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An Analysis on Behaviors of Real Estate Developers and Government in Sustainable Building Decision Making

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Abstract:

Purpose: The Chinese government takes measures to promote the development of green building (GB). But until 2013, there are only few green buildings in China. The real estate developers are skeptical in entering GB market, which requires theories to explain developers and government's behaviors.

Design/methodology/approach: In this study, we attempt Evolutionary game theory and System dynamics (SD) into the analysis. A system dynamics model is built for studying evolutionary games between the government and developers in greening building decision making.

Findings and Originality/value: The results of mixed-strategy stability analysis and SD simulation show that evolutionary equilibrium does not exist with a static government incentive. Therefore, a dynamical incentive is suggested in the SD model for promoting the green building market. The symmetric game and asymmetric game between two developers show, if the primary proportion who choose GB strategy is lower, all the group in game may finally evolve to GB strategy. In this case and in this time, the government should take measures to encourage developers to enter into the GB market. If the proportion who choose GB strategy is high enough, the government should gradually cancel or reduce those incentive measure.

Research limitations/implications: an Evolution Analysis and System Dynamics Simulation on Behaviors of Real Estate Developers and Government could give some advice for the government to promote the green building market.

Keywords: green building, evolutionary game, system dynamics, real estate market

1. Introduction

With the development of modernization and urbanization, building energy consumption has steadily increased in China, also causing negative impacts on the environment. The implementation of building energy efficiency standards can reduce a large amount of pollutants emissions, like Carbon footprint emission (Pilar, 2013), and increase the GDP at the same time (Liu & Geoffrey, 2009). The Chinese government takes measures to promote the development of green building, including the formulation of laws and regulations, incentive policies, assessment system, etc. (Sauer & Siddiqi, 2009). In 2008 china begin to adopt a system of green labeling for new constructed residential and business building. The system, called 'Green Building Label', has been publicized in the county. But until 2012, only 661 building projects were awarded the Green Building Label (Figure 1). As indicated in Figure 2, from 2008 to 2012， the proportion of Green Building in Floor Space under Construction increased, but no more than 0.29%.

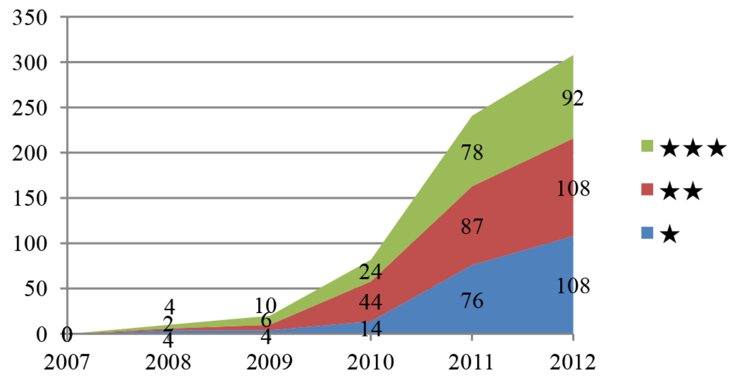

Figure 1. The number of Chinese Green Building label from 2008 to 2012

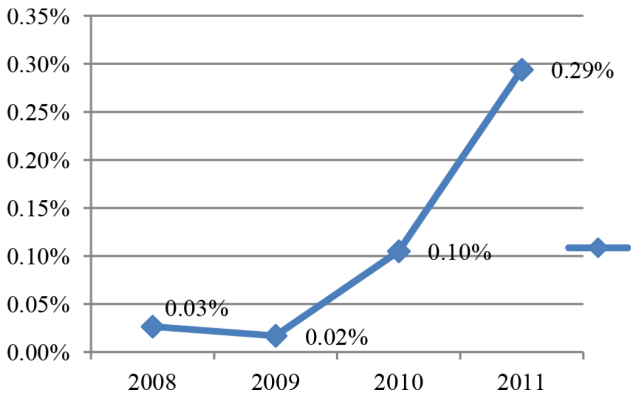

Figure 2. The proportion of Green Building in Floor Space under Construction in China

It is widely believed that the additional investment on Green building can promote energy savings, water savings, and healthier indoor environments, also should return price premium for the Green certified buildings. Some studies suggest that the additional investment on GB should be well paid off by higher selling prices. the Green Mark certified buildings in the Singapore housing market are substantial price premium (Deng, Li & Quigley, 2012). The intangible effects of the label itself seem to play a role in determining the value of green buildings in the marketplace (Eichholtz, Kok & John, 2009; 2010). The label still yields positive effects on a building's value.

Real estate developers are profit driven and working in a competitive environment. There are so many benefits developing GB, but why real estate developers are skeptical in entering the GB market, which requires alternate theories to explain their behaviors. Researchers also apply game theory to explain and analyze a wide array of phenomenon in the field of energy efficiency. Game theory was used to study incentive measures or behaviors that in green building (energy efficiency) areas. In this paper, the market behavior of government and developers are discussed based on the principle of evolutionary game theory. We use SD model to simulation the behavior and analyze the affection factors of real estate developers in GB investment.

Game theory has been widely used as a methodology to explain human interactions. So far, the most widely used model in Evolutionary Game Theory is "Replicator Dynamics Model" (Taylor & Jonke, 1978) which is proposed by Taylor and Jonker. The real onset of the theory can be dated to two seminal books in the early 1980s: Smith's *Evolution and the Theory of Games* (Smith, 1982), which introduced the concept of evolutionary stable strategies (ESS), and Axelrod's *The Evolution of Cooperation* (Axelrod, 1984), which opened up the field for economics and social sciences. Hirshleifer proposed the conception of evolutionary equilibrium (EE) and tried to describe the evolutionary stability (Hirshleifer, 1982; and Friedman, 1998) gave more detailed conditions and application on EE.

Queena K. Qian attempt incorporating transaction cost economics (TCE) and game theoretical frameworks into the analysis of the real estate developer's behaviors to explain why real estate developers are skeptical in entering the BEE market (Qian, Chan & Choy., 2013). Kim and Kim proposed an SD model for a mixed-strategy game between police and driver and carried out a qualitative analysis on its simulation result (Kim & Kim, 1997). Wang, Cai & We built an SD model to simulate an evolutionary game between the government that manages environmental pollution and the firms that contaminate during their production processes (Wang, Cai & Zeng, 2011).

2. Evolutionary game between government and developers

We suppose that such a game can be used to describe the interaction between government and the developers. Government hopes the developers to build more green building. Developers have two strategies, namely, build GB or normal building (NB). Government has two choices, "valid incentive (Incentive)" and "invalid or no incentive (N-incentive)". The incentive measures including financial subsidy, tax incentives, and other government incentive. Table 1 presents the simplified payoff matrix of game players.

A better strategy for the developers is NB when the government choose Incentive ($c_1>a_1$) or the NB when N-incentive ($b_1>d_1$). Similarly, Incentive is the better choice for the government when developers choose NB ($a_2>b_2$). But N-incentive is the better strategy when developers choose GB ($d_2>c_2$).

Supposing the mixed-strategy of the government is x, where x is the probability with which the government chooses to incentive. Let y is the proportion of developers choose to build normal building. U_g is the government's average expected payoff, and U_d is the developer's average expected payoff.

$$U_g=x[y a_2+(1-y)c_2]+(1-x)[y b_2+(1-y)d_2] \tag{1}$$

$$U_d=y[x a_1+(1-x)b_1]+(1-y)[x c_1+(1-x)d_1] \tag{2}$$

Strategies		The government	
		Incentive	N-incentive
Developers	GB	a_1,a_2	b_1, b_2
	NB	c_1, c_2	d_1, d_2

Table 1. The payoff matrix of government and developers

With the greatest expected utilities, we can get the Nash equilibrium state(x*, y*):

$$x^*=\frac{b_1-d_1}{c_1-a_1+b_1-d_1} \quad (3)$$

$$y^*=\frac{d_2-c_2}{a_2-b_2-c_2+d_2} \quad (4)$$

The government’s Replicator dynamic function (Fudenberg & Maskin, 1990) is:

$$\frac{d_x}{d_t}=F(x)=y(1-y)\left[(a_1-c_1-b_1+d_1)x+b_1-d_1\right] \quad (5)$$

$$\frac{d_y}{d_t}=G(y)=x(1-x)\left[(a_2-b_2-c_2+d_2)y+c_2-d_2\right] \quad (6)$$

$X=\begin{pmatrix}F(x)\\G(y)\end{pmatrix}=0$, gives the systemic stable equilibriums:

$$X_1=\begin{pmatrix}0\\0\end{pmatrix}, X_2=\begin{pmatrix}0\\1\end{pmatrix}, X_3=\begin{pmatrix}1\\0\end{pmatrix}, X_4=\begin{pmatrix}1\\1\end{pmatrix}$$

$$X_5=\begin{pmatrix}x^*\\y^*\end{pmatrix}=\begin{pmatrix}\frac{b_1-d_1}{c_1-a_1+b_1-d_1} & \frac{d_2-c_2}{a_2-b_2-c_2+d_2}\end{pmatrix}$$

This article uses Vensim PLE 6.0b to build the SD model of evolutionary game. Figure 3 shows the simplified model. The SD model mainly consists of four flow variables, two rate-changing variables and eight external variables. Table 2 presents the meanings of the external variables in the SD model. This SD model’s initial value assumed are INITIAL TIME = 0, FINAL TIME = 10000, TIME STEP = 0.5.

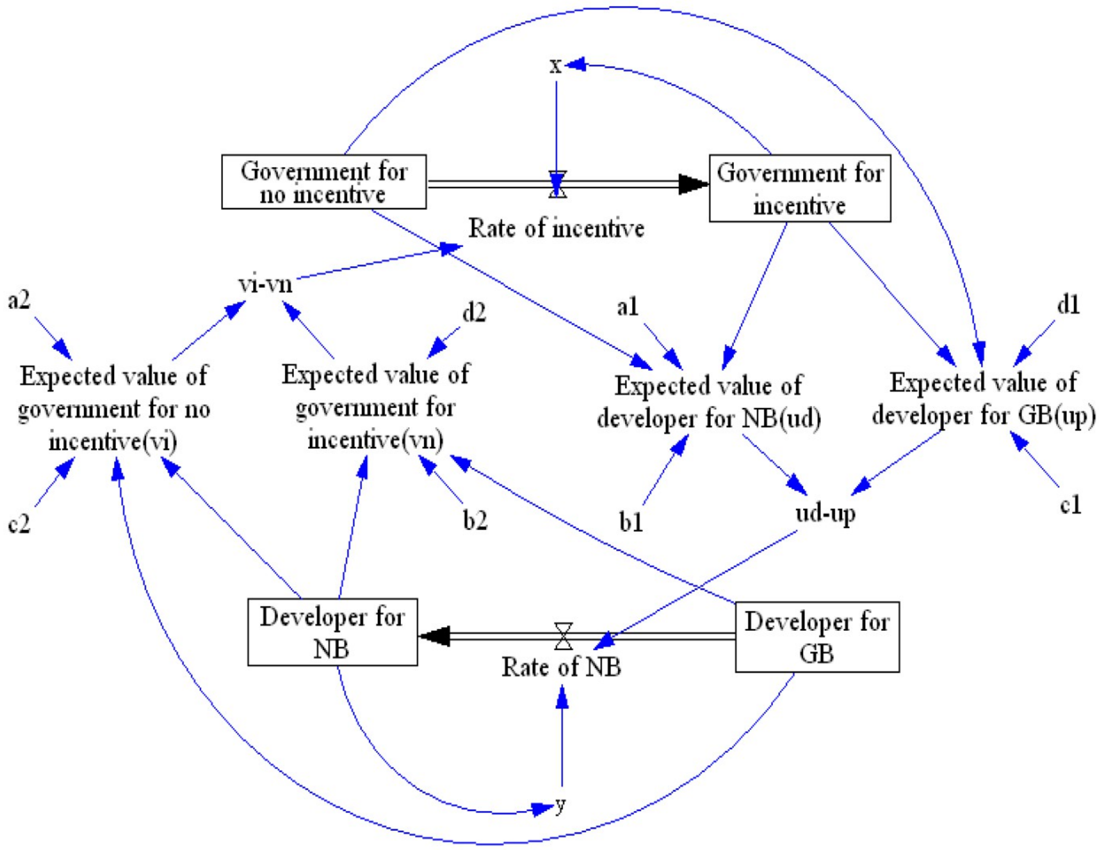

Figure 3. SD model of evolutionary game

Variables for payoff in Table 1	External variables in SD model	Value assumed
a_1	Developer payoff for NB with incentive	1
b_1	Developer payoff for NB with no incentive	4
c_1	Developer payoff for GB with incentive	3
d_1	Developer payoff for GB with no incentive	2
a_2	Government payoff for incentive with NB	4
b_2	Government payoff for no incentive with NB	1
c_2	Government payoff for incentive with GB	2
d_2	Government payoff for no incentive with GB	3

Table 2. Meanings of external variables in SD model

The equilibrium state in the model can be calculated by applying the Equation 3 and Equation 4 to the payoffs of Table 2. We get the following probabilities for the behavior of game players: $x^*=0.5$, $y^*=0.25$.

Figure 4 shows that no one of the game players will change his decision when his initial value is in stable point X_1, X_2, X_3, X_4, X_5. Figure 4 shows that the proportion of developers in GB strategy will increase from 1% to 100%, when the government makes a perfect incentive ($x=1$).

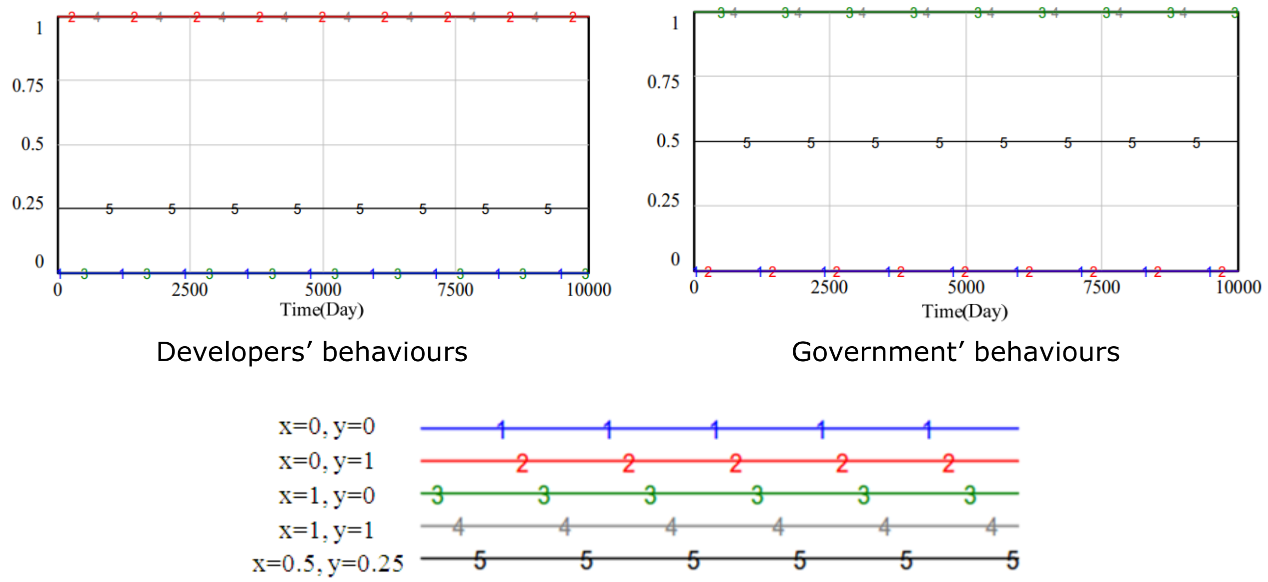

Figure 4. Developers and government' behavior in evolutionary game($X = X_1, X_2, X_3, X_4, X_5$)

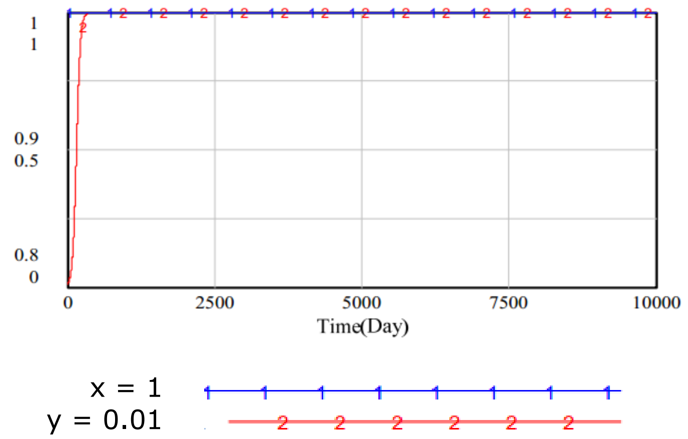

Figure 5. Developers and government' behavior in evolutionary game(x =1)

We suppose that the government acts with the probability $x = x^*$ while the firms act with the probability $y \neq y^*$. Figure 6 shows the simulation results when the government acts with the probability $x = x^*$, while the lines 1 and 2 represent the firms acting with the probabilities $y=0.1$ and $y = 0.9$, respectively. We can see from Figure 6 the probability of NB is fluctuate, is instable.

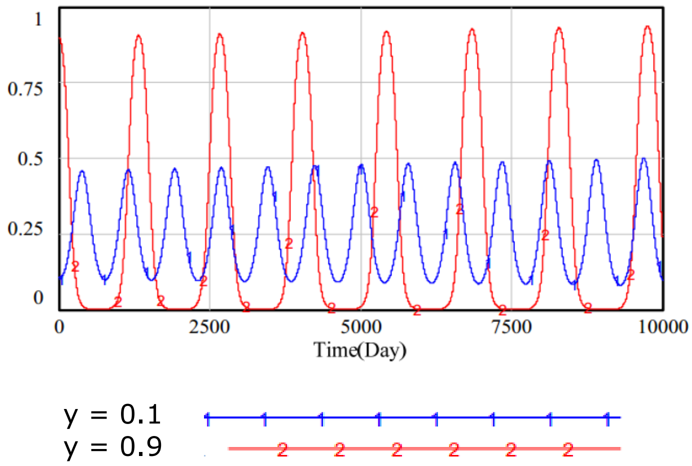

Figure 6. Developer' behavior in evolutionary game when x = 0.5

Figure 7 shows SD model for automatic/dynamical incentive management system, which including in c1 is calculated as follows:

$$Incentive(y) = (1 - y) \times k \quad (7)$$

In this function, Incentive(y)≥0, k is basic value of incentive, including financial subsidy, tax incentives, etc. When y reduced, Incentive(y) increase, this means if the proportion of developers in building GB decline, the government will gradually increase its value of incentive measures. Similarly, if there are more developers in building GB, the government will gradually reduce its value of incentive measures. Compared Figure 6 and Figure 7, we can see dynamical incentive is more effective than a static incentive. Figure 7 implies that under the dynamical incentive, developing normal building can be restrained to a very low level.

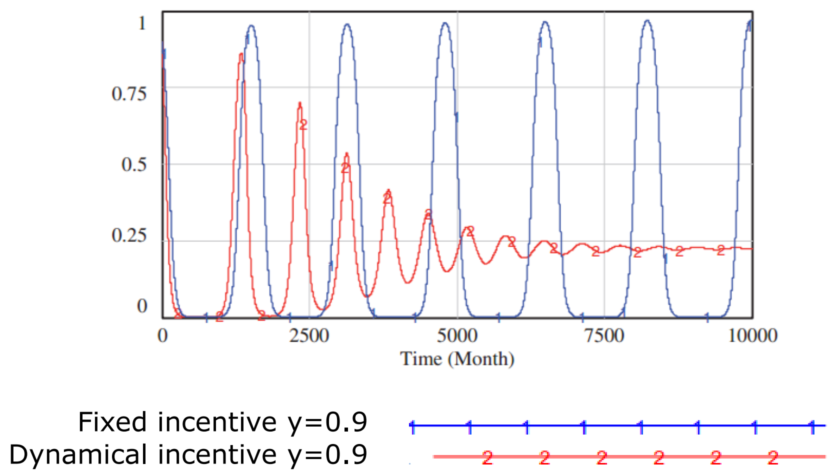

Figure 7. Behaviors of developer in different incentive mechanisms when x=0.5

3. Modeling the GB decision-makings between developers

Based on the Replicator Dynamics Model, we study the developer's concerns in GB decision making. We present the game model of the GB decision making in a two-developer setting, the two both pursuit maximization of profits in the GB market. We suppose there are two situations, Symmetric Games and Asymmetric Games. In Symmetric Games, developer1 and developer 2 have similar strength in the real estate market. When they make a same decision, their cost and benefit are exactly same. In Asymmetric Games, developer1 and developer 2 have different strength in the real estate market, one is more competitive than another. When they make a same decision, their cost and benefit are different.

3.1 Symmetric Games between two developers

Consider the symmetric 2*2 game G of Figure 1. Let S_1 and S_2 be the players 1and 2's pure strategy set in a symmetric game. S_1 is the decision of developing green building (GB) and S_2 is the decision of developing normal building (NB). A developer playing S1 and meeting an opponent who plays S_1 receives an expected benefit of $P+I_1+I_2$. A developer playing S_2 and meeting an opponent who plays S_2 receives an expected benefit of P; A developer playing S_1 and meeting an opponent who plays S_2 receives an expected benefit of $P-C+I_2$. If a developer plays S_1 in a population where proportion x and 1-x of her opponent plays S_1 and Short S_2,then the developer' s expected payoff , denoted by $U(S_1)$, is given by

$$U(S_1) = x(P+I_1+I_2) + (1-x)\,(P-C+I_2) \quad (8)$$

In the same, $U\,(S_2) = x\,P + (1 - x)\,P$ (9)

Strategies		Developer 2	
		GB	NB
Developers 1	GB	$P+I_1+I_2$, $P+I_1+I_2$	$P-C+I_2$, P
	NB	P, $P-C+I_2$	P, P

Table 3. The Benefit matrix of game G

Variables	Definition
P	Benefit of normal building
I_1	Additional benefit of green building, including the price premium of GB, etc..
I_2	Financial subsidy, tax incentives, and other government incentive.
C	Additional payment of green building, including the additional cost of green building construction etc.

Table 4. Relevant variables in Table 3

The replicator dynamics formula of developer1 population is:

$$F(x)=\frac{d_x}{d_t}=x(1-x)[x(I_1+I_2)-(1-x)(C-I_2)] \quad (10)$$

Let F(x) = 0, then $x_1=0$, $x_2=1$, $x_3=\frac{C-I_2}{C+I_1}$. But not all this three point are ESS. $x_1=0$, $x_2=1$ is ESS, $x_3=\frac{C-I_2}{C+I_1}$ is one of this RD' three stabilization, but is not an equilibrium.

1) In this game, when primary $x\in[0, \frac{C-I_2}{C+I_1}]$, the game tends to equilibrium points x = 0, which means that "normal building" is the final choice of all players.

2) In this game, when primary $x\in[\frac{C-I_2}{C+I_1}, 1]$, the game tends to equilibrium points x = 1, which means that "green building" is the final choice of all players.

Different primary x leads to different equilibrium. Which strategy will be chosen eventually depends upon the primary proportion of various strategies. C, I_1, I_2 are the factors influencing x_3, we can see from Figure 8, the value of C is lower and I_2 is higher, the value of x_3 is lower, the interval $[0, x_3]$ is small, and the interval $[x_3, 0]$ is large, so the probability of all the developer group choosing GB strategy is higher. We can conclude:

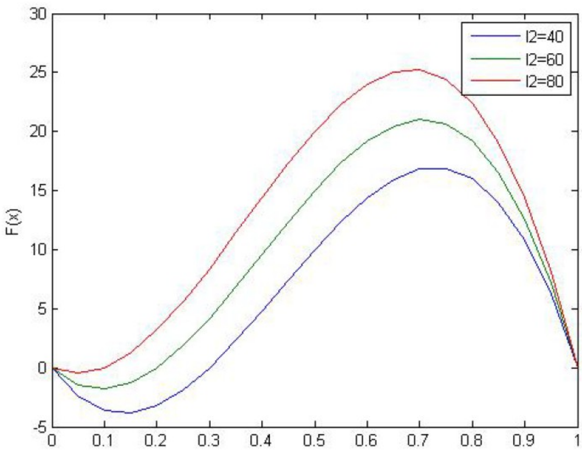

Figure 8. Evolutionary game RD diagram

1) If the government increases the financial subsidy or reduces rate of tax, then the value of I_2 increase, x_3 is reduced. The interval of $[x_3, 1]$ is enlarged. The possibility of developers choosing the strategy of "Green building" is increase.

2) If the benefit I_1 increases or the cost reduces, x_3 is reduced. The possibility of developers choosing the strategy of "Green building" is increase.

3) When $x > \frac{C-I_2}{C+I_1}$, all developers will evolve to x=1， which all developer will choose the strategy of "green building". This is a market spontaneous process, government shall cancel the policy like financial subsidy or tax incentive.

3.2 Asymmetric Games two developers

Let the developer 1 and developer 2 be the set of the player in the game model. Let S = {S_1, S_2; S_1 = Building GB, S_2 = Building normal building} denote a finite set of pure strategies for the game G′-"GB investment decision. These two players are to play G′, each of whom must make a choice from S. Developer1 is more competitive than developer 2 in real estate market. When developer 1 and developer 2 all choose S_2, they will respectively gain the profit p_1 and p_2 of developing normal buildings； when developer 1 and developer 2 all choose S_1， they can respectively get value-added benefits from the green building investment d_1 and d_2 (d_1, $d_2 > 0$)，and all additional benefits $d = d_1+d_2$; C_1 and C_2 is the cost to develop GB for developer 1 and developer 2. Let I denote the subsidies and tax preferences from government**.** The payoff matrix is Table 1.

Strategies		Developer 2	
		GB	N-GB
Developers 1	GB	p_1+d_1+I, p_2+d_2+I	p_1-C_1+I, p_2
	N-GB	p_1, p_2-C_2+I	p_1, p_2

Table 5. The benefit matrix of game G′

Let x denote the proportion/probability of the developer 1 who wish to play strategy S_1 and the rest (1-x) prefer to implement strategy S_2. Likewise, the proportion/probability of developer 2 playing strategy S_1 is denoted by y and so we conclude that the strategy S_2 is being tried by (1–y). Then the developer 1's expected benefit, denoted by U_1, when developer 1 play S1, is given by

$$U_1(S_1) = y(p_1 + d_1 + I) + (1 - y)(p_1 - C_1 + I) \tag{11}$$

In the same, when developer 1 play S_2,

$$U_1(S_2) = y\, p_1 + (1 - y)\, p_1$$

$\bar{U}1$ is the expected benefit of developer 1：

$$\bar{U}1 = xU_1(S_1) + (1 - x)U_1(S_2)$$

The replicator dynamics formula of developer1 population is:

$$\frac{d_x}{d_t} = x(1-x)\left[\left(d_1 + C_1\right)y - C_1 + I\right] \quad (12)$$

Similarly, the replicator dynamic equation of developer 2 population is:

$$\frac{d_y}{d_t} = y(1-y)\left[\left(d_2 + C_2\right)x - C_2 + I\right] \quad (13)$$

So, the evolution process of choosing to construct green building can be illustrated by Equations 11 and 12. We use the standard Jacobian Matrix (J) for evaluating the asymptotic stability of an equilibrium strategy pair and obtain the ESS values：

$$J = \begin{bmatrix} (1-2x)[(C_1+d_1)y - C_1 + I] & x(1-x)(C_1+d_1) \\ y(1-y)(C_2+d_2) & (1-2y)[(C_2+d_2)x - C_2 + I] \end{bmatrix}$$

On the basis of Jacobian Matrix J, we can find five partial equilibrium points in plane coordinate system S = {(x, y), x ≥ 0,y ≤ 1}, they are O(0,0), A(1,0), B(1,0), C(1,1), D(X_D,Y_D).

$$x_D = \frac{C_2 - I}{\left(d_2 + C_2\right)} \quad (14)$$

$$y_D = \frac{C_1 - I}{\left(d_1 + C_1\right)} \quad (15)$$

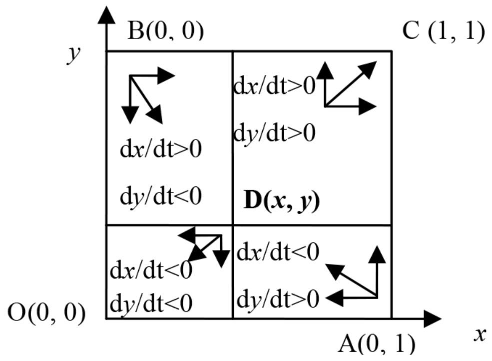

Figure 10. Replicator dynamics phase chart

In these five points, O and C is ESS, O (x = 0, y = 0) means that developer 1 and developer 2 finally choose to developing green building, C (x = 1, y = 1) means that developer 1 and developer 2 finally choose to developing normal building. There are two unstable equilibrium point A and B, one saddle point D. The dynamic behaviors of this system can be visualized in the Figure 10.

Different primary D(x, y) leads to different equilibrium. Which strategy will be chosen eventually depends upon the primary proportion of various strategies. C_1, C_2, d_1, d_2, I are the factors influencing D(x, y). The value of D(x, y) is lower, the probability of all the developer group choosing GB strategy (evolve to C (1, 1)) is higher.

4. Conclusion

In the analysis of game between government and developers, SD simulation provides a very convenient and visual method for the policy maker to make decisions without the complicated processes of mathematical solving and proving. We can see a fixed incentive measure couldn’t promote more developer entering into the GB market, the proportion of GB developers is fluctuant. A dynamical incentive is maybe more effective than a static incentive.

We use evolutionary game theory to analyze the GB decision-making behaviors between developers. The symmetric game and asymmetric game between two developers show, if the primary proportion who choose GB strategy is lower, all the group in game may finally evolve to GB strategy. In this case and in this time, the government should take measures to encourage developers to enter into the GB market. If the proportion who choose GB strategy is high enough, the government should gradually cancel or reduce those incentive measure.

Acknowledgments

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