the dynamic game model of the supply side of green building, judge the relationship between the factors and factors influencing the game selection strategy, simulate dynamic evolution process of the parties, analyzes the evolution law, and puts forward the long-term coordination mechanism and decision-making suggestions for green building advancement.

### 3.2. Green building developer - home buyers evolutionary game analysis

In the static game of the two game groups of the green building, green building developers and home buyers average expected return are  $\bar{u}_s$  and  $\bar{u}_g$ , respectively.

$$\bar{u}_s = [(\lambda_1 - \varphi_1 + \rho_1 - \varphi_1')y + (\lambda_1 - \varphi_1 - \varphi_1')(1-y)]x + [-\varphi_1y + (\lambda_1 - \varphi_1)(1-y)](1-x)$$

$$\bar{u}_g = (\lambda_2 - \varphi_2 + \rho_2 - \varphi_2')xy + [(\lambda_2 - \varphi_2)x + (\lambda_2 - \varphi_2)(1-x)](1-y)$$

According to the expected return of the two game groups, green building developers can get green building strategy. The copy dynamic equation for home buyers is:

$$H(x) = \frac{dx}{dt} = (\rho_1y + \lambda_1y - \varphi_1')x(1-x)$$

$$H(y) = \frac{dy}{dt} = [\lambda_2x - \varphi_2x + \rho_2x - \varphi_2'x - \lambda_2 + \varphi_2]y(1-y)$$

Make:

$$H(x) = \frac{dx}{dt} = 0 \quad H(y) = \frac{dy}{dt} = 0$$

Solving differential equations, get:

$$x = 0, x = 1, y^* = \frac{\varphi_1'}{\rho_1 + \lambda_1}$$

$$y = 0, y = 1, x^* = \frac{\lambda_2 - \varphi_2}{\lambda_2 - \varphi_2 + \rho_2 - \varphi_2'}$$

Based on the above calculation, the 5 partial equilibrium points of the dynamic evolutionary game matrix composed of two groups of game groups, green building developers and home buyers, are obtained:

$$O(0,0), A(0,1), B(1,0), C(1,1), D(x^*, y^*)$$

A series of equilibrium points are obtained by the equation group, which is the choice of the strategy of the collective set in the equilibrium state. However, not all of the equilibrium state is stable, so the stability of the equilibrium point is analyzed[30,31]. Therefore, in this paper, by using the local stability analysis method of Friedman, by (3), (4) the dynamic equation can be used to get the real estate developer - the determinant and trace of Jacobi matrix determinant and its trace. As shown below:

$$Det(J) = \begin{vmatrix} \frac{\partial H(x)}{\partial x} & \frac{\partial H(x)}{\partial y} \\ \frac{\partial H(y)}{\partial x} & \frac{\partial H(y)}{\partial y} \end{vmatrix} = (1-2x)[(\rho_1 + \lambda_1)y - \varphi_1'](1-2y)$$

$$[(\lambda_2 - \varphi_2 + \rho_2 - \varphi_2')x - (\lambda_2 - \varphi_2)] - x(1-x)[(\rho_1 + \lambda_1)y(1-y)(\lambda_2 - \varphi_2 + \rho_2 - \varphi_2')$$

$$Tr(J) = \frac{\partial H(x)}{\partial x} + \frac{\partial H(y)}{\partial y} = (1-2x)[(\rho_1 + \lambda_1)y - \varphi_1'] + (1-2y)[(\rho_1 + \lambda_1)y - \varphi_1'] + (1-2y)[(\lambda_2 - \varphi_2 + \rho_2 - \varphi_2')x - (\lambda_2 - \varphi_2)]$$

The five equilibrium points obtained from the above deductions correspond to  $Det(J)$  and  $Tr(J)$ , and the stability conditions are determined

according to the results. The stability of the local equilibrium points is discussed respectively. Green building developers - buyers system Jacobian matrix results in Table 2.

Table 2  
Green Building Developers - Homebuyer Systems Jacobian Matrix

equilibrium	$Det(J)$	$Tr(J)$
$O(0,0)$	$\varphi_1'(\lambda_2 - \varphi_2)$	$-\varphi_1' - \lambda_2 - \varphi_2$
$A(0,1)$	$(\rho_1 + \lambda_1 + \varphi_1')(\lambda_2 - \varphi_2)$	$\rho_1 + \lambda_1 - \varphi_1' + \lambda_2 - \varphi_2$
$B(1,0)$	$-\varphi_1'(\rho_2 - \varphi_2')$	$\varphi_1' - \rho_2 + \varphi_2'$
$C(1,1)$	$(\rho_1 + \lambda_1 - \varphi_1')(\rho_2 - \varphi_2')$	$-\rho_1 - \rho_1 + \varphi_1' - \rho_2 + \varphi_2'$

Table 3  
Green building developer - home buyers local stability analysis results of the system

condition	Equilibrium point	$Det(J)$ symbol	$Tr(J)$ symbol	result
$\rho_1 - \varphi_1' > 0$ $\rho_2 - \varphi_2' > 0$	$O(0,0)$	+	-	stable
	$A(0,1)$	+	+	Unstable
	$B(1,0)$	-	+/-	Unstable
	$C(1,1)$	+	-	stable
	$D(x^*, y^*)$	+/-	0	Saddle point
$\rho_1 - \varphi_1' < 0$ $\rho_2 - \varphi_2' > 0$	$O(0,0)$	+	-	stable
	$A(0,1)$	-	+/-	Unstable
	$B(1,0)$	-	+/-	Unstable
	$C(1,1)$	-	+/-	Unstable
	$D(x^*, y^*)$	+/-	0	Saddle point
$\rho_1 - \varphi_1' > 0$ $\rho_2 - \varphi_2' < 0$	$O(0,0)$	+	-	stable
	$A(0,1)$	+	+	Unstable
	$B(1,0)$	+	+	Unstable
	$C(1,1)$	-	+/-	Unstable
	$D(x^*, y^*)$	+/-	0	Saddle point
$\rho_1 - \varphi_1' < 0$ $\rho_2 - \varphi_2' < 0$	$O(0,0)$	+	-	stable
	$A(0,1)$	-	+/-	Unstable
	$B(1,0)$	+	+	Unstable
	$C(1,1)$	+	+	Unstable
	$D(x^*, y^*)$	+/-	0	Saddle point

**Conclusion 1:** green building developers to develop green building incremental gains and buyers to participate in green building can get incremental benefits are positive. The probability combination ABOD of two game groups converges to (not develop, do not participate in) the strategy choice, ADBC probability combination group converges to (development, participation) strategy combination.

$D(x^*, y^*)$	$A'$	0
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Real estate developers to develop green buildings on the premise that the development of ordinary buildings to ensure a certain economic benefits, so  $\lambda_1 - \varphi_1 > 0$ . Similarly, home buyers to participate in green building is to meet the ordinary building guarantee income, and then in the green building and general construction of low-carbon environmental aspects of the balance, so  $\lambda_2 - \varphi_2 > 0$ . Therefore, in this condition, the green building developers - buyers of local stability of the system need to discuss a total of four kinds of situations, the results of the analysis in Table 3.

When  $\rho_1 - \varphi_1' > 0$ ,  $\rho_2 - \varphi_2' > 0$ , green building developers to develop green building and buyers to participate in green building can get positive incremental gains. Saddle point  $D(x^*, y^*)$  and two unstable points  $A(0,1)$ ,  $B(1,0)$  joined the broken line to the system is divided into two states converge in different parts. The evolutionary game system of

the two groups has two convergent directions, namely, the strategies of convergence (not development, non-participation) or the strategy of convergence (development, participation).

**Conclusion 2:** Green building developers, home buyers any party into the green building transaction market incremental cost higher than its incremental revenue, through the continuous evolution of the market, the final strategic choice will be stable to the green building developers do not develop green building, home buyers do not And then the purchase of green property strategy.

When  $\rho_1 - \varphi'_1 < 0$ ,  $\rho_2 - \varphi'_2 > 0$ , green building developers to develop green building incremental gain is negative, that the development of green building incremental cost is higher than the incremental revenue decline. When  $\rho_1 - \varphi'_1 > 0$ ,  $\rho_2 - \varphi'_2 < 0$ , Home buyers to participate in green building incremental revenue is negative, that buyers purchase green property incremental benefit is lower than incremental costs. When  $\rho_1 - \varphi'_1 < 0$ ,  $\rho_2 - \varphi'_2 < 0$ , both green building developers and buyers enter the green building market, both incremental costs are higher than the incremental gains of the game groups, the evolutionary game of the two game groups has only one evolutionary stabilization strategy (not development, not participation).

#### 4. Green Building Developer - Government Evolutionary Game Analysis

Traditional logistic regression using the maximum likelihood method to estimate basic model parameters, to maximize the classification accuracy of the model while however, this method ignore the data in the value of different classes, this could lead to a model in the class imbalance problem cannot very good fitting the minority class instance, leading to model generalization performance is very low in the minority class. In the following figure 5 and 6, we show the sample logistic regression model. Because the territory asked has brought a series of questions not balanced, first is the sorter performance large scale drop, obtains the sorter has the very big deviation, the most common performance is the rare territory recognition rate is lower than the big territory by far influence to the rare territory. So long as in the rare territory existence minority noise sample as can affect this territory decision surface the study. In other words, rare territory anti-chirp ability is weak, and

the sorter differentiates the rare territory sample and the noise data with difficulty.

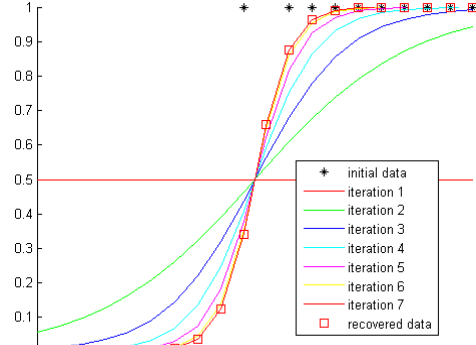


Fig.3. The Logistic Regression in the Multiple Dataset

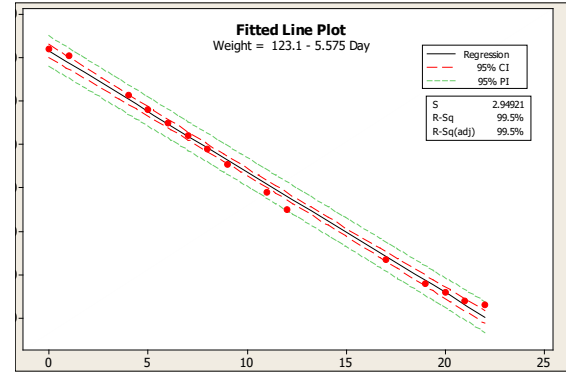


Fig.4. The Index Prediction Model Result

Green building developers and the government's average expected returns were  $\bar{\rho}_x, \bar{\rho}_z$ .

$$\bar{\rho}_x = [(\rho_1 - \varphi'_1 + \pi_1)z + (\rho_1 - \varphi'_1)(1-z)]x + (-\pi_2 z)(1-x)$$

$$\bar{\rho}_z = [(\rho_3 - \pi_1)x + (-\rho_3 + \pi_2)(1-x)]z + \rho_3 x(1-z)$$

$$G(x) = \frac{dx}{dt} = (\pi_1 z + \rho_1 - \varphi'_1 + \pi_2 z)x(1-x)$$

$$G(z) = \frac{dz}{dt} = [(\rho_3 x - \pi_1 x + \pi_2 - \rho_3 - \pi_2 x)z(1-z)]$$

$G(x) = \frac{dx}{dt} = 0$ ,  $G(z) = \frac{dz}{dt} = 0$  can be obtained at the same time:

$$x = 0, x = 1, z^* = \frac{\varphi'_1 - \rho_1}{\pi_1 + \pi_2}$$

$$z = 0, z = 1, x^* = \frac{\rho_3 - \pi_2}{\rho_3 - \pi_1 - \pi_2}$$

Table 4

Results of green building developers and government systems  
Jacobi matrix

Equilibrium point	$Det(J)$	$Tr(J)$
$E_1(0,0)$	$(\rho_1 - \varphi'_1)(\pi_2 - \pi_3)$	$\rho_1 - \varphi'_1 + \pi_2 - \rho_3$
$E_2(0,1)$	$-(\rho_1 + \varphi'_1 + \pi_1 + \pi_2)(\pi_2 - \rho_3)$	$\varphi'_1 - \rho_1 - \pi_1 - \rho_3$
$E_3(1,0)$	$(\rho_1 - \varphi'_1)\pi_1$	$\varphi'_1 - \rho_1 - \pi_1$
$E_4(1,1)$	$-(\pi_1 + \rho_1 - \varphi'_1 + \pi_2)\pi_1$	$\varphi'_1 - \rho_1 - \pi_2$
$E_5(x^*, y^*)$	$A$	0

The local equilibrium point of dynamic evolutionary game matrix composed of green building developers and government:

$$E_1(0,0), \quad E_2(0,1), \quad E_3(1,0), \quad E_4(1,1),$$

$$E_5\left(\frac{\rho_3 - \pi_2}{\rho_3 - \pi_1 - \pi_2}, \frac{\varphi'_1 - \rho_1}{\pi_1 + \pi_2}\right)$$

According to Eqs. (9) and (10), we obtain the Jacobian matrix determinant and the trace of the game system composed by the green building developer-government, and obtain the Jacobian matrix determinant and traces described in the following table.

Stability of equilibrium point is discussed according to the condition of stability determination. The results of local stability analysis are shown in Table 5. In the game behavior of green building developers and government, when the government takes incentive policy, the government will adopt the strategy of substituting for the award and use a fine instead of punishment.

Table 5  
Local stability analysis of green building developers and government systems

condition	Equilibrium point	$Det(J)$	$Tr(J)$	result
$\rho_1 - \varphi'_1 > 0$ $-\rho_3 + \pi_2 > 0$	$E_1(0,0)$	+	+	Unstable
	$E_2(0,1)$	-	-	Unstable
	$E_3(1,0)$	+	-	stable
	$E_4(1,1)$	-	-	Unstable
	$E_5(x^*, y^*)$	+/-	0	Saddle point
$\rho_1 - \varphi'_1 > 0$ $-\rho_3 + \pi_2 < 0$	$E_1(0,0)$	-	+/-	Unstable
	$E_2(0,1)$	+	-	stable
	$E_3(1,0)$	+	-	stable
	$E_4(1,1)$	-	-	Unstable
	$E_5(x^*, y^*)$	+/-	0	Saddle point
$\rho_1 - \varphi'_1 < 0$ $-\rho_3 + \pi_2 < 0$ (if $\rho_1 - \varphi'_1 < -\pi_2$ )	$E_1(0,0)$	+	-	stable
	$E_2(0,1)$	+	+/-	Unstable
	$E_3(1,0)$	-	+/-	Unstable
	$E_4(1,1)$	-	+/- (+)	Unstable (stable)
	$E_5(x^*, y^*)$	+/-	0	Saddle point
$\rho_1 - \varphi'_1 < 0$ $-\rho_3 + \pi_2 > 0$ (if $\rho_1 - \varphi'_1 < \pi_2$ )	$E_1(0,0)$	-	-	Unstable
	$E_2(0,1)$	+	+/-	Unstable
	$E_3(1,0)$	-	+/-	Unstable
	$E_4(1,1)$	-	+/- (+)	Unstable (stable)
	$E_5(x^*, y^*)$	+/-	0	Saddle point



## 5. Construction of Green Building Evaluation System

### 5.1. Preliminary screening of evaluation index

The analysis and study of evaluation index of green building mainly combine with the Germany DGNB sustainable building evaluation system, the British BREEAM sustainable building evaluation system and the related evaluation index in Chinese evaluation system of green building for effective analysis. To ensure the selected evaluation index has the same evaluation project which mainly involves the indoor environment quality, resource conservation and so on, and to unified define the higher similarity evaluation index contained in evaluation project as the basic evaluation index.

### 5.2. Correlation determination between the indicators

In preliminary screening of evaluation index , combine with related literature review to have effective selection, there will be a phenomenon of information overlapping between indicators. Therefore in the indicator analyzing process will have the situation of analysis complex, and the results of the analysis can not guarantee strong accuracy. However, to avoid this case, this paper mainly used principal component analysis for effective screening of evaluation index.

Based on the examples of energy utilization indexes (specific in Table 6 and Table 7), in the indexes of “renewable energy utilization” and “use of clean power” the reflected correlation coefficient are 0.785, but the clean power belongs to renewable energy, so it can be merged into the evaluation index of renewable energy utilization. In addition, emission of carbon dioxide is one of the main indicators to effectively measure the green building, and its value is not only depends on the amount of energy utilization, but also be affected by water resource utilization and material utilization. The definition of energy utilization obviously has irrationality. Through component matrix can effectively establish indicators of energy utilization, and effectively retain the six indicators, and through this method to have corresponding analysis on the relevance judgment of other indicators. In order to ensure that the evaluation results can reach the purpose of objective and fair, to make the construction quality and the impact of environment and economy can get a more comprehensive response, the evaluation index in this paper is mainly divided into

three major categories, the first one is economic quality, the second one is low carbon and resource conservation, the last one is the service quality of construction, the concrete evaluation index is shown in Table 8.

Table 7  
Component matrix of index on energy utilization

Index	Component					
	1	2	3	4	5	6
Building envelope structure	.464	-.026	-.087	-.609	.499	.218
CO2 discharge	-.270	.216	-.150	.425	.764	.188
Renewable energy utilization	.800	-.338	.003	.224	-.052	-.033
Use of clean power	.821	.022	-.551	.575	-.172	.266
Energy-saving electrical equipment	.414	.778	.213	-.078	.011	.152
Large home appliance consumption	.174	.866	-.121	-.066	-.274	-.028
Lighting system	.266	.170	.679	.391	.255	.378
Air-conditioning system consumption	-.552	.023	.540	.140	-.199	.492
Living hot water consumption	-.077	-.301	.483	-.013	.578	.308

Note: Valid questionnaire for 31 copies

### 5.3. model building

The current evaluation method of green building in China is usually that with the expert scoring to determine the score of each evaluation index, sum up the score of each evaluation index to get a total evaluation index score, then to define the level of evaluation index. However, this method can not fully reflect the specific difference of the content between each indicator, which makes the attached connotation of green building become fuzzier, inter evaluation indexes can not achieve the goal of coordinated development. On the basis of Table 4, this paper concretely constructed for the space model of evaluation system of green building, and has a further exploration of the evaluation results comprehensiveness of green building by this model.

Table 6  
Correlation matrix of index on energy utilization

Index	Building envelope structure	CO2 discharge	Renewable energy utilization	Use of clean power	Energy-saving electrical equipment
Building envelope structure	1.000	-.020	.213	-.060	.185
CO2 discharge	-.020	1.000	-.227	.074	.021
Renewable energy utilization	.213	-.227	1.000	.785	.089
Use of clean power	-.060	.074	.785	1.000	.040
Energy-saving electrical equipment	.185	.021	.089	.040	1.000
Large home appliance consumption	-.020	-.047	-.160	.144	.892
Lighting system	-.048	.096	.203	-.100	.252
Air-conditioning system consumption	-.297	.026	-.336	-.225	-.047
Living hot water consumption	.168	-.221	.419	.022	.100
Index	Large home appliance consumption	Lighting system	Air-conditioning system consumption	Living hot water consumption	
Building envelope structure	-.020	-.048	-.297	.168	
CO2 discharge	-.047	.096	.026	-.221	
Renewable energy utilization	-.160	.203	-.336	.419	
Use of clean power	.144	-.100	-.255	.022	
Energy-saving electrical equipment	.892	.252	-.047	.100	
Large home appliance consumption	1.000	.036	-.114	-.134	
Lighting system	.036	1.000	.089	.237	
Air-conditioning system consumption	-.114	.089	1.000	-.043	
Living hot water consumption	-.134	.237	-.043	1.000	

Table 8  
List of green building evaluation index system and related instructions

First-class Index	Second-class Index	Third-class Index	Illustration
Economic quality U1	Cost U11	Construction cost U111	Cost in implementation phase
		Construction operation cost U112	Maintenance fees of materials and equipment, property management fees
	Benefit U12	Customer satisfaction U121	Users' perception results of the house
		Extra cost payback period U122	Increase cost payback period
Low-carbon and resource conservation U2	Energy utilization U21	Building envelope structure U211	Heat transfer coefficient of external wall, ground, roof, external window, etc, building shape coefficient and other indicators
		Renewable energy utilization U212	Renewable energy utilization ratio
		Energy saving electrical equipment U213	Energy-saving transformers, electrical components and other utilizations
		Lighting system U214	Efficient lighting tool in public places, the use of automatic energy-saving control
		Energy consumption of air-conditioning system U215	Equipment performance coefficient, energy saving ratio
		Living hot water consumption U216	Hot water system power consumption and transmission efficiency
	Water resources utilization U22	Less water U221	Water-saving appliances and water-saving measures

		Waste water treatment U222	Wastewater discharge amount and processing amount
		Non-traditional water use planning U223	Non-traditional use of rainwater, recycled water, etc.
		Water saving U224	Water resources use excess carbon emissions
	Material resources utilization U23	Local material utilization U231	Local materials accounted for the proportion of material consumption
		Use energy-saving materials U232	The proportion of energy-saving materials
		Environmental impact U233	Material production carbon emissions
Buildings use quality U3	Outdoor ecological environment U31	Waste utilization U234	Waste recovery and recycling rates
		Residential location U311	The content of harmful substances in the soil, the original river, wetland
		Infrastructure U312	Facilities, barrier free facilities
		Virescence U313	Green space ratio
		Traffic condition U314	Underground garage proportion, public accessibility
		Noise abatement U315	Noise sound pressure and noise reduction measures
	Indoor environmental quality U32	Microclimate U316	Settlements humidity, harmful content and measuring ratio of external settlements
		Indoor environmental quality U321	Air quality, light environment, acoustic environment, thermal environment
	Operation management U33	Moistureproof quality U322	Rain and snow weather indoor humidity
		Garbage disposal U331	Garbage classification and flow control
		Residential security U332	Intelligent systems, unit area and security number
Note: In the table except for a few determined implementation of indicators in design stage, other indicators need to review the real situation in final acceptance or operate more than one year.			

## 6. Countermeasures and Suggestions

Based on the green building developers and the supply side "bilateral evolutionary game" analysis, combined with the "economic interests" and "emotion" and "policy oriented" three major constraints on green building dynamic game model based on promoting mechanism put forward countermeasures three aspects of suggestions:

- Economic interests: Green building supply side should integrate green building upstream and downstream industry chain. Mature industrial chain contributes to the formation of scale benefits green building industry. Through the scale effect, improve incremental income, reduce incremental costs. After the accumulation of advanced technology digestion understanding, can increase the incremental economic benefits of green building. At the same time, the domestic and international green building new technology actively introduce, promote, adopt subsidies, incentives and other incentive policy, for green building developers to reduce investment development design green building incremental cost.

- Emotional cognition: Green building supply side should strengthen the green building products marketing planning. When the incremental benefits of both sides of the game groups are greater than incremental costs, it is very important for green building investment to develop green buildings and buyers involved in the purchase of the probability combination. Home buyers to participate in the higher the degree of green building, green construction enterprises to invest in the development of green building accounts will increase, promote the promotion of green building market development.
- Policy orientation: Green building supply side should establish feasible and effective green building supervision system. Perfecting the legal system and strengthen supervision, especially the increase of the development of green building, green building, fake fake shoddy behavior severely ruling. At the same time, should also encourage green building technology independent research and innovation. In the green building technology development stage, economic benefits are not significant, developers will face greater financial pressure is difficult to maintain, through policy, subsidies and other ways to help develop-

ers solve the technical problems of green building

## 7. Conclusions

Green building is an important carrier to achieve sustainable development of the construction industry, and exploring the relationship between stakeholders is a problem worthy of attention and research in the sustainable development of the construction industry. This paper from the perspective of supply side reform of green building developers -- buyers from three dimensions of economic interests, emotion cognition and policy orientation is established, two groups of developers -- model of government supply side dynamic evolution game, the stability of evolutionary equilibrium evolution strategies are analyzed and discussed.

In the dynamic game developers - buyers, the incremental cost of the supply side of any party to the transaction market is higher than the incremental revenue, promoting mechanism will fail; convergence direction of incremental profit of green building developers on the supply side of the development of random. If the green building developers and property buyers the incremental cost of any party involved in green building trades than the incremental income, after the evolution of the market, the final choice of strategy will stabilize to green building developers does not invest in the development of green building, buyers choose not to purchase green building strategies. If the two party participation in green building transactions are profitable, the incremental income is greater than the incremental cost, then the model will provide two different strategies (development, participation), (no, not to participate in the development of evolution). Under this condition, the initial game green building investment development green building and property buyers involved in the purchase of the probability combination is particularly important.

In the dynamic game of the developer government, the initial incentive measures for supply side have guiding effect on green building. The incentive reward the government to adopt green building developers did not become the important factors affecting the promotion of green building in the evolutionary game, the incremental cost and development of green building is a key factor in promoting the green building. Secondly, the incremental profit developers invest in the development of green building green

building is positive, the government to take regulatory punitive measures the extent to which directly affect the final results of both sides of the game evolution; third, incremental profit developers invest in the development of green building green building is negative, the government even draconian penalties may not be able to correctly guide the green developers investment and development of green building. Finally, if developers invest in the development of green building green building incremental profit is negative, the government guarantee of green building green building development enterprises not punished the loss is higher than that in the government does not take the incentive policy of green building enterprise development green building loss loss, to a large extent, choose the development of green building green building developers guide strategy.

Based on the green building developers and the supply side "bilateral evolutionary game" analysis, combined with the "economic interests" and "emotion" and "policy oriented" three constraints, put forward the green building green building supply side should integrate upstream and downstream industry chain; strengthen the marketing planning of green building products; the establishment of feasible and effective the supervision system and the development of green building energy consumption tax, environmental tax and other measures.

## Acknowledgment

This paper is funded by National Scientific Fund(No. 51108185 and No. 51778235), Province natural science fund of Guangdong(No. 2016A030313513), State Key Laboratory of Subtropical Building Science(No. 2013KB24), Guangzhou development and reform commission energy-saving special fund project (Technology research of regional energy based on the energy cascade utilization), Basic scientific research fund of South China University of Technology(No. 2015ZM013) and fund of Guangdong modern architectural creation and engineering technology research centre (No.2016AZ28).

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