The Evolutionary Game and Simulation Study of Guaranteed Rental Housing Policy

Zhengzheng Xie(✉) and Yang Shen

College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, Jiangsu, China
{xiezhengzheng,shen.y}@nuaa.edu.cn

Abstract. With the accelerated urbanization in China, a large number of new citizens and young people have flocked to big cities, but are facing the housing dilemma of "not being able to afford to buy or rent a house". In order to solve this problem, the government attaches great importance to and introduces the policy of guaranteed rental housing. This paper constructs a three-party evolutionary game model of government, enterprises and new citizens from the perspective of the new citizens as the main body of the policy and conducts simulation analysis based on the theoretical basis of evolutionary game theory. The research results show that: (1) policy subsidies can effectively motivate enterprises to participate in the construction of guaranteed rental housing. (2) The strategy choice of enterprises is influenced by the net income after responding to the strategy. (3) The new citizens' trade-off between the net benefit of another rent and the risk cost of failure to participate in the rent is an important basis for their strategy choice. Finally, recommendations related to the development of guaranteed rental housing policies are proposed based on the findings of the study.

Keywords: Guaranteed rental housing · Evolutionary game · Matlab simulation

1 Introduction

1.1 Background

As China's urbanization process accelerates, the size of the floating population is gradually increasing, and a large number of new citizens are coming to big cities. For the new citizens, they do not have enough financial ability to buy a complete set of housing, nor do they meet the minimum security standards of the old housing security system, and it is difficult to meet their own housing needs in the rental market.

Faced with the increasingly serious housing problem of new citizens, the government has attached great importance to the issue and introduced corresponding support and management policies. Therefore, based on the evolutionary game theory, this paper builds a three-party evolutionary game with the government, enterprises and new citizens as the main actors, and explores the interests, demands, interaction process and overall system of each of them. Therefore, based on the evolutionary game theory, this paper constructs

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a tripartite evolutionary game with the government, enterprises and new citizens as the main players, and explores the interests of each player, the interaction process and the evolutionary equilibrium stability of the overall system.

1.2 Literature Review

Many scholars have used the evolutionary game approach to study the problems related to subsidized housing. Zeng Hui et al. [1] studied the administrative management in the public housing system, and constructed an evolutionary game model to study the influence of the prosecution behavior of government departments on the tenant group's rent relying and rent cheating behavior; Yu Xiaofen et al. [2] studied the effectiveness of government regulation on promoting the participation of social forces in the construction of subsidized housing, analyzed the evolutionary path of the behavioral strategies of both, and proposed that the existing incentive and constraint mechanisms should be improved; Li et al. [3] analyzed the interest relationship between governmental supervisors, censors and tenants in the process of illegal subletting, constructed an evolutionary game model, and made some suggestions for the innovation of the path of China's public housing regulatory system; Huan et al. [4] studied the conflict of interests between the government as the policy maker and regulator, and the developer as the policy implementer in the process of subsidized housing practice, and discussed this problem based on evolutionary game. The study found that the rationality of government supervision and punishment, the scientificity of relevant policy formulation, and the developers' own understanding of the nature of the people's livelihood project of subsidized housing construction would affect the evolutionary outcome; Zhou et al. [5] developed a dynamic game model under incomplete contract conditions for public housing PPP (Public-Private Partnership) projects and analyzed the key factors affecting PPP contracting, and found that fiscal expenditure smoothing, risk transfer, and government performance can facilitate the government's adoption of cooperative strategies.

In the research of guaranteed rental housing and evolutionary games, scholars have come up with certain research results. However, after in-depth analysis, it is found that there is still room for further development in the current research:

(1) In terms of the newly introduced policy of guaranteed rental housing, studies on the operation mechanism of guaranteed rental housing are still relatively scarce.
(2) The research on the game of interests in the guaranteed rental housing market is not yet comprehensive. The introduction of guaranteed rental housing introduces the new subject of "non-real estate development enterprises" into the guaranteed housing system, which will bring a new perspective to the evolution of the game among various subjects in the guaranteed housing market.

2 Model Construction

2.1 Analysis of Participant Behavior

(1) Government: The government encourages local qualified enterprises to build subsidized rental housing through self-build and reconstruction. The equilibrium point of the government's interest in the game lies in the positive relationship between the total policy cost and the actual social benefits generated.

(2) Enterprises: The strategy choices of enterprises include responding to the policy and not responding to the policy. The equilibrium point for enterprises' interests is the relationship between policy conditions and rental income, i.e. the overall project profitability after considering all factors.
(3) New citizens: The equilibrium point of new citizens' interests in the game lies in the comparison between their own rental needs and the actual housing conditions.

2.2 Model Hypothesis and Construction

Hypothesis 1: The government, enterprises and new citizens are all finite rational.

Hypothesis 2: All three parties in the game have two behavioral strategy choices. The government can choose to actively adopt incentives to support the development of the guaranteed rental housing market, or choose not to adopt substantive incentives, but only to provide formal support, and its strategy set is {active support, formal support}; enterprises can choose to respond to the policy or not to respond, and its strategy set is {response, not respond}; new citizens can choose to rent guaranteed rental housing or other private scattered rent, and its strategy set is {participate in renting, rent another}.

Hypothesis 3: At time t, the probability of the government choosing active support is x, the probability of formal support is $1 - x$, the probability of enterprises choosing response is y, the probability of non-response is $1 - y$, and the probability of new citizens choosing to rent is z, the probability of renting is $1 - z$. The values of x, y and z are all in the range [0, 1] and are all functions of time t. formal support.

Hypothesis 4: When the government chooses the active support strategy, it needs to pay the policy implementation and supervision cost C_1, and the total amount of various tax breaks, subsidies and other benefits issued to the enterprises that choose to respond to the policy is B; when the government chooses the formal support strategy, it pays a lower cost C_2 ($C_2 < C_1$). When enterprises respond and new citizens participate in renting, it means that the guaranteed rental housing market has been developed positively. If the government chooses the strategy of active support at this time, the government can obtain a higher social benefit R_1, and if it chooses the strategy of formal support, the overall policy effect will be discounted and obtain a relatively low social benefit R_2 ($R_2 < R_1$). Regardless of the government's choice of strategy, when new citizens choose to rent another, the government needs to pay additional regulatory costs C_3 in order to control rental chaos such as illegal group rentals.

Hypothesis 5: When enterprises choose to respond to the policy, they need to pay construction cost C_4, and get subsidy B when the government carries out active support; if new citizens choose to participate in renting at this time, enterprises get rental income R_3.

Hypothesis 6: When new citizens choose to participate in renting and enterprises respond, they pay rental cost C_5, and when the government actively supports, new citizens' own housing needs are better met and they get gain R_4; when the government formally supports, the overall quality of living environment decreases and new citizens get lower gain, which is recorded as R_5 ($R_5 < R_4$). When the new citizen chooses to participate in renting but the enterprise does not respond to the policy, the loss is L. When the new citizen chooses to rent another, he or she pays the rental cost C_6 and gains R_6 when the demand is satisfied. regardless of whether the government provides

Table 1. Tri-party evolutionary game payment matrix.

	Strategy Selection		active support	formal support
Enterprise	response	participate in renting	$R_1 - C_1 - B$, $R_3 + B - C_4, R_4 - C_5$	$R_2 - C_2$, $R_3 - C_4, R_5 - C_5$
		rent another	$-C_1 - B - C_3$, $B - C_4, R_6 - C_6$	$-C_2 - C_3$, $-C_4, R_6 - C_6$
	not response	participate in renting	$-C_1, 0, -L$	$-C_2, 0, -L$
		rent another	$-C_1 - C_3, 0, R_6 - C_6$	$-C_2 - C_3$, $0, R_6 - C_6$

active support, when the new citizen chooses to participate in renting, his or her net gain must be higher than that when he or she rents another, i.e., $(R_4 - C_5) > (R_6 - C_6)$, $(R_5 - C_5) > (R_6 - C_6)$.

Based on the above assumptions and parameters, a tripartite evolutionary game payment matrix for the government, enterprises, and new citizens is constructed (Table 1).

3 Model Analysis

3.1 Analysis of Equilibrium Points

First solve the equilibrium points of the model, and get the 14 equilibrium points of the system, which are: $E_1(0, 0, 0)$, $E_2(1, 0, 0)$, $E_3(0, 1, 0)$, $E_4(0, 0, 1)$, $E_5(1, 1, 0)$, $E_6(1, 0, 1)$, $E_7(0, 1, 1)$, $E_8(1, 1, 1)$, $E_9((C_4 - R_3)/B, (C_2 - C_1)/(B - R_1 + R_2), 1)$, $E_{10}((C_5 - C_6 - R_5 + R_6)/(R_4 - C_5), 1, (B + C_1 - C_2)/(R_1 - R_2))$, $E_{11}(0, (L - C_6 + R_6)/(L - C_5 + R_5), C_4/R_3)$, $E_{12}(1, (L - C_6 + R_6)/(L - C_5 + R_4), (C_4 - B)/R_3)$, $E_{13}(C_4/B, (C_2 - C_1)/B, 0)$, and since the expression of E_{14} is too complicated and lengthy, it is simplified here as $E_{14}(a^*, b^*, c^*)$.

Among the above 14 equilibria, the first eight equilibria $E_1(0, 0, 0)$, $E_2(1, 0, 0)$, $E_3(0, 1, 0)$, $E_4(0, 0, 1)$, $E_5(1, 1, 0)$, $E_6(1, 0, 1)$, $E_7(0, 1, 1)$, $E_8(1, 1, 1)$ are pure strategy Nash equilibria, while E_9 to E_{14} are all mixed strategy Nash equilibrium. The mixed-strategy Nash equilibrium is only the "central point" of the system in the dynamic evolution process, not the asym-ptotic stabilization point of the system, therefore, only the eight pure-strategy Nash equilibria are focused on this paper.

The Jacobi matrix of the evolving game system is:

$$S = \begin{bmatrix} \partial F(x)/\partial x & \partial F(x)/\partial y & \partial F(x)/\partial z \\ \partial F(y)/\partial x & \partial F(y)/\partial y & \partial F(y)/\partial z \\ \partial F(z)/\partial x & \partial F(z)/\partial y & \partial F(z)/\partial z \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \tag{1}$$

$a_{11} = (2x-1)\big[yB - (R_1 - R_2)yz + C_1 - C_2\big]$, $a_{12} = x(x-1)[B - (R_1 - R_2)z]$, $a_{13} = x(1-x)y(R_1 - R_2)$, $a_{21} = y(1-y)B$, $a_{22} = (2y-1)(C_4 - xB - zR_3)$, $a_{23} = y(1-y)R_3$,

$a_{31} = z(1-z)y(R_4 - R_5)$, $a_{32} = z(1-z)[(R_4 - R_5)]x + R_5 - C_5 + L]$, $a_{33} = (2z-1)\big[-y(R_5 - C_5 + L) - xy(R_4 - R_5) - C_6 + R_6 + L\big]$.

The stability of each equilibrium point is solved according to Lyapunov's first method.

The eigenvalues of each equilibrium point after substitution into the Jacobi matrix and the conditions required for them to reach a steady state equilibrium are shown in Tables 2.

The "+" sign in the table below indicates that the corresponding eigenvalue has a positive real part, the "-" sign indicates that it has a negative real part, and the "*" sign indicates that it is impossible to determine the sign of its real part, which requires a certain condition constraint.

For subsequent discussion, let $u = C_6 - R_6 - L$, $v = R_3 - C_4$, $w = C_2 - C_1 + R_1 - R_2 - B$. There are seven main possible stability cases in the system.

Case 1: When $u < 0$, $w < 0$, $v < 0$, or $u < 0$, $w > 0$, $v + B < 0$, $E_1(0, 0, 0)$ is the only strategy stabilization point of the evolving system.
Case 2: When $u > 0$, $v < 0$, and at least one of $w < 0$ and $v + B < 0$ holds, $E_4(0, 0, 1)$ is the only strategy stabilization point of the evolving system.
Case 3: When $u > 0$, $w < 0$, $v > 0$, $E_7(0, 1, 1)$ is the only strategy stabilization point of the evolving system.
Case 4: When > 0, $w > 0$, $v > 0$, $E_8(1, 1, 1)$ is the only strategy stabilization point of the evolving system.

Table 2. Eigenvalues and stability of equilibrium points.

equilibrium point	λ_1, λ_3	the sign of real part	conditions for reaching steady state
$E_1(0,0,0)$	$C_2 - C_1, -C_4,$ $C_6 - R_6 - L$	-, -, *	$C_6 - R_6 - L < 0$
$E_2(1,0,0)$	$C_1 - C_2, B - C_4,$ $C_6 - R_6 - L$	+, *, *	/
$E_3(0,1,0)$	$C_2 - C_1 - B, C_4,$ $C_6 - C_5 + R_5 - R_6$	-, +, +	/
$E_4(0,0,1)$	$C_2 - C_1, R_3 - C_4,$ $C_6 - C_5 + R_5 - R_6$	-, *, *	$R_3 - C_4 < 0,$ $C_6 - R_6 - L > 0$
$E_5(1,1,0)$	$B + C_1 - C_2, C_4 - B,$ $C_6 - C_5 + R_4 - R_6$	+, *, +	/
$E_6(1,0,1)$	$C_1 - C_2, B - C_4 + R_3,$ $L - C_6 + R_6$	+, *, *	/
$E_7(0,1,1)$	$C_2 - C_1 + R_1 - R_2 - B,$ $C_4 - R_3,$ $C_5 - C_6 - R_5 + R_6$	*, *, -	$C_2 - C_1 + R_1 - R_2 - B < 0,$ $R_3 - C_4 > 0$
$E_8(1,1,1)$	$B + C_1 - C_2 - R_1 + R_2,$ $C_4 - R_3 - B,$ $C_5 - C_6 - R_4 + R_6$	*, *, -	$C_2 - C_1 + R_1 - R_2 - B > 0,$ $C_4 - R_3 - B < 0$

Case 5: When $u < 0$, $w < 0$, $v > 0$, the system has two stable equilibria $E_1(0, 0, 0)$ and $E_7(0, 1, 1)$.
Case 6: When $u < 0$, $w > 0$, $v + B > 0$, the system has two stable equilibria $E_1(0, 0, 0)$ and $E_8(1, 1, 1)$.
Case 7: When $u > 0$, $w > 0$, $-B < v < 0$, the system has two stable equilibrium points $E_4(0, 0, 1)$ and $E_8(1, 1, 1)$.

3.2 Model Simulation

Among the above seven scenarios, only scenario 3 and scenario 4 are ideal evolutionary stable states, and the rest of the scenarios do not have positive reference values, so only scenario 3 and scenario 4 are simulated and analyzed. The three-way evolutionary game model is simulated and analyzed using Matlab software.

The parameters are assigned the following values according to the conditions of case 3: $C_1 = 10$, $C_2 = 5$, $C_3 = 30$, $C_5 = 30$, $C_6 = 18$, $R_1 = 60$, $R_2 = 20$, $R_3 = 36$, $R_4 = 48$, $R_5 = 42$, $R_6 = 12$, $B = 45$, $L = 3.6$. The simulation results are shown in Fig. 1.

Case 3 indicates that when the net benefit of the government's choice of active support is smaller than that of formal support, and the enterprises can make profits without government subsidies, the government prefers formal support, the enterprises will still respond to the policy, and the new citizens, seeking better living conditions, will also choose to participate in rent. Obviously, such an ideal state requires the development of the guaranteed rental housing market to a large enough scale before it can be realized. At this point, almost all local new citizens will choose to rent subsidized housing, and enterprises will be able to generate enough revenue and continuously respond to the policy to expand the supply of housing, indicating that the situation can be improved by the self-regulation of the market itself in such a state. The marginal benefits of the government's subsidies and other preferential policies have reached a relatively saturated

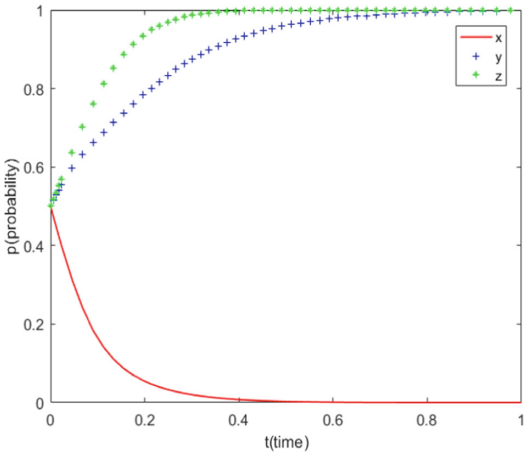

Fig. 1. Case 3 Simulation Analysis.

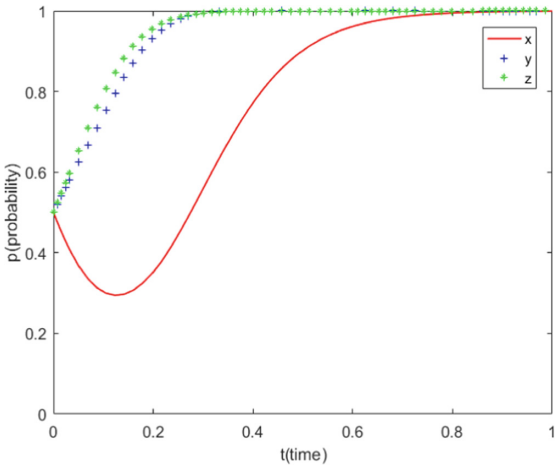

Fig. 2. Case 4 Simulation Analysis.

state, and the government can slowly let go of the market and provide minimal support and regulation.

The parameters are assigned the following values according to the conditions of case 3: $C_1 = 10$, $C_2 = 5$, $C_3 = 30$, $C_5 = 30$, $C_6 = 18$, $R_1 = 100$, $R_2 = 40$, $R_3 = 36$, $R_4 = 48$, $R_5 = 42$, $R_6 = 12$, $B = 45$, $L = 3.6$. The simulation results are shown in Fig. 2.

Case 4 shows that when the net benefit of government choice of active support is smaller than the net benefit of formal support, and enterprises need to be subsidized by the government to ensure profitability, the government will provide active support, enterprises will respond to the policy, and new citizens will choose to participate in renting, which is the ideal state at the early stage of the development of subsidized rental housing policy. Since the policy has not been implemented for long enough, enterprises do not have enough confidence in the market scale of subsidized rental housing, and they will only choose to respond to the policy when they are sure that they can get a stable and sufficient source of subsidies from the government. For the new citizens, the relevant policy can undoubtedly improve their net income from rental housing, and the new citizens, noting the government's positive guiding attitude and the enterprises' response, are very optimistic about the supply of housing, so they are also willing to choose to participate in renting. For the government, the government's intervention in the market can still be effective, so the government will continue to actively promote the policy development, forming a virtuous cycle.

4 Conclusions and Policy Recommendations

4.1 Conclusions

The comprehensive model analysis and simulation results can lead to the following conclusions.

(1) The government has a dominant position in the development process of guaranteed rental housing. The housing problem of new citizens cannot be effectively solved by market self-regulation alone, and government intervention is needed, especially at the early stage of policy development, when the government needs to use substantial incentives, not just at the formal level, otherwise it is difficult to make effective changes to the status.
(2) Policy subsidies can effectively motivate enterprises to participate in the construction of subsidized rental housing, but when the subsidies are too strong, it is not conducive to the sustainable development of the policy.
(3) The strategy choice of enterprises is influenced by the net income after responding to the strategy. The higher the net income, the higher the probability of enterprises responding to the policy, but if the market demand is unstable, enterprises may eventually tend not to respond to the policy.
(4) The new citizens' trade-off between the net benefit of another rent and the risk cost of failure to participate in the rent is an important basis for their strategy choice. When there is a lack of effective administrative regulation and stable supply of subsidized rental housing, the loss L of failure to participate in renting increases, and new citizens tend to choose to rent.

4.2 Policy Recommendations

Comprehensive of the above, the following suggestions are made for the development of guaranteed rental housing policies.

(1) Improve policy efficiency and actively take various measures to provide policy support for guaranteed rental housing.
(2) Appropriately increase the financial subsidies and policy preferences for relevant enterprises at the early stage of development to motivate them to participate in the construction of guaranteed rental housing and ensure the supply of housing.
(3) Fully mobilize young people and new citizen groups to participate in leasing subsidized housing. On the one hand, we should make use of social media and other information channels to strengthen policy propaganda and interpretation and increase the policy knowledge rate of policy targets; on the other hand, we should strictly control housing quality, strengthen policy supervision, improve relevant laws and regulations, protect the rental rights and interests of young people and new citizens, and enhance the willingness to participate in renting.

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