

# Study on Incentive and Constraint Mechanism of Green Building Development Based on Evolutionary Game Theory

Dekun Dong, Li Zhang and Yaping Lu

*Qingdao University of Technology, No. 2, Changjiang Middle Road, Huangdao District, Qingdao, Shandong Province, China.*

*kunded@163.com, 460576059@qq.com, 670723662@qq.com*

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**Abstract:** Developing green building is an effective way to promote innovation and promote the application of new energy. However, due to its high pre-construction costs, long return period, strong external economy and other characteristics, it is difficult to implement in the developer groups. This paper uses evolutionary game theory to construct the payment function of government and developer groups under the condition of bounded rationality, establishing a duplicate dynamic equation, analyzing the evolutionarily stable equilibrium after initial strategy and incentive and constraint adjustment. It is concluded that under the condition of intensifying the economic incentive to green buildings and raising the taxation standards for non-green buildings, the government will promote the game of government and developer groups to develop in the direction of optimal evolution and stability and balance, to promote green Building development.

## 1 INTRODUCTION

The production and transportation of raw materials before the building constructed, design and manufacture, to the final construction waste recycling, building energy consumption is ubiquitous. Therefore, on the basis of the continuous increase of total building energy consumption, how to save energy and reduce emissions is the key to the reform of the construction industry. As the development trend of the construction industry in the world today, green building can greatly reduce building energy consumption due to the use of renewable energy such as solar energy, wind energy and geothermal energy. It plays the role of protecting the environment, cultivating new industries and accelerating the transformation of the construction industry. However, due to the late start of green building in our country, the system is still not perfect, leading to its insufficient development momentum. The goal of realizing industrialization and scale of the green building is a difficult problem for the government.

At present, China's research on green building policies mainly focuses on two aspects: The first is to study the foreign green building policies and regulations, from which enlightenment can be obtained. Such as: Zheng Guorui(2014) compared the

implementation of green building policies in Japan and Australia with China, pointed out the problems in our green building policies and proposed corresponding countermeasures and suggestions. Chen Yan and Yue X.(2010) think that the green building in the United States can better benefit from the good design of policy tools such as the compulsory green building codes and standards, which is of great reference to the construction of China's green building policy system. The second aspect is from the perspective of incentive to explore the importance of incentive policies for the development of green building industry. Such as Zhang Shilian et al.(2006) that the use of economic incentives can play the economic characteristics of green buildings and improve the social production of green buildings.Liu Yuming(2012) argues that in the early stage of green building development, incentives should be provided from both the supply and consumption ends, incentives should be reduced at maturity and market regulation should be gradually brought into play. Liu Ge and Li Xue(2014) think that the cost of green building is relatively high and the cost recovery period is longer, we should promote the healthy development of green building through policy guidance.

By reading the previous literature, at this stage, obstructing the development of green building in our

country is no longer a technical issue, but the support of policies and regulations. During the development of green building, the design of the government's incentive and restraint mechanism affects the game strategy of the government and developer groups. On the one hand, developer groups decide whether to develop green buildings based on policy conditions and their relevant interests; On the other hand, the government adjusted the intensity of incentives and restraints according to the implementation of the policies and dynamically adjusted the existing policies. Both of them kept on playing games and jointly promoted the development of green buildings. Based on this, this paper establishes an evolutionary game model between government and real estate developers, explores the optimal balance of government incentive and restraint mechanisms for real estate developers.

## 2 THE THEORETICAL BASIS OF EVOLUTIONARY GAME

Evolutionary game theory holds that participants are affected by individual selection and mutation, which belongs to bounded rationality, and they achieve stable equilibrium through mutual imitation and learning (Helbing D., 1996). Evolutionary game includes evolutionary stabilization strategy and replication dynamic equation.

The strategy of evolutionary stability holds that the strategy of participant population can obtain the best returns and eliminate the influence of individual mutation participants during the evolution of the group game. Suppose that  $x$  represents the existing strategy and  $y$  represents the mutation strategy.  $E[y, \varepsilon y + (1 - \varepsilon)x]$  represents the return of the existing strategy,  $\varepsilon \in (0, 1)$  which indicates the proportion of mutation participants. If  $E[x, \varepsilon y + (1 - \varepsilon)x] > E[y, \varepsilon y + (1 - \varepsilon)x]$  holds for any  $\varepsilon$ , then  $x$  is an evolutionary stabilization strategy (Liu Jia et al., 2016). Replicating dynamic equation describes a first-order differential equation in which a strategy is subjected to dynamic changes in frequency over time. If a pure strategy is chosen and the payment always paid more than the average of the group, this strategy will develop in the population and evolve into a stable equilibrium strategy (Xie Zhiyu, 2002). The equation is:

$$F(x) = \frac{dx_i}{dt} = x_i [E(s_i, x) - E(x, x)] \quad (1)$$

Where  $x_i$  is the proportion of individuals who choose the strategy;  $E(s_i, x)$  is the expected return

of participants in the selection strategy;  $E(x, x)$  is the average expected return of the participant population. The conditions for achieving a stable equilibrium strategy are  $F(x) = 0$ ,  $F'(x) < 0$ .

## 3 EVOLUTIONARY GAME ANALYSIS BETWEEN GOVERNMENT AND REAL ESTATE DEVELOPERS

### 3.1 Basic assumptions

(1) The government and real estate developers for both sides of the game. The government formulates relevant policies to guide the behaviour of developers to achieve the policy goals;

(2) There are only two types of construction products on the market: green buildings and ordinary buildings (non-green buildings). Developers have two options to develop green buildings or ordinary buildings. Green building here refers to the building products that meet the national green building design standards. The government has two policy options for developers' behaviour: implementing economic incentive policies and not implementing economic incentive policies.

(3) Both government and real estate developers are limited rationality gamers. They can not find the optimal strategy from the very beginning and need a process of imitation, study and adjustment, and finally, reach a game equilibrium.

### 3.2 Model Construction

Based on the above assumptions, this paper constructs a game model of government and real estate developers, the payment function shown in Figure 1.

		Developers	
		Development $y$	Not developed $(1-y)$
Government	Encourage $x$	$\alpha R_g - C_g - C_p, \beta I_n - rC_b + C_g$	$R_g - C - C_p + f, I_n - C_b - f$
	Do not encourage $(1-x)$	$\alpha R_g, \beta I_n - rC_b$	$R_g - C, I_n - C_b$

Figure 1: Government and real estate developers game model

Figure 1, the meaning of the letters:  $x$  for the government to choose the proportion of incentive policies,  $(1-x)$  for the government to choose not to implement the incentive policy ratio;  $y$  for developers to choose the proportion of green building,  $(1-y)$  is Developers to develop the proportion of ordinary buildings.

Profit and loss variables affecting government decisions:

1)  $R_g$  refers to the government's failure to encourage the development of non-green buildings.  $\alpha R_g$  represents the government's choice to encourage the development of green buildings, where  $\alpha > 1$ .

2)  $C_g$  is the incentive cost when the government implements the economic incentive policy and the developer chooses to develop the green building, such as government financial subsidies, tax and loan preferences.

3)  $C_p$  is the policy expenditure incurred when the government implements the economic incentive policy, such as the special fund invested by the Aid R & D in the technical standards, materials, evaluation and energy efficiency evaluation of green building.

4)  $C$  is due to the external non-green building non-economic, developers choose to develop non-green buildings, the government to address the issue of high energy consumption, high pollution caused by incremental resources and energy-saving renovation costs.

Profit and Loss Variables Affecting Real Estate Developers' Decision Making:

1)  $C_b$  is the cost of developing non-green buildings for real estate developers, and  $rC_b$  is the cost of developing green buildings for real estate developers, where  $r > 1$ . China's green building exists in rank,  $r$  increases with the level of increase.

2)  $I_n$  is the profit obtained when developers choose to develop non-green buildings,  $\beta I_n$  is the profit obtained when choosing green building,  $\beta$  is the developer's income coefficient,  $\beta > 1$  including the premium obtained by green certification to enhance brand value.

3)  $C_g$  is the economic incentive income when developers choose to develop green buildings, such as the central government subsidies, local government incentives, financial incentives and so on.

4)  $f$  is an incremental tax, which is generated by the government's incentives for green buildings and the increased taxation of non-green buildings, such as non-green buildings to impose a high standard tax rate, or begin to impose carbon tax, energy tax and so on.

### 3.3 Evolutionary Game Analysis

(1) The government's expected return

Expected benefits of implementing economic incentives:

$$E_{11} = y(\alpha R_g - C_g - C_p) + (1-y)(R_g - C - C_p + f) \quad (2)$$

Expected benefits of not implementing economic incentives:

$$E_{12} = y\alpha R_g + (1-y)(R_g - C) \quad (3)$$

Government's average expected return:

$$E_1 = E_{11}x + E_{12}(1-x) \quad (4)$$

The government's replication dynamic equation is:

$$F(x) = \frac{dx}{dt} = x(E_{11} - E_1) = x(1-x)[f(1-y) - C_g y - C_p] \quad (5)$$

Let  $F(x) = 0$ , then  $x_1^* = 0, x_2^* = 1, y^* = \frac{f - C_p}{f + C_g}$ . According to the stability theorem of the replicator's dynamic equation and the nature of the evolutionary stabilization strategy,  $x$  satisfies the following evolutionary stability strategy:  $F(x) = 0, F'(x) < 0$ .

1) When  $y = y^* = \frac{f - C_p}{f + C_g}, F(x) = 0, F'(x) = 0$  and all  $x$  values are in steady state. It shows that when developers develop green buildings at the level of  $y^*$ , there is no difference between the government's options of motivation or non-motivation.

2) When  $y < y^* = \frac{f - C_p}{f + C_g}, x_1 = 0, x_2 = 1$  is the two possible stability points for  $x$ .  $F(0) = 0,$

$F'(0) < 0$  and  $F(1) = 0, F'(1) > 0$ , Therefore  $x_1=0$  is globally unique evolutionary stabilization strategy. At this time, when developers develop green buildings below the level of  $\frac{f-C_p}{f+C_g}$  the government shifts from an "incentive" strategy to an "inactivity" strategy. The "no incentive" strategy is an evolutionary stabilization strategy.

3)When  $y > \frac{f-C_p}{f+C_g}$ ,  $x_1 = 0, x_2 = 1$  is the two possible stability points for x.  $F(0) = 0, F'(0) > 0$  and  $F(1) = 0, F'(1) < 0$ . Therefore,  $x_2=1$  is globally unique evolutionary stabilization strategy. At this time, when developers develop green buildings at a level above  $\frac{f-C_p}{f+C_g}$ , the government shifts from an "Inactive" strategy to an "Incentive" strategy, which is an evolutionary stabilization strategy.

(2)Developers expected return:

Expected benefits of developing green buildings:

$$E_{21} = x(\beta I_n - rC_b + C_g) + (1-x)(\beta I_n - rC_b) \quad (6)$$

Expected benefits of developing non-green buildings:

$$E_{22} = x(I_n - C_b - f) + (1-x)(I_n - C_b) \quad (7)$$

Average expected revenue from developers:

$$E_2 = E_{21}y + E_{22}(1-y) \quad (8)$$

The developers' replication dynamic equation is:

$$F(y) = \frac{dy}{dt} = y(E_{21} - E_2) = y(1-y)[C_g x + \beta I_n - rC_b - I_n + C_b + fx] \quad (9)$$

Let  $F(y) = 0$ , then  $y_1^* = 0, y_2^* = 1, x^* = \frac{(r-1)C_b - (\beta-1)I_n}{f+C_g}$ . According to the stability theorem of evolutionary equation and the nature of evolutionary stabilization strategy, y satisfies the evolutionary stability strategy:  $F(y) = 0, F'(y) < 0$ .

1)When  $(r-1)C_b - (\beta-1)I_n > 0$ , Costs outweigh the benefits of developing green building losses.

① When  $x = x^* = \frac{(r-1)C_b - (\beta-1)I_n}{f+C_g}, F(y) = 0,$

$F'(y) = 0$  all in a steady state. Description When the government to  $x^*$  economic incentives to stimulate developers, developers choose to develop or not to develop green buildings there is no difference.

②When  $x < x^* = \frac{(r-1)C_b - (\beta-1)I_n}{f+C_g}, y_1 = 0, y_2 = 1$  is the two possible stability points for y.  $F(0) = 0, F'(0) < 0$  and  $F(1) = 0, F'(1) > 0$ , Therefore,  $y_1 = 0$  is globally unique evolutionary stabilization strategy. At this time, when the government stimulates developers with economic incentives less than  $\frac{(r-1)C_b - (\beta-1)I_n}{f+C_g}$ , the developers move from "development" Strategy transfer, "undeveloped" strategy is evolutionary stabilization strategy.

③When  $x > x^* = \frac{(r-1)C_b - (\beta-1)I_n}{f+C_g}, y_1 = 0, y_2 = 1$  is the two possible stability points for y.  $F(0) = 0, F'(0) > 0$  and  $F(1) = 0, F'(1) < 0$ , Therefore,  $y_2=1$  is globally unique evolutionary stabilization strategy. At this time, when the government stimulates developers with an economic incentive higher than  $\frac{(r-1)C_b - (\beta-1)I_n}{f+C_g}$ , developers move from "undeveloped" Strategy transfer, "development" strategy for evolutionary stability strategy.

2)When  $(r-1)C_b - (\beta-1)I_n < 0$ , The cost is less than revenue, developing green building profitability.  $y_1 = 0, y_2 = 1$  is the two possible stability points for x.  $F(0) = 0, F'(0) > 0$  and  $F(1) = 0, F'(1) < 0$ , Therefore,  $y_2=1$  is globally unique evolutionary stabilization strategy. At this point, no matter what kind of strategy the government adopts, the "development" strategy is always the evolutionary stability strategy of the developer.

The above conclusion with two-dimensional coordinate plan shows that the government and developers can get the game phase diagram, shown in Figure 2.

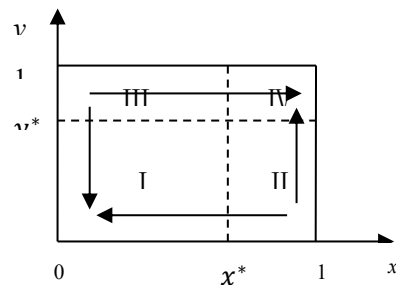


Figure 2: Government and developers game phase

It can be seen from the figure that both (0,0) and (1,1) are evolutionary stabilization strategies of this game, but the initial state of the system determines the final convergence to that strategy. When the initial state of the system falls on region I, the system will converge to a poor equilibrium (0, 0), it will not implement economic incentive policies and develop ordinary buildings. When the initial state of the system falls in Region IV, the system will converge to the optimal equilibrium (1,1), implementing economic incentives and developing green buildings. When the initial state of the system falls on regions II and III, the direction of evolution of the system is indefinite. It is possible to converge to (0,0) in region I and to (1,1) in region IV, depending on the speed at which the players imitate, learn and adjust.

$x^* = \frac{(r-1)c_b - (\beta-1)l_n}{f+c_g}$  and  $y^* = \frac{f-c_p}{f+c_g}$  is the saddle point of the evolution of game structure evolution characteristics. When the initial state of the system is around  $(x^*, y^*)$ , a small change in the initial state will affect the final result of the game, this reflects the sensitivity of the evolutionary game to the initial conditions. When the initial state of the system falls in area I and area IV, the final state of the game is definite, it shows the dependence of the result of evolutionary game on the initial state. Therefore, when formulating the green building economic incentive policy, government should take into account the characteristic of "the dependence of game outcome on the initial state", such as intensifying incentives and combining some mandatory measures to reach the optimal equilibrium finally.

#### 4 CONCLUSION

In this paper, evolutionary game theory is used to analyze the behavioural strategies of government and developer groups in the development of green buildings. The results show that the initial state plays an important role in the evolutionary equilibrium of both players, and adjusting the initial strategy will change the evolution and stability of the game Equilibrium status. Therefore, in order to promote the development of green building, promote the application of new energy and promote the concept of energy saving and emission reduction, it is considered that the government should increase the economic incentive to green building and raise the restriction on the taxation standard for non-green building, and promote the game between the government and developer groups is moving in the direction of optimal evolution and stability and

balance so as to promote the large-scale development of green buildings.

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