Evolutionary Game Analysis of Government Incentive Mechanism for Green Buildings

Lixing Zhang 1*, Shaoyan Wu 1

1 School of Management, Tianjin University of Technology, Tianjin 300384, China
2 lixingzhang558@163.com

Abstract. With the increasingly serious environmental pollution problem, the development of green building scale has become the fundamental way to transform urban development, and this development is the result of continuous game between government, public consumers and developers. In order to analyse the evolutionary equilibrium between the initial strategy and the incentive and constraint adjustment, this paper constructed a three-party evolutionary game model between government, developers and public consumers, and under different subsidy levels, inspection frequency and pollution tax, the government. The behavioural changes of developers and public consumers were simulated. The study found that government financial subsidies, irregular inspections and pollution taxes will have a positive effect on the scale of green buildings. Moderate financial subsidies, low frequency inspections and high pollution taxes have the most obvious effect on the development of green houses.

1. Introduction

In recent years, China's urbanization process has accelerated, the energy consumption of the construction industry has grown rapidly, and the problem of environmental pollution has become increasingly prominent. In order to control the smog caused by environmental pollution and global warming, the government promised to achieve a 40%-50% reduction in CO2 emissions per unit of GDP in 2020 at the Copenhagen Climate Conference [1]. In this context, green buildings have become the target of government attention because of their low energy consumption, green environmental protection and natural coexistence. Therefore, green building promotion is imperative [2]. However, China's green building market is still not perfect, which makes the development of green buildings have certain risks, resulting in developers' enthusiasm for green buildings; at the same time, public consumers have to pay extra costs for the supervision of developers, and greatly reduce the enthusiasm of public consumers to promote green homes. The internal and external characteristics of the green building market determine that its development needs government policy promotion, incentive policies are more flexible than mandatory policies, and incentive design is the key to guiding the rapid and healthy development of the green building market[3].

Domestic and foreign scholars have carried out research on green building incentive policies, and explored the game behaviour of local governments and developers from the perspective of game theory. Liu Ge et al. [4] and Chen Xiaolong et al. [5] studied the incentives for green buildings. Chen Xiaolong pointed out that reducing transaction costs would increase the willingness of real estate companies to develop green buildings. Qian [6] believed that the scale of green building was conducive to the acquisition of interests of both local governments and developers, and was the fundamental way to transform the urban development model. Wu Wenhao [7] showed that the government should provide financial subsidies to green building developers and implement high tax
policies for traditional residential developers, forcing traditional real estate developers to transform and upgrade. Liu Jia [8] believed that the government will increase the economic incentives for green buildings and raise the taxation standards for non-green buildings, which will promote the development of green buildings. Based on the reality of green housing in China, Guo Bin [9] proposed an incentive policy combining subsidy and punishment, which concluded that the policy is more effective in promoting green buildings and mobilizes the enthusiasm of relevant stakeholders. In addition, Rehm & Ade analysed the interests of both parties in the green building operation management process from the perspective of green building developers and owners, and proposes government-level incentives that are conducive to green building development and operation [10]. The promotion of green buildings involves the game of government, developers and public consumers, while the literature on the relationship between government, developers and public consumers in the process of green building development based on the theory of game theory is scarce.

In summary, most governments use large-scale taxation or financial subsidy policies to guide developers and promote the scale of green buildings. The government's prevention of "scams" will conduct random checks on developers, but from practical considerations, it is impossible for the government to inspect every real estate. Therefore, the public consumer supervision mechanism is introduced in this model. The evolutionary game model will be used to simulate the evolution of behaviours of government, developers and public consumers under the different incentives, and the reasonable subsidy level, inspection frequency and Pollution taxation, and finally draw conclusions and make relevant recommendations.

2. Green building evolution game model

2.1 Evolutionary game model hypothesis

According to the relevant theories of the participating subjects and the evolutionary game model, the hypothesis is as follows:

H1: Developers, governments, and consumers have two choices of behavior, namely, whether the developer company conducts a “green” strategy, whether the government conducts incentives, and whether consumers conduct green building development supervision, the probability of selection of the corresponding strategy is expressed as \( x, y, z \), and \( x, y, z \in [0, 1] \), which are all functions of time \( t \).

H2: Under the incentive strategy of the government, if the enterprise adopts a “green” strategy, the government will provide financial subsidies to the enterprise, the subsidy quota is \( A \), the subsidy intensity factor \( \alpha \), and the cost consumed is \( \alpha A \). There will also be a certain probability \( \beta \) to check the implementation of the development of green buildings, the inspection cost is \( Q \), and the cost is \( \beta Q \). If the enterprise adopts the “traditional” strategy, the pollution tax is imposed on the enterprise, and its execution intensity factor \( \gamma \), the cost consumed is \( \gamma K \).

H3: The profit of the developer's choice of “traditional” strategy for production is \( R \). After the “green” strategy, the revenue is increased by \( \Delta R \), and the developer's “green” strategy is increased by \( \Delta R_g \) (government incentive public supervision), \( \Delta R_d \) (the government does not motivate the public to supervise), \( \Delta R_p \) (the government encourages the public to not supervise), and 0 (the government does not encourage the public to disregard). The additional cost consumed by the developer adopting the “green” strategy is \( C \); the green environmental benefits obtained by the government and the public are \( R_g \), \( R_m \), the losses are \( S_g \), \( S_m \), and the public supervision cost is \( C_m \).

2.2 Evolutionary game model construction

According to the above assumptions, the participation of the government, the enterprise and the public in the consumer evolution game payment matrix is constructed based on the difference between the profit of the participants and the difference between the profit and the cost (see Table 1 - Table 4).
Because developers, governments, and public consumers have asymmetry in information acquisition, the three parties will choose their own decisions through continuous trial and error learning and historical experience to determine the strategies of other players. When \( x, y, z \) dynamically adjusts its own strategy, it shows the dynamic replication process described by evolutionary game theory. Let \( E_1, E_2, E_3 \) denote the average expected return of the developer, government and public consumers under the hybrid strategy, respectively, and \( t \) indicate the time when the behaviour strategy evolves.

According to Table 1 - Table 2, the average income of developers is:

\[
E_i = E_{1i}x + E_{12}(1 - x)
\]

Among them, \( E_{11} \) indicates that the enterprise chooses the expected return under the “green” strategy, and \( E_{12} \) indicates that the enterprise does not perform the expected return under the “green” strategy.

\[
E_{11} = (R + \Delta R_g + \alpha A - C_1)yz + (R + \Delta R_g - C1)z(1 - y) + (R - C_1)(1 - z)(1 - y)
\]

\[
E_{12} = (R - \gamma K)yz + Rz(1 - y) + (R - \gamma K)(1 - z) + R(1 - z)(1 - y)
\]

Similarly, the governments expected return is

\[
E_i = E_{21}y + E_{2a}(1 - y)
\]

The expected return of the public consumer is

\[
E_i = E_{31}z + E_{3a}(1 - z)
\]
2.3 Asymptotic Stability Analysis of Evolutionary Game

In the three-party game between developers, government and public consumers, the dynamic replication process of equations (6)-(8) describes that the bounded rationales learn, and when the three parties reach a steady state, it means that the players participate in the trial and error. Found a valid Nash equilibrium. In order to seek a balance point for developers to adopt a “green” strategy,

\[
\begin{align*}
U_1(x) &= \frac{dx}{dt} = x(1-x) \left[ (\Delta R_1 - \Delta R_2 - \Delta R_3) yz + \Delta R_2 z + \Delta R_3 y + C_i + \gamma K y \right] \\
U_2(y) &= \frac{dy}{dt} = y(1-y) (S_g x - \gamma K x - \beta J x + S_g + \gamma K + \beta Q) \\
U_3(z) &= \frac{dz}{dt} = z(1-z) (C_{m_2} y - C_{m_1} y - C_{m_2}) 
\end{align*}
\] (6) (7) (8)

From equation (9), there are eight special equilibrium points in the equation. That is (0,0,0), (0,1,0), (0,0,1), (1,1,1), (1,0,0), (1,0,1), (0,1,1), (1,1,0), according to the relevant nature of the evolutionary game, when \(U_1'(x) < 0, U_2'(y) < 0, U_3'(z) < 0\), the strategy shown in equation (9) represents the stability strategy (ESS) adopted by the three parties.

\[
\begin{align*}
U_1'(x) &= (1-x) \left[ (\Delta R_1 - \Delta R_2 - \Delta R_3) yz + \Delta R_2 z + \Delta R_3 y + C_i + \gamma K y \right] \\
U_2'(y) &= (1-y) (S_g x - \gamma K x - \beta J x + S_g + \gamma K + \beta Q) \\
U_3'(z) &= (1-z) (C_{m_2} y - C_{m_1} y - C_{m_2}) 
\end{align*}
\] (10) (11) (12)

3. Simulation analysis

In order to analyse the execution force under different incentive policies, the developer implements the gradual stable operation track of the “green” strategy, and uses the MATLAB simulation tool to simulate and analyse the above evolutionary game model. Initially, the core enterprise, government and public consumers are all set to have a probability of 0.5 to choose different behavioural decisions. In order to more accurately reflect the evolutionary trajectory of the system, the time step is set to 0.01.

3.1 The impact of government subsidy policies on system evolution

The supervision behaviour of consumers with the subsidy intensity strengthened and gradually evolved to zero. Government subsidies as cost compensation reduce the cost of developing green homes for developers. However, government subsidy investment has increased government fiscal expenditures, resulting in increased subsidy pressure. As can be seen from Figure 1-2, moderate financial subsidies can promote government incentives, but high-intensity financial subsidies allow the government to abandon incentives. For consumers, with the advancement of green houses, the natural
environment is continuously optimized. In order to save their own costs, the public consumers will gradually relax the environmental supervision of enterprises.

3.2 The government regularly checks the impact on system evolution

![Figure 2. System evolution track of government inspection at different frequencies](image)

It is known that with the increase of the inspection frequency, the developers and consumers of the public choose “green” and supervision as the final strategy. As can be seen from the figure2, the government has reached the state of evolutionary stability as soon as it checks whether the developer implements green houses as required, while the speed at which enterprises and public consumers reach a steady state is slow. This is because government and public consumers have to pay for inspections and supervision. At the same time, the costs incurred by developers in adopting “green” strategies are passed on to the public consumers. With the high frequency of government inspections, the cost of consumers and developers is increasing, thus slowing down the pace of corporate green building and consumer environmental regulation. In addition, due to the asymmetry of information, the frequency of government inspections is high, which inhibits the initiative of developers and thus has an indirect negative impact on the behaviour of enterprises to develop green buildings.

3.3 Impact of pollution taxation on the system

![Figure 3. System Evolution Track of Pollution Tax under Different Execution Strength Factors.](image)

With the deepening of pollution tax intensity, the evolution of corporate “green” strategy behaviour is accelerating; Figure 3 shows that with the reduction of government incentives, public consumers have gradually played a major supervisory role. This is because, for developers, as the government increases the intensity of pollution taxes, companies will abandon traditional houses and choose green houses. When the company constantly adjusts its own strategy, the ecological environment will improve, and the government gradually cancels the pollution tax policy. With the increase in the government's pollution tax collection, public consumers will consciously enhance the supervision of enterprises.

4. In conclusion

From the perspective of stakeholder theory, this paper analyzes the interests and powers of government, developers and public consumers. Through the simulation analysis of evolutionary game, it draws conclusions: (1) financial subsidies, regular inspections and pollution taxes on corporate greens Housing will have a positive effect. (2) The government's low frequency inspection can
promote enterprises to develop green houses. (3) High-intensity financial subsidies to promote enterprises to develop green houses. (4) When the pollution tax is high, it can promote the development of green housing.

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