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Evolutionary game theory based evaluation system of green building scheme design

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Abstract

The scale development of the green building is the fundamental way to transform the urban development model and is the result of continuous evolutionary game between local government and developer group. The evolutionary game theory is used to construct the payoff function of the government and developer group under the condition of limited rationality and build duplicator dynamic equation so as to analyze the evolutionary stable equilibrium after the adjustment of the initial strategy and incentive and restriction. Then, the discounted repeated game algorithm is designed, that is, the peril point is obtained by making use of compactness and convexity of the public area made up of a player's feasible utility set, combined with Nash Negotiation Solution. If the game player deviates from the operating point and the amount of later changes, then the deviation will be detected and the punishing operation will be implemented on its power index. Finally, the validity of the proposed algorithm is verified by simulation experiment.

Keywords: Incentive mechanism; Green building; Scheme design; Evaluation system; Repeated game

1. Introduction

The green buildings in China account for 1% of the total building volume and the building energy consumption accounts for more than 30% of the total energy consumption of the whole society (Coenen, 2010). Pursuant to Implementation Suggestions on Accelerating the Development of Green Buildings in China, it points out that the target to build new green building area of more than 1 billion m^2 shall be completed during the 12th Five-Year Plan (Ferreira, Pinheiro, & Brito, 2014). However, as of July 2015, the total scale of green building in China was about 360 million m^2, with large gap between the target of the 12th Five-Year Plan (Giurco, Cohen, & Langham, 2011). The scale development of green building faces great challenges. In order to promote the development of green building, the governments in China have adopted a number of administrative means, such as, financial incentive was implemented for two or three-star green building in 2012, and the incentive standard was 45 yuan/m^2 and 80 yuan/m^2 respectively (Singh, Singh, & Singh, 2012). The imprest fund was given to green ecological urban area (Bygrave, 2004; Graaf and Haigh, 2011; Jones and Ewell, 2009). At the same time, the government has also increased investment in the policy support, standard specification formulation, technology promotion, industrial support and accreditation evaluation. However, the incremental cost of green buildings was greater than the government subsidy from the market level, and it has enjoyed low recognition in the market. According to the estimation of a well-known domestic developer, the standard incremental cost of one to three-star green buildings is 50 yuan/m^2, 100 yuan/m^2 and 300 yuan/m^2 respectively in accordance with the

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current standard of green building evaluation in China (Maerefat and Shafie, 2014; Phelps, 1996; Zhuang and Liu, 2013). From the policy level, the formulation and implementation of green building policy is still in its infancy (Meng and Arunkumar, 2018; Mohammed et al., 2018; Mutlag, Ghani, Arunkumar, Mohamed, & Mohd, 2018; Neibergs, Mahnken, & Moore, 2015; Tharwat et al., 2018). Due to incomplete incentive and restraint mechanism and lack of impetus for green building development, realizing the scale development of green building has become a difficult problem in front of the government (Ashokkumar, Arunkumar, & Don, 2018; Liu and Arunkumar, 2018; Sarvaghad-Moghaddam et al., 2018).

In recent years, the research on green building policy is mainly focused on two aspects: one is policy discussion. Zhang Shilian et al. (Coenen, 2010) believed that the economic incentive policy could give full play to the economic characteristics of green buildings and improve the social production of green buildings. Liu Yuming (Ferreira et al., 2014) thought that the incentive should be carried out from the supply and consumer in the early stage of green building development, and it should be reduced in the mature period to gradually give play to the regulatory role of the market. The other is the analysis of game model. Liu Yi et al. (Giurco et al., 2011) believed that the healthy development of green building should be promoted through policy guidance due to relative high cost of green building, long cost recovery and limited profit space. Chen Xiaolong et al. (Singh et al., 2012) pointed out that the transaction cost of the green building market has a great influence on the decision of the developers, and the incentive policy is beneficial to eliminate unfair competition. Wang Jinghui et al. (Bygrave, 2004) thought that excess income, discount factor, profit loss and non scale net loss are the main factors affecting the willingness of developers to develop green buildings. Wang Yanyan et al (Jones, 2009) believed that the greater the risk aversion of the developers is, the higher the cost coefficient is, the smaller the risk sharing is and the greater the incentive intensity needs.

The government's incentive and constraint mechanism design affects the game strategy of the government and the developer group in the course of developing green building. On the one hand, the developer group decides whether to develop green building according to the policy conditions. On the other hand, the government adjusts the incentive and constraint intensity according to the implementation effect of the policy, and adjusts the current policy dynamically. The continuous game between them promotes the scale development of green building together. At present, there is no research on the evolutionary game between the government and the developers in the context of promoting the scale development of green building. This Paper establishes the evolutionary game model of the two sides, analyzes their strategic selection, and demonstrates the impact of different decision parameter changes on game equilibrium through case simulation.

2. Construction of demand side game evolution model for green building project

(1) Players: the demand side evolution model of green building project has two bounded rationality players. Suppose that a developer who develops green building projects or ordinary construction projects is called the developers for short, and the other is an owner who selects green building projects or ordinary construction project is called the owner for short.

(2) Action: suppose an action set that can be selected by the developer when a building project is positioned to consider the green building project is A1 = {developing green building, developing ordinary building}. The action set that can be selected by the owner when purchasing the house is A2 = {purchasing green building, purchasing ordinary building}.

(3) Payoff: It is assumed that many developers are currently carrying out multiple project development and positioning decisions, that is, green building projects or ordinary construction projects are considered, and the owners choose between multiple building projects, that is, whether to buy green building projects or not, therefore, it can be deemed that there is a game between multiple developers and multiple owners. The game characteristics of both sides meet the basic assumptions of evolutionary game. Both sides choose and adjust their strategies according to the relative fitness of their members based on the strategy choices of other members. In the payoff matrix, the symbol PC_o and PD_o represent the profits of the owners and developers respectively when they buy the ordinary building project and develop jointly ordinary building strategy. RC_o and RD_o represent the risk of owners and developers respectively when they purchase ordinary building project and develop ordinary building strategy (for the convenience of analysis, all of them are assumed as 1, and this assumption does not affect the analysis conclusion). It is known from the previous literature that developers face certain incremental costs in developing green building projects, expressed by ΔCD_g. Meanwhile, ΔRD_g is used to express that developers face certain incremental risks when developing green building projects, while owners face incremental costs when they purchase green building projects and the same grade ordinary buildings, expressed by ΔCC_g. At the same time, ΔRC_g is used to express that the owners face certain incremental risks when purchasing green building projects. Similarly, ΔPC_g and ΔPD_g represent respectively the incremental income of the owners and developers when purchasing green building project and developing green building strategy jointly, relative to ordinary building project. PC_g and PD_g respectively represent net incremental income of the owners and developers when purchasing green