

Article

The Influence of Government's Economic Management Strategies on the Prefabricated Buildings Promoting Policies: Analysis of Quadripartite Evolutionary Game

Yinghui Song ¹ , Junwu Wang ^{1,2}, Denghui Liu ^{3,*}, Yanru Huangfu ⁴, Feng Guo ¹  and Yipeng Liu ^{1,2} 

¹ School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan 430070, China; songyinghui@whut.edu.cn (Y.S.); 267544@whut.edu.cn (J.W.); guofeng777@whut.edu.cn (F.G.); 222745@whut.edu.cn (Y.L.)

² Sanya Science and Education Innovation Park, Wuhan University of Technology, Sanya 572025, China

³ China Construction First Group Corporation Limited, Beijing 100161, China

⁴ School of Art and Design, Zhengzhou University of Light Industry, Zhengzhou 450002, China; 2004069@email.zzuli.edu.cn

* Correspondence: 306616@whut.edu.cn

Abstract: As an efficient measure to protect the environment and reduce energy consumption, promoting prefabricated buildings can lead to the sustainable development of the world economy and long-term economic benefits for society. Nevertheless, for China, it is immature because of the high cost and difficulties in the promotion. The government's strategies in economy and management are crucial to promoting prefabricated building policies. This paper establishes a quadripartite evolutionary game model composed of construction units, property developers, homebuyers, and government departments under the government supervision system by analyzing the entire interest chain of prefabricated buildings projects. It aims to study the impact of government management and economic strategies on promoting prefabricated building policies. The results show that: (1) The government should ensure the construction safety of projects through mature supervision systems to reduce citizens' resistant moods caused by project quality problems; (2) The government should improve the reward and punishment mechanism to motivate construction units and developers; (3) The government should invite supervision consulting companies to increase information transparency, avoiding the economic losses of the people and the obstruction of policy implementation caused by information imbalance.

Keywords: prefabricated buildings policy; economy; management; quadripartite evolutionary game model; government supervision



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1. Introduction

With the development of global science and technology and the improvement of the supply chain system, the industrialization and urbanization grow faster. It is universally acknowledged that the carbon dioxide emitted by traditional construction industries which consume large amounts of resources will exacerbate the global greenhouse effect [1,2]. What's worse, construction wastes can cause irreversible pollution to the environment. The survey data shows that China's CO₂ emissions increased 390.7% times from 1995 to 2011, and the total emissions in 2011 reached 30,359,000 tons [3]. Therefore, the Chinese government has launched the 14th Five-Year Plan for China's National Economic and Social Development and Long-Range Objectives Through 2035 in the context of the world's environmental protection and China's social development. Additionally, replacing the currently commonly used cast-in-place buildings with prefabricated buildings has become the main method of energy saving and emission reduction [4].

The prefabricated building refers to the building whose main body is composed of prefabricated components [5]. The prefabricated components are produced and stored

in factories, then installed on the construction site by placing them to the designated location and bonding them with special materials at the joints [6]. Prefabricated buildings whose safety management can be controlled [7], can cut down carbon emissions effectively [8] and reduce wastes generated during construction [9]. In addition, they can contribute to ever-increasing long-term social benefits [10]. Therefore, the buildings are considered an important way to achieve industrialization of construction and sustainability of the building life cycle [11–15].

However, compared to most developed countries, China's prefabricated building industry is currently in its infancy. It can be seen that China's prefabricated building industry which embraces weak design capability and low prefabrication rate has no complete standards, and the unit price of prefabricated components is slightly higher compare to the corresponding cast-in-place buildings. In China, prefabricated buildings cost about 200CNY more per square meter than cast-in-place buildings [16,17]. Therefore, in order to maximize economic benefits, construction units and property developers may cut some costs when developing prefabricated buildings and ignore safety regulations during construction to obtain some illegal benefits [18]. In order to prevent the above situation, between 2017 and 2020, the Chinese government formulated the "Thirteenth Five-Year Plan Project" and rewards and punishments for prefabricated buildings [19]. However, they are not adjustable and manipulative and lack theoretical support and regulatory systems. Although supported by the government, it is hard to ensure a smooth construction process [20].

To sum up, it is an urgent issue for government departments to promote the prefabricated policy while ensuring projects' safety and people's economic interests. In order to fill the gaps in these problems, this study facilitates the policy promotion of prefabricated buildings under the regulatory system through an evolutionary game model among government departments, project subjects, and homebuyers. Besides, various mechanisms of interaction between cost and strategy choice of each party under multi-party regulation are revealed, followed by numerical simulations using MATLAB software. The simulated results are analyzed later in this paper to explain the changes in strategy choices of each party due to parameter changes. Finally, this paper put forward some suggestions to help the promotion of prefabricated buildings in China.

The remaining five sections are organized as follows. Section 2 summarizes previous scholars' research. Section 3 introduces the evolutionary game theory and establishes the quadripartite evolutionary game model. Section 4 makes a simulation of the model and finds out solutions. Section 5 debugs the parameter changes of the model and analyses the sensitivity parameters. Section 6 analyzes solutions by discussing the mode and summarizes the whole paper to provide a general direction for future research.

2. Literature Review

Prefabricated buildings have been used in several developed countries, among which Singapore, Japan, the United Kingdom, and Sweden master the relatively mature techniques [21–24]. What's more, located in different areas, these countries have more complete policies for the economic management of prefabricated buildings [25]. In this paper, a literature review was conducted on "Web of Science" by searching for terms of prefabricated building, policy, factor. It demonstrated that 221 papers were related to this study between 2015 and 2021. Then, a summary of the previous studies is presented. The overlay visualization diagram related to the economic management policy of prefabricated buildings is shown in Figure 1. From the results of Figure 1, the following studies can be conducted on policies of prefabricated buildings.

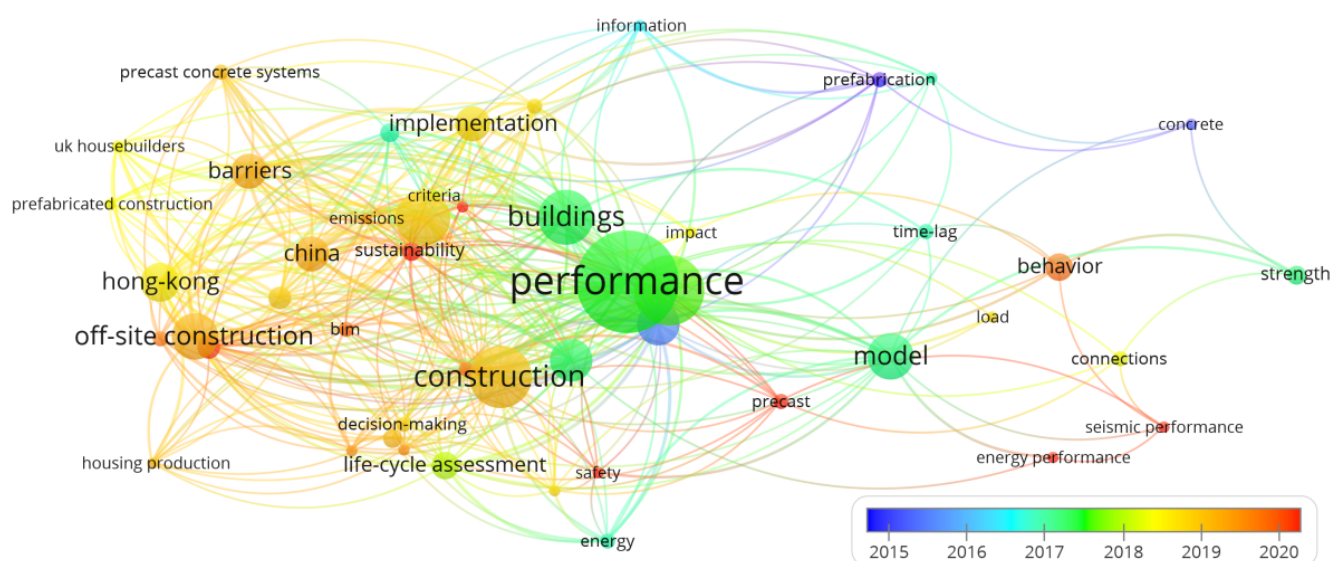


Figure 1. Overlay visualization diagram related to the economic management policy of prefabricated buildings.

2.1. Development of Prefabricated Buildings

In response to the shortage of resources and labor after World War II, Sweden formulated prefabricated buildings promotion policies in 1965. The policies were planned to address the housing shortage by initiating the Million Building Project in 1974 [26]. During this period, the Swedish government proposed a standardization program for prefabricated buildings to promote uniform construction units and component manufacturing factories [27]. On the other hand, the UK built prefabricated buildings based on an industrialized system and promoted relevant policies through an industrialized regulatory system [28]. In 2005, with the government providing subsidies and public investment to stimulate more prefabricated buildings, 35% of the new houses in the UK were prefabricated buildings. [29] The prefabricated project policy was promoted for the third time in Singapore in 2011. The Government Housing Development Bureau vigorously recommended prefabricated buildings, and this model was widely used in public projects invested by the government, but it was still not commonly accepted in private projects [30]. Subsequently, the quality of prefabricated buildings has been improved significantly due to the Bureau's strict review of its supervision system [31]. In conclusion, most of the methods to stimulate prefabricated policy promotion in these countries focus on the construction units and aim at controlling the land instead of attracting developers through customers and making them take the initiative to create prefabricated buildings. Moreover, these mature policies which have not been tested in developing countries are mainly applicable to developed countries [32].

2.2. Factors Affecting the Promotion of Prefabricated Building Policies

The difficulties of promoting prefabricated building policies come from economics, management, technique and government, among which economic factors are widely focused on and researched by scholars. Vaccaro (2010) believed that price was not the only factor that could drive consumers' initiative, and investors' influence can also affect consumers' choices to a great extent [33]. In addition, government management plays a crucial role in policy promotion. The government can attract investors to invest in specific construction projects through tax relief and land price subsidies [34]. Moon (1997) found that when the government set standardized regulations in an industry, it could promote the industry's development, increase efficiency and save economy [35]. However, in most scholars' studies, too much attention was paid to the relationship between government departments and construction units. They believed that the supervision to construction

units would be beneficial to the safety and economy of the project. This method can indeed be motivational, but it can neither raise the enthusiasm nor promote the policy [36]. Some scholars have found that the developers play a greater influence on construction units than government departments because the government departments regulate behaviors but the developers make investments. What motivates construction units most is economic income, and only the investment of developers can fully mobilize their enthusiasm. If the relevant departments desire large investments in prefabricated buildings, in addition to the government's tax reduction and exemption policies for developers, they also need to mobilize the people's purchasing intention. Subsidies to the customers will accelerate the cycle of the entire interest chain [37–43]. Therefore, only by treating the government, construction units, developers, and the public as four independent strategic individuals in an overall cycle can we analyze how to promote policies more effectively [37–43].

3. Method and Model Building

3.1. Evolutionary Game Theory

Game theory can apply mathematical models to investigate and infer strategy choices among stakeholders [44]. Under certain assumptions, it can better address the strategy choices made by different individuals for their benefits under the conditions of cooperation and competition [45]. The theory can be divided into complete information game theory and incomplete information game theory according to the players' strategies and the completeness of the information [46].

Evolutionary game theory, developed from biological evolutionary theory, is a complement to game theory. Its strategies can replace mixed strategies in game theory by a percentage of group selection [47], which analyzes the different strategies adopted by individuals in the model [48,49].

According to the analysis of Section 2, the mode in this paper consists of five subjects. However, because the supervision company is considered as the agency of the government, the model of this paper is quadripartite evolutionary game model. The diagram is shown in Figure 2.

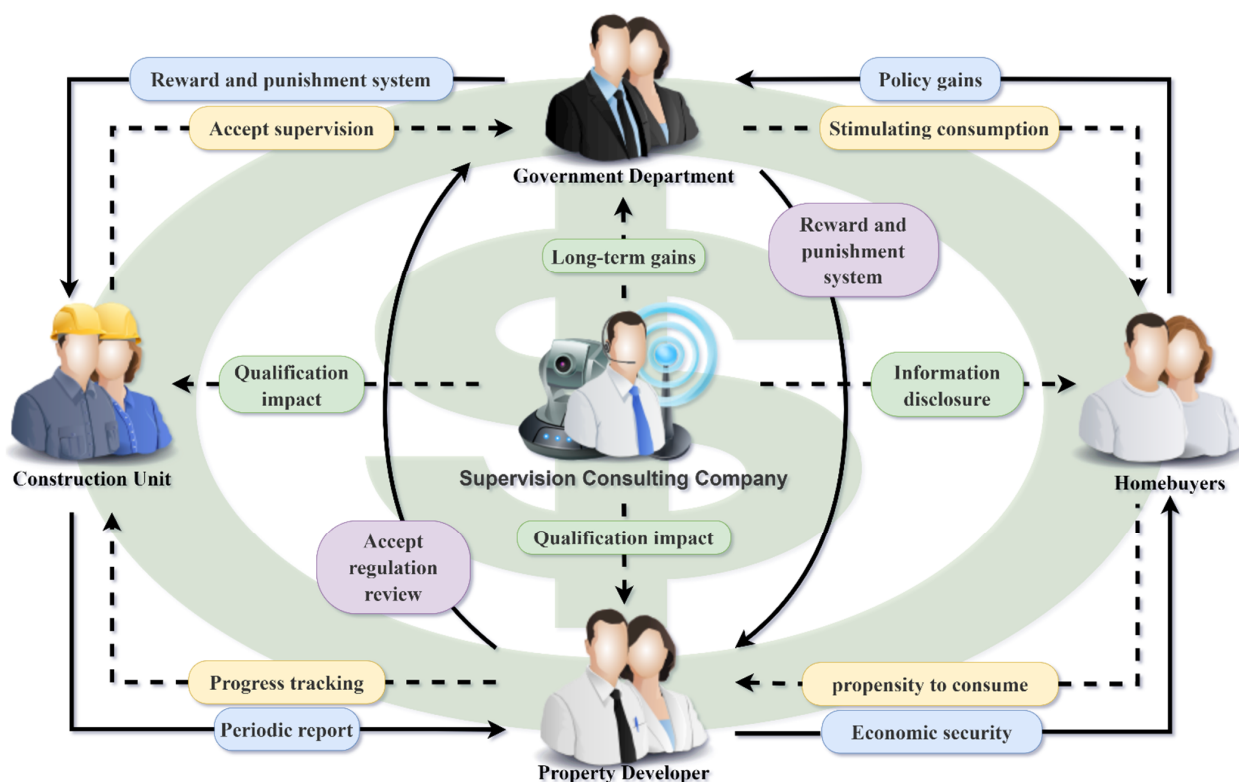


Figure 2. Quadripartite relationship diagram of government, construction unit, properly developer, and homebuyers.

3.2. Model Building

Model Hypotheses

In order to build a game model between various stakeholders that can release the overall construction evaluation and supervision report under the prefabricated building policy, and to study the quality control strategy of the government policy to promote construction under the feedback of the general public, the following hypotheses are made:

Hypothesis 1. *In this research, the government department, property developer, construction unit, and homebuyers are chosen as the subject of the game. The construction unit will make a construction quality periodic report (CQPR) that is sufficient and contains the corresponding construction rules with a probability of a to announce the quality and safety of the main project during the construction process. It will be called “Demonstration Project Periodic Quality Report”. It will also publish an incomplete CQPR with a probability of $1 - a$, called the “Unqualified Periodic Quality Report”. The CQPR submitted by the construction unit needs to be processed and released by a property developer. To ensure the compliance and authenticity of the report, the probability of a consulting supervision company reviewing the report of the construction unit is b , and the probability that the developer company will directly release the phase report of the construction unit is $1 - b$. The probability that the homebuyers evaluate CQPR then follow the policy through the authenticity is c , while the probability of directly believing in the report is $1 - c$. During the policy promotion, since the homebuyers are sensitive to quality reports related to prefabricated buildings, the probability that the government will supervise and conduct high-quality supervision of the construction unit as well as the reporting entities before CQPR release is e , and the probability of performing low-quality supervision, which can also be called lax supervision, is $1 - e$; $a, b, c, e \in [0, 1]$. Extending the hypothesis to the entire social group, the probability of each subject of the game can represent the proportion of a certain selection among the subjects. Among the four subjects in this study, they are risk-neutral and aim to maximize their interests.*

Hypothesis 2. *After the construction unit provides CQPR, it will receive comprehensive benefits of S , such as stage construction incentives, compliance construction revenue, and construction qualification enhancement. The construction unit needs to invest more in time, personnel arrangements, and construction quality inspection instruments purchases when conducting CQPR, and its cost is C_{ch} . The cost of incomplete CQPR is C_{cl} . Since the developers’ revenue is related to their attention in society, they release property information and quality reports actively to obtain advance payments from homebuyers during the policy promotion. The income relative to the construction investment is W , while the cost of validating CQPR is C_{ah} , and the cost without validation but of direct information processing and releasing is C_{al} . In China, the homebuyers make choices rely on the economic strength of developers. Suppose the influence of the developers is θ , $\theta \in [0, 1]$, which indicates that the information related to the construction project released by developers will be paid attention to by θ proportion of the homebuyers and influence their choices. The probability that the individual homebuyers are influenced by developers’ information is θ . Some individual homebuyers use personal social connections, consult relevant materials or field visits to identify the credibility of the information released by developers. The cost of identifying information is C_{yc} . The cost of strict supervision by the government department on the process of quality control is C_{gh} , and the cost of lax supervision is C_{gl} .*

Hypothesis 3. *CQPR that are strictly regulated and conform to the specifications have positive effects which are respectively P_g and P_y on the government’s policy promotion and the public’s trust in the government’s policy, while the confusing CQPR that do not conform to the technical specifications hurts the government and the public. The effects are respectively N_g and N_y .*

Hypothesis 4. *Under the promotion of prefabricated buildings, the government regulatory department can timely supervise and evaluate the possible social effects caused by low-quality and falsified CQPR, to restrict the release of such reports, then punish and lower the qualifications of construction the unit and developers, the punishment effects are D_c and D_d . In addition, the rectifi-*

cation is necessary. If the above measures can be implemented, the loss of social effects caused by the non-conforming CQPR will be reduced effectively.

Hypothesis 5. When low-quality and falsified CQPRs are released, some homebuyers report them to the government. Then the construction unit is ordered to make corrections, and the non-compliance has to be revised to pass the review. The qualification review needs to be re-declared, and the overall qualification effect loss is Q_c . On the other hand, the property developer will get a Q_d comprehensive benefit loss because of its tax deductions that cater to government policies and land purchase discounts, as well as the reduction of their influence on public platforms. According to Chinese policy, all large-scale projects' construction process should be supervised by a supervision consulting company. If homebuyers believe the low-quality and false CQPRs, they will be skeptical of the government's policies, thus leading to a long-term impact on social development and damaging the government's reputation. The possibility that a supervision consulting company discovering CQPR is ε . It can review the quality report, which reduces the loss of the homebuyers and the impact on the government's policy of promoting prefabricated buildings. However, it will still damage the construction unit's qualification and the reputation of the property developers. The positive effects on homebuyers and the government are I_y and I_g , respectively.

The quadripartite game payoff matrix of construction stage quality review under the supervision of the government and supervision consulting company is shown in Table 1 [47].

Table 1. Quadripartite game payoff matrix of construction stage quality supervision.

Construction Unit	Property Developer	Government Department Regulation			
		Strict Regulation e		Lax Regulation $1-e$	
		Homebuyers Subjective c	Homebuyers Blind $1-c$	Homebuyers Subjective c	Homebuyers Blind $1-c$
High-quality CQPR a	Reviewed Report b	$S - C_{ch}$ $W - C_{dh}$ $P_g - C_{gh}$ $P_y - C_{yc}$	$S - C_{ch}$ $W - C_{dh}$ $P_g - C_{gh}$ P_y	$S - C_{ch}$ $W - C_{dh}$ $P_g - C_{gl}$ $P_y - C_{yc}$	$S - C_{ch}$ $W - C_{dh}$ $P_g - C_{gl}$ P_y
	Unreviewed Reports $1-b$	$S - C_{ch}$ $W - C_{dl}$ $P_g - C_{gh}$ $P_y - C_{yc}$	$S - C_{ch}$ $W - C_{dl}$ $P_g - C_{gh}$ P_y	$S - C_{ch}$ $W - C_{dl}$ $P_g - C_{gl}$ $P_y - C_{yc}$	$S - C_{ch}$ $W - C_{dl}$ $P_g - C_{gl}$ P_y
Low-quality CQPR $1-a$	Reviewed Report b	$-C_{cl}$ $-C_{dh}$ 0 0	$-C_{cl}$ $-C_{dh}$ 0 0	$-C_{cl}$ $-C_{dh}$ 0 0	$-C_{cl}$ $-C_{dh}$ 0 0
	Unreviewed Reports $1-b$	$-C_{cl} - D_c$ $-C_{dl} - D_d$ $D_c + D_d - C_{gh}$ 0	$-C_{cl} - D_c$ $-C_{dl} - D_d$ $D_c + D_d - C_{gh}$ 0	$-C_{cl} - Q_c$ $-C_{dl} - Q_d$ $-C_{gl}$ $-C_{yc}$	$S - C_{cl} - \varepsilon D_c$ $W - C_{dl} - \varepsilon Q_d$ $-C_{gl} - N_g + \varepsilon I_g$ $-N_o + \varepsilon I_y$

3.3. Equilibrium Equation of Expected Benefits for Each Party

3.3.1. Revenue Equation of Construction Quality Control by the Construction Unit

According to the payoff matrix and hypothesis above, E_1 can be the average expected revenue of the construction unit, E_{11} can be the expected benefit when conducting a high-quality CQPR, and E_{12} can be the expected benefit when performing a low-quality CQPR. Therefore, the replication dynamic equation for the construction unit quality strategy is shown below:

$$E_{11} = \theta(S - C_{ch}) \quad (1)$$

$$E_{12} = \theta\{(1-b)(1-c)(1-e)S - C_{cl} - (1-b)eD_c - (1-b)(1-e)[c + (1-c)\varepsilon]Q_c\} \quad (2)$$

$$\begin{aligned}
 E_1 &= aE_{11} + (1-a)E_{12} \\
 &= a\theta(S - C_{ch}) \\
 &\quad + (1-a)\theta\{(1-b)(1-c)(1-e)S - C_{cl} - (1-b)dD_c - (1-b)(1-e)[c + (1-c)\varepsilon]Q_c\}
 \end{aligned} \quad (3)$$

$$\begin{aligned}
 F(a) = da/dt &= a(E_{11} - E_1) \\
 &= (a - a^2)\{S[1 - (1-b)(1-c)(1-e)] + Q_c[c + \varepsilon(1-c)](1-b)(1-e) + (1-b)eD_c \\
 &\quad - C_{ch} + C_{cl}\}\theta
 \end{aligned} \quad (4)$$

3.3.2. Revenue Equation of Property Developers' Review and Regulation

According to the payoff matrix and hypothesis above, E_2 can be considered as the average expected revenue of property developers, E_{21} as the expected benefit when the report is reviewed, and E_{22} as the expected benefit when the report is not checked. Therefore, the replication dynamic equation for the construction unit quality strategy is shown below:

$$E_{21} = \theta(aW - C_{dh}) \quad (5)$$

$$E_{22} = \theta\{[a + (1-a)(1-c)(1-e)W] - (1-a)(1-e)[c + (1-c)\varepsilon]Q_d - (1-a)eD_d - C_{dl}\} \quad (6)$$

$$\begin{aligned}
 E_2 &= bE_{21} + (1-b)E_{22} \\
 &= b\theta(aW - C_{dh}) \\
 &\quad + (1-b)\theta\{[a + (1-a)(1-c)(1-e)W] - (1-a)(1-e)[c + (1-c)\varepsilon]Q_d \\
 &\quad - (1-a)dD_d - C_{dl}\}
 \end{aligned} \quad (7)$$

$$\begin{aligned}
 F(b) = db/dt &= b(E_{21} - E_2) \\
 &= (b - b^2)\{Q_d(1-a)(1-e)[c + (1-c)\varepsilon] + e(1-a)D_d - W(1-a)(1-c)(1-e) \\
 &\quad + C_{dl} - C_{dh}\}\theta
 \end{aligned} \quad (8)$$

3.3.3. Revenue Equation of Homebuyers' Selections

According to the payoff matrix and hypothesis above, E_3 can be defined as the average expected revenue of homebuyers, E_{31} as the expected benefit when homebuyers are skeptical of CQPR, and E_{32} as the expected benefit when homebuyers trust it. Therefore, the replication dynamic equation for the construction unit quality strategy is shown below:

$$E_{31} = [a(P_y - C_{yc}) - C_{yc}(1-a)(1-b)(1-e)]\theta \quad (9)$$

$$E_{32} = [aP_y - (N_y - \varepsilon I_y)(1-a)(1-b)(1-e)]\theta \quad (10)$$

$$\begin{aligned}
 E_3 &= cE_{31} + (1-c)E_{32} \\
 &= c\theta[aP_y - (1+a)(1-a)(1-b)(1-e)C_{yc}] \\
 &\quad + (1-c)\theta[aP_y - (1+a)(1-a)(1-b)(1-e)(N_y - \varepsilon I_y)]
 \end{aligned} \quad (11)$$

$$F(c) = dc/dt = c(E_{31} - E_3) = (c - c^2)[(1-a)(1-b)(1-e)(N_y - \varepsilon I_y - C_{yc}) - aC_{yc}]\theta \quad (12)$$

3.3.4. Revenue Equation of Government Department's Regulatory Strategies

According to the payoff matrix and hypothesis above, E_4 can be regarded as the average expected revenue of government department's regulation, E_{41} as the expected benefit under strict regulation, and E_{42} as the expected benefit under lax regulation. Therefore, the replication dynamic equation for the construction unit quality strategy is shown below:

$$E_{41} = [a(P_g - C_{gh}) - (D_c - D_h - C_{gh})(1-a)(1-b)]\theta \quad (13)$$

$$E_{42} = [a(P_g - C_{gl}) - C_{gl}(1-a)(1-b) + (\varepsilon I_g - N_g)(1-a)(1-b)(1-c)]\theta \quad (14)$$

$$\begin{aligned}
 E_4 &= dE_{41} + (1-e)E_{42} \\
 &= e\theta \left[a(P_g - C_{gh}) - (D_c - D_h - C_{gh})(1-a)(1-b) \right] \\
 &\quad + (1-e)\theta \left[a(P_g - C_{gl}) - C_{gl}(1-a)(1-b) + (\varepsilon I_g - N_g)(1-a)(1-b)(1-c) \right]
 \end{aligned} \quad (15)$$

$$\begin{aligned}
 F(e) &= dd/dt = e(E_{41} - E_4) \\
 &= (e - e^2) \left\{ (C_{gl} - C_{gh})(a + (1-a)(1-b)) \right. \\
 &\quad \left. + (1-a)(1-b)[D_c + D_d + (1-c)(N_g - \varepsilon I_g)] \right\} \theta
 \end{aligned} \quad (16)$$

3.4. Analysis of Stability of Each Party's Revenue Equation

3.4.1. Analysis of Stability of Quality Control Conducted by the Construction Unit

The derivative for the replicated dynamic equation above is shown in Equation (17). According to the stability of the differential equation, only when $F(a) = 0$ and $F'(a) < 0$, that the construction unit controls the quality in the construction process can be stable.

$$F'(a) = (1-2a) \{ S[1 - (1-b)(1-c)(1-e)] + Q_c[c + \varepsilon(1-c)](1-b)(1-e) + (1-b)eD_c - C_{ch} + C_{cl} \} \theta \quad (17)$$

There exists an initial value of c_0 . When $c < c_0$, the construction unit reaches a stable state by issuing a low-quality CQPR; When $c > c_0$, the construction unit comes a steady-state by giving a high-quality CQPR; When $c = c_0$, the stable state of the construction unit is uncertain. Wherein the threshold value of $c_0 = -\{S[1 - (1-b)(1-e)] + \varepsilon Q_c(1-b)(1-e) + (1-b)eD_c - C_{ch} + C_{cl}\} / Q_c(1-\varepsilon)(1-b)(1-e) + S(1-b)(1-e)$.

If,

$$K(c) = S[1 - (1-b)(1-c)(1-e)] + Q_c[c + \varepsilon(1-c)](1-b)(1-e) + (1-b)eD_c - C_{ch} + C_{cl},$$

and because $\partial K(c) / \partial c > 0$, the function is monotonically increasing. When $c < c_0$, it shows that $K(c) < 0$, $F(a)|_{a=0} = 0$ and $F'(a)|_{a=0} < 0$, which proves that $a = 0$ has stability; When $c > c_0$, it shows that $K(c) > 0$, $F(a)|_{a=1} = 0$ and $F'(a)|_{a=1} < 0$, which proves that $a = 1$ has stability; When $c = c_0$, it shows that $K(c) = 0$, $F(a) = 0$ and $F'(a) = 0$. So when $a \in [0, 1]$, all of them have stability, but the strategy cannot be decided. According to the inferences above, the strategy selection phase diagram of construction unit is shown in Figure 3:

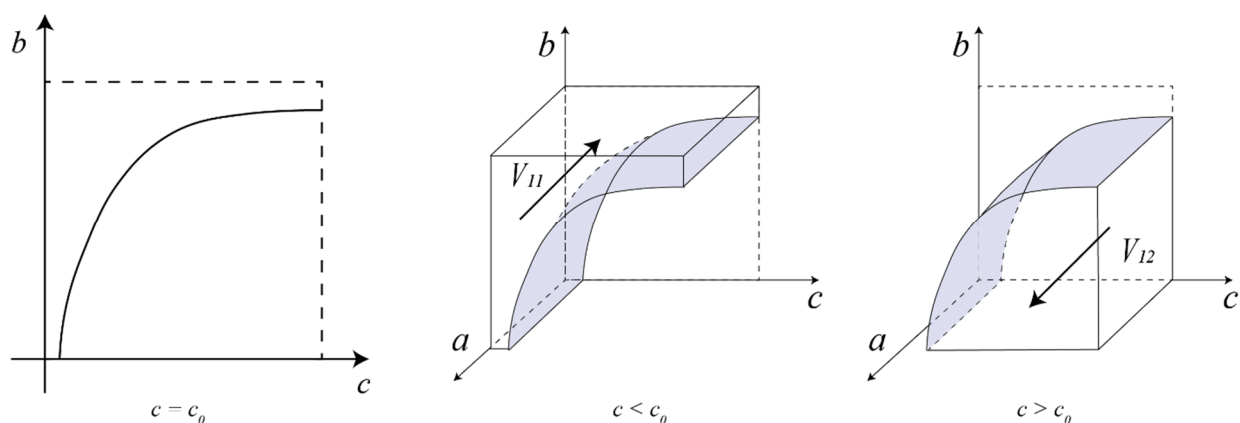


Figure 3. Strategy selection phase diagram of construction unit.

In the figure, the construction unit's strategy choices are segmented by a curved surface. V_{11} represents the probability of high-quality control, and V_{12} represents the prob-

ability of low-quality control. The probability can be derived from the value of the double integral of the formula c_0 . The volume in the figure is the value of the double integral.

$$V_{11} = \int_0^1 \int_0^1 \{C_{ch} + S(1-d) - c(1-d)(S + Q_c - \varepsilon Q_c) - S - C_{cl} / [S(1-d) - c(1-d)(S + Q_c - \varepsilon Q_c)]\} dadc \quad (18)$$

$$= 1 - \ln \frac{(1-e)(\varepsilon Q_c - S)}{eD_c + (1-e)Q_c} \frac{S - C_{ch} + C_{cl}}{(1-e)[S + Q_c(1-\varepsilon)]}$$

$$V_{12} = 1 - V_{11} = \ln \frac{(1-e)(\varepsilon Q_c - S)}{eD_c + (1-e)Q_c} \frac{S - C_{ch} + C_{cl}}{(1-e)[S + Q_c(1-\varepsilon)]} \quad (19)$$

Under the promotion of the policy, if homebuyers can make judgments based on their will and prevent them from being interfered by cluttered information, the losses caused by quality problems of houses can be avoided. If the construction unit provides low-quality CQPRs on its construction quality control, it will lose revenue, and its construction qualification will be reduced. Therefore, with the rising of homebuyers' subjectivity, the construction unit should implement the stabilization strategy by providing high-quality CQPRs. During the policy promotion, a government-supervised supervision system should be established, and the homebuyers are encouraged to inquire about relevant information to investigate on their own. The strategy should be determined when the construction unit provides high-quality periodic reports.

Homebuyers are easily influenced by the promotion of the construction unit and the property developer. Affected by the reputation of the contractor, most people follow it blindly instead of verifying the relevant information. It follows that the government should establish a monitoring system to encourage prefabricated buildings constructions. In the meantime, it should also strengthen the review, and encourage homebuyers to defend their rights. Besides, faulty construction units should be warned to avoid safety accidents and economic losses caused by jerry-building and other behaviors.

3.4.2. Analysis of Stability of Regulatory Control of Property Developers

The derivative for the replicated dynamic equation above is shown in Equation (20). According to the stability of the differential equation, it follows that when $F(b) = 0$ and $F'(b) < 0$, developers can be stable for quality supervision during construction.

$$F'(b) = (1-2b)\{Q_d(1-a)(1-e)[c + (1-c)\varepsilon] + e(1-a)D_d - W(1-a)(1-c)(1-e) + C_{dl} - C_{dh}\}\theta \quad (20)$$

There exists an initial value of e_0 . When $e < e_0$, property developers achieve a stable state without review of CQPR; When $e > e_0$, property developers achieve a stable state with review of CQPR; When $e = e_0$, the stable state of construction unit is uncertain. Wherein the threshold value of $e_0 = [C_{dh} - C_{dl} + (1-a)(1-c)W - (1-a)[c + (1-c)\varepsilon]Q_d] / \{(1-a)(1-c)W + (1-a)D_d - (1-a)[c + (1-c)\varepsilon]Q_d\}$. If, $L(e) = (1-a)(1-e)[(c + \varepsilon - c\varepsilon)Q_d - (1-c)W + Q_d(1-c)e + C_{dl} - C_{dh}]$, and because $\partial L(e)/\partial e > 0$, the function is monotonically increasing. When $e < e_0$, it shows that $L(e) < 0$, $F(b)|_{b=0} = 0$ and $F'(b)|_{b=0} < 0$, which proves that $b = 0$ has stability; When $e > e_0$, it shows that $L(e) > 0$, $F(b)|_{b=1} = 0$ and $F'(b)|_{b=1} < 0$, which proves that $b = 1$ has stability; When $e = e_0$, it shows that $L(e) = 0$, $F(b) = 0$ and $F'(b) = 0$. So when $b \in [0, 1]$, all of them have stability, but the strategy cannot be decided. According to the inferences above, the strategy selection phase diagram of property developers is shown in Figure 4:

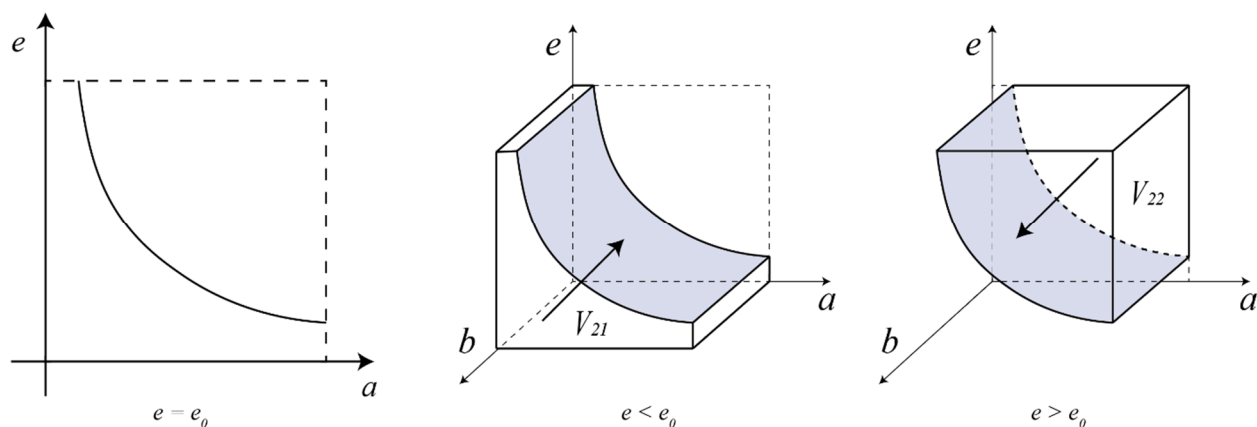


Figure 4. Strategy selection phase diagram of property developers.

In the figure, the property developers' strategy choices are segmented by a curved surface. V_{21} represents the probability with review, and V_{22} represents the probability without review. The probability can be derived from the value of the double integral of the formula e_0 . The volume in the figure is the value of the double integral.

$$V_{21} = \int_0^1 \int_0^1 \frac{C_{dl} - C_{dh} + D_d(1-a)}{W(1-a)(1-c) + D_d(1-a) - (1-a)(\epsilon - \epsilon c + c)Q_d} da db = \frac{\ln a(C_{dl} - C_{dh}) + aD_d}{W(1-c) + D_d - Q_d(\epsilon - \epsilon c + c)} \quad (21)$$

$$V_{22} = 1 - V_{21} = 1 + \frac{[\ln a(C_{dl} - C_{dh}) + aD_d]}{[W(1-c) + D_d - Q_d(\epsilon - \epsilon c + c)]} \quad (22)$$

According to the phase diagram, when property developers promote widely and rank in the domestic market, the government punishment and corporate reputation loss will increase if they relax their quality supervision reviews. If some homebuyers suffer economic losses due to the deregulation of the developers, they will lose faith in government's policies, which will adversely affect the government's long-term benefits. Therefore, government departments should set up a punishment mechanism to effectively improve the strictness of the review of CQPRs by the developers. In addition, developers will review CQPRs more strictly because of the losses of reputation. The probability of the buyer's economic losses will be reduced so that the long-term benefits of the government will also be compensated.

3.4.3. Analysis of Stability of Homebuyers' Selections

The derivative for the replicated dynamic equation above is shown in Equation (23). According to the stability of the differential equation, it follows that when $F(c) = 0$ and $F'(c) < 0$, the developers' quality supervision of the construction process can be stable.

$$F'(c) = (1 - 2c)[(1 - a)(1 - b)(1 - e)(N_y - \epsilon I_y - C_{yc}) - aC_{yc}]\theta \quad (23)$$

There exists an initial value of b_0 , when $b < b_0$, the homebuyers can review the developers' promotion and quality reports subjectively, and can achieve a stable state by field exploration and inquiring about relevant information; When $b > b_0$, homebuyers blindly follow the developers' promotion and quality reports to achieve a stable state; When $b = b_0$, the stable state of the homebuyers cannot be determined. Wherein the threshold value of $b_0 = 1 - aC_{yc} / [(N_y - C_{yc} - \epsilon I_y)(1 - a)(1 - e)]$.

If $(b) = (1 - a)(1 - b)(1 - e)(N_y - \epsilon I_y - C_{yc}) - aC_{yc}$, and because $\partial M(b)/\partial b < 0$, the function is monotonically decreasing. When $b < b_0$, it shows that $M(b) > 0$, $F(c)|_{c=1} = 0$ and $F'(c)|_{c=1} < 0$, which proves that $c = 1$ has stability; When $b > b_0$, it shows that $M(b) < 0$, $F(c)|_{c=0} = 0$ and $F'(c)|_{c=0} < 0$, which proves that $b = 0$ has stability; When $b = b_0$, it shows that $M(b) = 0$, $F(c) = 0$ and $F'(c) = 0$. So when $c \in [0, 1]$, all of them have

stability, but the strategy cannot be decided. According to inferences above, the strategy selection phase diagram of homebuyers is shown in Figure 5:

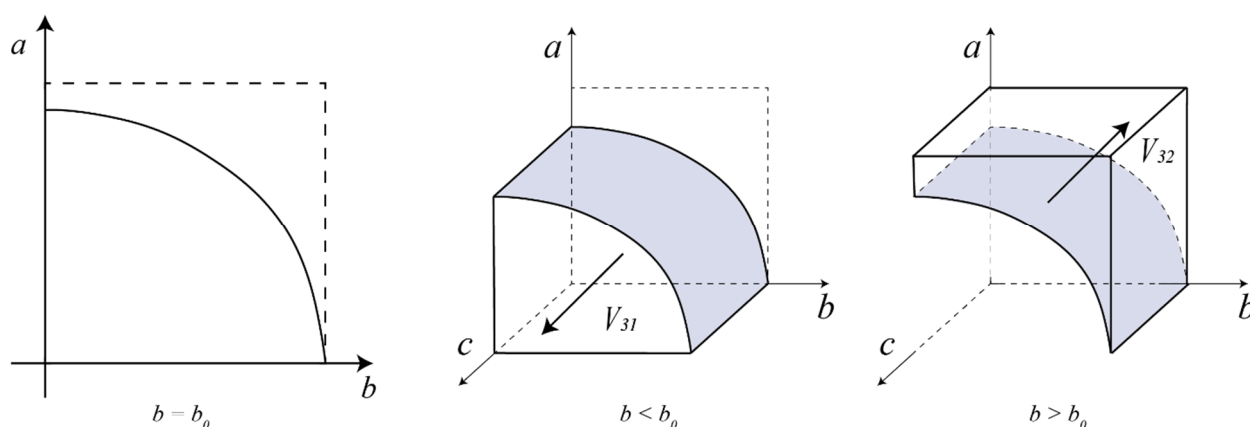


Figure 5. Strategy selection phase diagram of homebuyers.

In the figure, homebuyers' strategy selections are segmented by a curved surface. a represents the probability of reviewing the reports and promotional information subjectively, and V_{31} represents the probability of reviewing the reports and promotional information subjectively, and V_{32} represents the probability of not censoring the information released by the developer. The probability can be derived from the value of the double integral of the formula b_0 . The volume in the figure is the value of the double integral.

$$V_{31} = \int_0^1 \int_0^1 1 - \frac{aC_{yc}}{(N_y - C_{yc} - \varepsilon I_y)(1-a)(1-e)} da dc = a + \frac{a \ln(1-a)C_{yc}}{(N_y - C_{yc} - \varepsilon I_y)(1-e)} \quad (24)$$

$$V_{32} = 1 - V_{31} = 1 - a - \frac{a \ln(a-1)C_{yc}}{(N_y - C_{yc} - \varepsilon I_y)(1-e)} \quad (25)$$

According to the phase diagram, if developers control the construction process strictly, the CQPR will attract more purchasers. The growth of homebuyers will increase the developers' influence, thus gradually increasing the buyer's trust in the information released by the developer, which drastically reduces the cost of information verification and field surveys. However, suppose the developers are more likely to not control the developers' CQPRs. In that case, there is a greater probability of causing homebuyers' economic losses, cutting down developers' influences. The probability of subjective discernment among the homebuyers rises substantially, eventually stabilizing into a distrustful attitude towards the developer's information. As a result, the number of homebuyers decreases, and the benefits to developers are also reduced.

3.4.4. Analysis of Stability of Government Supervision Decision

The derivative for the replicated dynamic equation above is shown in Equation (26). According to the stability of the differential equation, it follows that when $F(e) = 0$ and $F'(e) < 0$, the developers' quality supervision during the construction can be stable.

$$F'(e) = (1-2e)\{(C_{gl} - C_{gh})(a + (1-a)(1-b)) + (1-a)(1-b)[D_c + D_d + (1-c)(N_g - \varepsilon I_g)]\}\theta \quad (26)$$

Since the government regulation is closely related to homebuyers, there exists an initial value of c_1 . When $c < c_1$, the government reaches the steady state by strict regulations; When $c > c_1$, the stable state realized by lax regulations; When $c = c_1$, the stable state cannot be determined. Wherein the threshold value of $c_1 = 1 - \left\{ (1-a)(1-b)(D_c + D_d) + (C_{gl} - C_{gh})[a + (1-a)(1-b)] \right\} / [(1-a)(1-b)(N_g - \varepsilon I_g)]$.

If $(b) = (C_{gl} - C_{gh})(a + (1-a)(1-b)) + (1-a)(1-b)[D_c + D_d + (1-c) \cdot (N_g - \varepsilon I_g)]$, and because $\partial N(c)/\partial c < 0$, the function is monotonically decreasing. When $c < c_1$,

it shows that $N(c) > 0, F(e)|_{e=1} = 0$ and $F'(e)|_{e=1} < 0$, which proves that has stability; When $c > c_1$, it shows that $N(b) < 0, F(e)|_{e=0} = 0$ and $F'(e)|_{e=0} < 0$, which proves that $e = 0$ has stability; When $c = c_1$, it shows that $N(b) = 0, F(e) = 0$ and $F'(e) = 0$. When $e \in [0, 1]$, all of them have stability, but the strategy cannot be decided. According to above inferences, the strategy selection phase diagram of the government is shown in Figure 6:

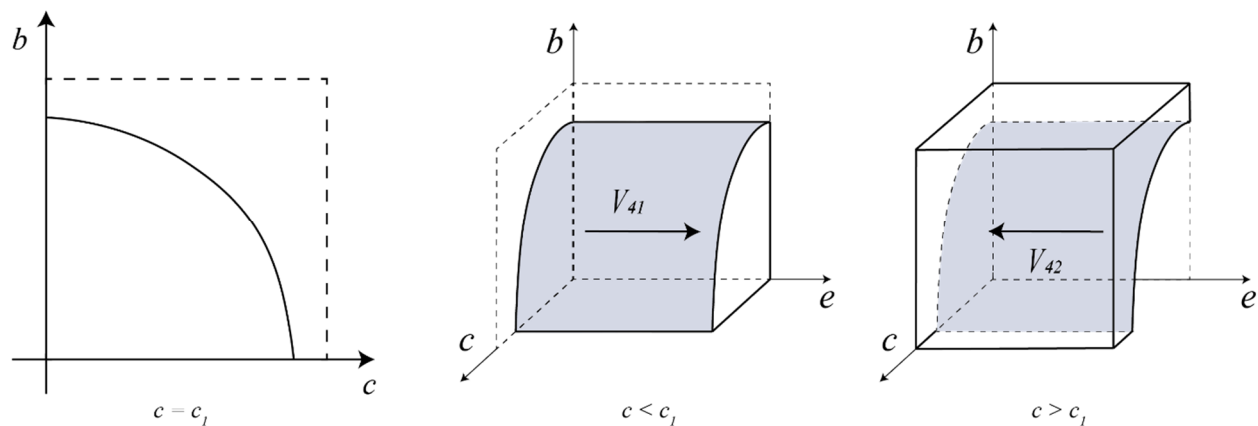


Figure 6. Strategy selection phase diagram of the government.

In the figure, the government's strategy selections are segmented by a curved surface. V_{41} represents the probability of performing subjective review of the reports and promotional information, and V_{42} represents the probability of not censoring the information released by the developer. The probability can be derived from the value of the double integral of the formula c_1 . The volume in the figure is the value of the double integral.

$$V_{41} = \int_0^1 \int_0^1 1 - \frac{(1-a)(1-b)(D_c + D_d) + (C_{gl} - C_{gh})[a + (1-a)(1-b)]}{(1-a)(1-b)(N_g - \epsilon I_g)} db de \quad (27)$$

$$= \frac{b[(1-a)(D_c + D_d) + (C_{gl} - C_{gh}) - (1-a)(N_g - \epsilon I_g)]}{(1-a)(N_g - \epsilon I_g)}$$

$$V_{42} = 1 - V_{31} = 1 - \frac{b[(1-a)(D_c + D_d) + (C_{gl} - C_{gh}) - (1-a)(N_g - \epsilon I_g)]}{(1-a)(N_g - \epsilon I_g)} \quad (28)$$

During the promotion of government policies, if the homebuyers get economic losses due to misinformation, the government will have a long-term loss of social returns. If the subjectivity of the owners increases, it will reduce the loss of social benefits, and the government will correspondingly reduce the strict supervision, which can save costs. It can be concluded that the government's regulation determines its social returns. The construction quality problems should be timely regulated and announced to avoid the social damage caused by greater economic loss to the homebuyers. Additionally, the relevant responsibility chain should be punished to prevent severer safety accidents and financial losses.

4. Results

4.1. Solution to Equilibrium Points of Evolutionary Game Model

According to the replication dynamic equation above, a quadripartite evolutionary game replication dynamic system consisting of government department, construction unit, property developers and homebuyers can be derived, and the Jacobian matrix [50] of the replication dynamic system is shown in Equation (29):

$$J = \begin{bmatrix} \frac{\partial F(a)}{\partial a} & \frac{\partial F(a)}{\partial b} & \frac{\partial F(a)}{\partial c} & \frac{\partial F(a)}{\partial e} \\ \frac{\partial F(b)}{\partial a} & \frac{\partial F(b)}{\partial b} & \frac{\partial F(b)}{\partial c} & \frac{\partial F(b)}{\partial e} \\ \frac{\partial F(c)}{\partial a} & \frac{\partial F(c)}{\partial b} & \frac{\partial F(c)}{\partial c} & \frac{\partial F(c)}{\partial e} \\ \frac{\partial F(e)}{\partial a} & \frac{\partial F(e)}{\partial b} & \frac{\partial F(e)}{\partial c} & \frac{\partial F(e)}{\partial e} \end{bmatrix} \quad (29)$$

The model reaches stability and stops evolving when the replication dynamic equation equals to 0. That is $F(a) = 0, F(b) = 0, F(c) = 0, F(e) = 0$; The corresponding equilibrium points (a, b, c, e) are

$$E_1 = (0, 0, 0, 0), E_2 = (1, 0, 0, 0), E_3 = (0, 1, 0, 0), E_4 = (0, 0, 1, 0), E_5 = (0, 0, 0, 1), E_6 = (1, 1, 0, 0), E_7 = (1, 0, 1, 0), E_8 = (1, 0, 0, 1), E_9 = (0, 1, 1, 0), E_{10} = (0, 1, 0, 1), E_{11} = (0, 0, 1, 1), E_{12} = (0, 1, 1, 1), E_{13} = (1, 0, 1, 1), E_{14} = (1, 1, 0, 1), E_{15} = (1, 1, 1, 0), E_{16} = (1, 1, 1, 1).$$

The eigenvalues of the Jacobian matrix are $\lambda_{11} = \partial F(a)/\partial a, \lambda_{22} = \partial F(b)/\partial b, \lambda_{33} = \partial F(c)/\partial c, \lambda_{44} = \partial F(e)/\partial e$. In this paper, the regulations of government department are the essential conditions, and the equilibrium point is determined by the condition shown in Equation (30):

$$\begin{cases} (C_{gl} - C_{gh})(a + (1-a)(1-b)) + (1-a)(1-b)[D_c + D_d + (1-c)(N_g - \varepsilon I_g)] < 0 & \textcircled{1} \\ (C_{gl} - C_{gh})(a + (1-a)(1-b)) + (1-a)(1-b)[D_c + D_d + (1-c)(N_g - \varepsilon I_g)] > 0 & \textcircled{2} \\ C_{cl} - C_{ch} + \varepsilon Q_c < 0 & \textcircled{3} \\ N_y - C_{yc} - \varepsilon I_y < 0 & \textcircled{4} \\ C_{ch} - C_{cl} - \varepsilon Q_c < 0 & \textcircled{5} \end{cases} \quad (30)$$

The point is called ‘Evolutionary Stability Strategy’(ESS) [48] point only when all the eigenvalues are negative, which means the dynamic evolution is stable. In this paper, the analysis of the value and stability condition of equilibrium point in replication dynamic system of quadripartite evolutionary game are shown in Tables 2 and 3.

Table 2. ESS of quadripartite evolutionary game replicated dynamic system.

Equilibrium Point	λ_{11}	λ_{22}	λ_{33}	λ_{44}
E_1	$(C_{cl} - C_{ch} + \varepsilon Q_c)\theta$	$(C_{dl} - C_{dh} + \varepsilon Q_d - W)\theta$	$(N_y - C_{yc} - \varepsilon I_y)\theta$	$(C_{gl} - C_{gh} - \varepsilon I_g + N_g + D_c + D_d)\theta$
E_2	$(C_{ch} - C_{cl} - \varepsilon Q_c)\theta$	$(C_{dl} - C_{dh})\theta$	$-C_{yc}\theta$	$(C_{gl} - C_{gh})\theta$
E_3	$(C_{cl} - C_{ch} + S)\theta$	$(C_{dh} - C_{dl} - \varepsilon Q_d + W)\theta$	0	0
E_4	$(C_{cl} - C_{ch} + S + Q_c)\theta$	$(C_{dl} - C_{dh} + \varepsilon Q_d)\theta$	$(C_{yc} - \varepsilon I_y - N_y)\theta$	$(C_{gl} - C_{gh} + D_c + D_d)\theta$
E_5	$(C_{cl} - C_{ch} + S + D_c)\theta$	$(C_{dl} - C_{dh} + Q_d)\theta$	0	$(C_{gh} - C_{gl} + \varepsilon I_g - N_g - D_c - D_d)\theta$
E_6	$(C_{ch} - C_{cl} - S)\theta$	$(C_{dh} - C_{dl})\theta$	$-C_{yc}\theta$	$(C_{gl} - C_{gh})\theta$
E_7	$(C_{ch} - C_{cl} - S - Q_c)\theta$	$(C_{dl} - C_{dh})\theta$	$C_{yc}\theta$	$(C_{gl} - C_{gh})\theta$
E_8	$(C_{ch} - C_{cl} - S - D_c)\theta$	$(C_{dl} - C_{dh})\theta$	$-C_{yc}\theta$	$(C_{gh} - C_{gl})\theta$
E_9	$(C_{cl} - C_{ch} + S)\theta$	$(C_{dh} - C_{dl} - Q_d)\theta$	0	0
E_{10}	$(C_{cl} - C_{ch} + S)\theta$	$(C_{dh} - C_{dl} - D_d)\theta$	0	0
E_{11}	$(C_{cl} - C_{ch} + S + D_c)\theta$	$(C_{dl} - C_{dh} + Q_d)\theta$	0	$(C_{gh} - C_{gl} - D_c - D_d)\theta$
E_{12}	$(C_{cl} - C_{ch} + S)\theta$	$(C_{dh} - C_{dl} - D_d)\theta$	0	0
E_{13}	$(C_{ch} - C_{cl} - S - D_c)\theta$	$(C_{dl} - C_{dh})\theta$	$C_{yc}\theta$	$(C_{gh} - C_{gl})\theta$
E_{14}	$(C_{ch} - C_{cl} - S)\theta$	$(C_{dh} - C_{dl})\theta$	$-C_{yc}\theta$	$(C_{gh} - C_{gl})\theta$
E_{15}	$(C_{ch} - C_{cl} - S)\theta$	$(C_{dh} - C_{dl})\theta$	$C_{yc}\theta$	$(C_{gl} - C_{gh})\theta$
E_{16}	$(C_{ch} - C_{cl} - S)\theta$	$(C_{dh} - C_{dl})\theta$	$C_{yc}\theta$	$(C_{gh} - C_{gl})\theta$

Table 3. Analysis of stable condition of ESS of quadripartite evolutionary game replicated dynamic system.

Equilibrium Point	λ_{11}	λ_{22}	λ_{33}	λ_{44}	Stable Situation	Stable Condition
E_1	$\mp$	—	$\mp$	—	ESS	match condition③④
E_2	$\mp$	—	—	—	ESS	match condition⑤
E_3	+	$\mp$	0	0	Unstable	
E_4	+	+	$\mp$	+	—	Not match condition①, non-existent
E_5	+	+	0	$\mp$	Unstable	
E_6	—	+	—	—	Unstable	
E_7	—	—	+	—	Unstable	
E_8	—	—	—	+	**	Not match condition②, non-existent
E_9	+	—	0	0	Unstable	
E_{10}	+	—	0	0	Unstable	
E_{11}	+	+	0	—	Unstable	
E_{12}	+	—	0	0	Unstable	
E_{13}	—	—	+	+	**	Not match condition②, non-existent
E_{14}	—	+	—	+	**	Not match condition②, non-existent
E_{15}	—	+	+	—	Unstable	
E_{16}	—	+	+	+	**	Not match condition②, non-existent

Notes: ' $\mp$ ' indicates the positive or negative sign cannot be determined; '—' and '**' means the precondition is not satisfied.

It can be seen from Tables 2 and 3 that E_1 and E_2 are possible stable strategies. E_1 refers to the situation where the construction units produce and report safely, the property developers' information is transparent, the government's supervision is relaxed, and the homebuyers are deeply affected by the information. If the four parties choose such strategies, the social surplus value will reach the highest. The situation of E_2 is different. When E_2 satisfies $N_y - C_{yc} - \varepsilon I_y < 0$, because there is a supervision consulting company that can adequately handle the low-quality CQPR of the construction unit, all parties will tend to a stable state. During the policy promotion, if the government's supervision is not strict, it will invalidate the promotion and reduce the trust of the homebuyers in the government, which is hard to form long-term social benefits. Therefore, the government should establish a sound system with third-party supervision to make high-quality CQPRs on construction quality a stable strategy for construction units. When the government implements strict supervision, there are no equilibrium points. The analysis of E_8 , E_{13} , E_{14} , and E_{16} shows that effective warnings and punishments will reduce the damage to social benefits caused by the construction units' low-quality reports, leading to an excellent social environment.

4.2. Simulation Analysis of Quadripartite Evolutionary Game

In order to reflect the influence of parameters on the evolutionary game process and results in the dynamic replication system more directly. MATLAB (R2016b, MathWork, Natick, MA, USA) software is used to perform numerical simulations in the evolutionary game model.

4.2.1. Parameter Setting

According to the above assumptions and analysis, this section reviews and summarizes many works of literature in terms of parameter determination. In addition, we made on-the-spot investigations on the prefabricated buildings of Chengxiang Construction Company, the prefabricated buildings of Chengdu Metro Building of China Construction Third Bureau, and the surface prefabricated buildings of Wuhan Municipal East Lake Deep Drainage Tunnel, and interviewed the project leaders to determine the initial parameter values according to the analysis results.

The probability of initial selection strategy for each player is $a = 0.5$, $b = 0.3$, $c = 0.3$, $e = 0.2$; Changes in P_g and P_y parameters do not affect replicating dynamic equations after reduction, so they are not set or discussed. The specific parameter settings are shown in Table 4.

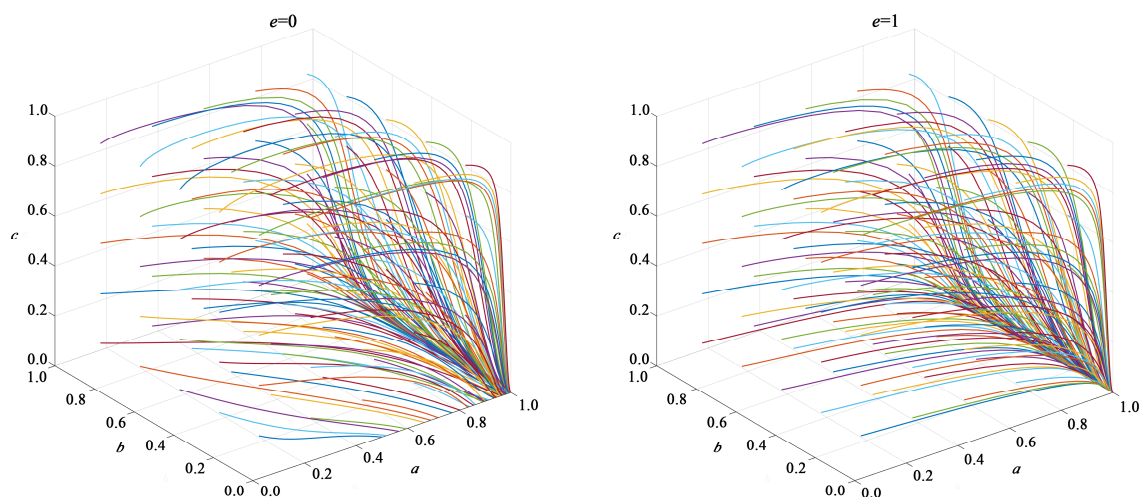
Table 4. Model parameter setting.

Parameter	Initial Value	Parameter	Initial Value	Parameter	Initial Value
a	0.5	b	0.3	c	0.3
e	0.2	C_{ch}	10	C_{cl}	2
C_{dh}	5	C_{dl}	1	C_{gh}	6
C_{gl}	1	S	22	W	12
D_c	10	D_d	6	C_{yc}	10
Q_c	25	Q_d	15	N_y	12
N_g	20	I_y	5	I_g	10
θ	0.7	ε	0.3	-	-

4.2.2. Impact of Government Supervision System on the Other Three Subjects under Policy Promotion

For the purpose of finding out whether the regulation system of the government has a significant impact on the other three parties under the promotion of the prefabricated building policy, the probability of total lax supervision is set to be $e = 0$ and government tracking supervision to be $e = 1$. The following is the numerical simulation result:

According to the Figure 7, when the government regulation system is not established ($e = 0$), the strategy selections of the construction unit and developers are unstable because there are no punishments and no constraints on the bidding qualifications for future projects. After the completion of the phase construction, they will not choose a high-quality safety acceptance plan to maximize the benefits; that is, the construction unit strives to start the following construction quickly, and the developers pursue to release influential promotion information swiftly. When the government establishes a sound quality tracking system ($e = 1$) punishments will be imposed for violations and the bidding qualifications will be reduced. Therefore, the construction unit pays more attention to construction quality and safety, and developers care more about the review of the construction unit, which maintains specific stability and is partly in line with the equilibrium point analysis.

**Figure 7.** The influence of government's regulatory system on the other three subjects under policy promotion.

4.2.3. Impact of Government's Punishments for Different Subjects

Change the government's punishments for the construction unit and developers, and set up three scenarios: (1) $\Delta_1 = -2$; (2) $\Delta_2 = 0$; (3) $\Delta_3 = 2$. The process of the quadripartite strategy evolutionary game under the government punishments mechanism is shown in Figure 8:

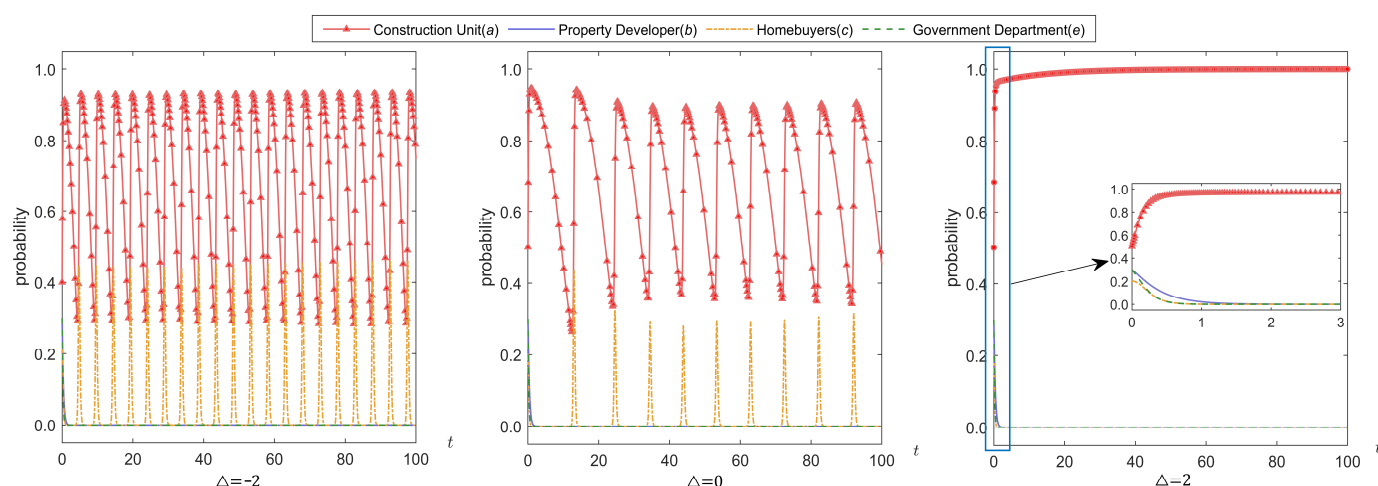


Figure 8. Process of the quadripartite strategy evolutionary game under the government punishment mechanism.

When the government increases punishment for insecurity and dishonesty, construction units will follow the rules and regulations. Gradually, developers and the government will lower the review requirements. Finally, the supervision mechanism will be canceled and homebuyers will fully believe in the developers' promotion and information disclosure system. When the government mitigates the punishment, the construction unit and property developers will gradually take risks to implement low-quality control of construction, and the homebuyers will make subjective judgments.

4.2.4. Impact of Costs of Strict Quality Control by the Construction Unit and Developers

Assign values to the parameters for strict quality control of the construction unit and developers. The assignment array is $[15, 10], [10, 5], [7, 2.5]$. The evolution process is shown in Figure 9:

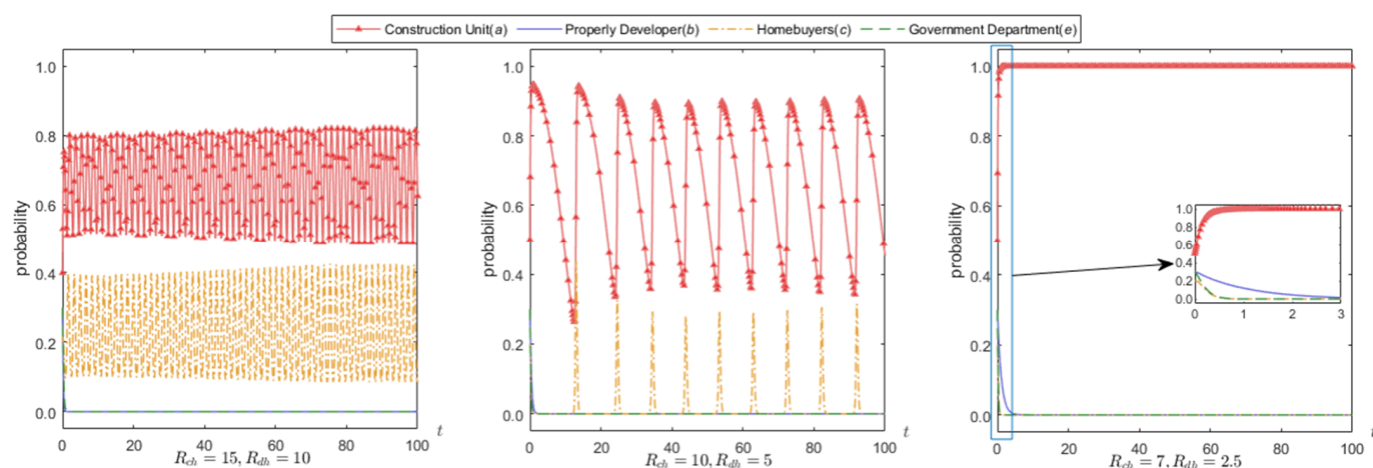


Figure 9. Impact of the cost of strict quality control by the construction unit and developers.

The figure shows that the quality control costs of the constructors and the developers largely influence the decision of the government and the homebuyer, where the most prominent change lies in the constructors. When the safety control cost is reduced, the construction is more inclined to provide safe and reliable project acceptances.

4.2.5. Impact of Government Supervision Costs and Involvement of Supervision Consulting Company

Assign C_{gh}, ϵ with $[0.2, 12], [0.3, 6], [0.6, 2]$. The impact of supervision costs of the government and the involvement of supervision consulting company are shown in Figure 10:

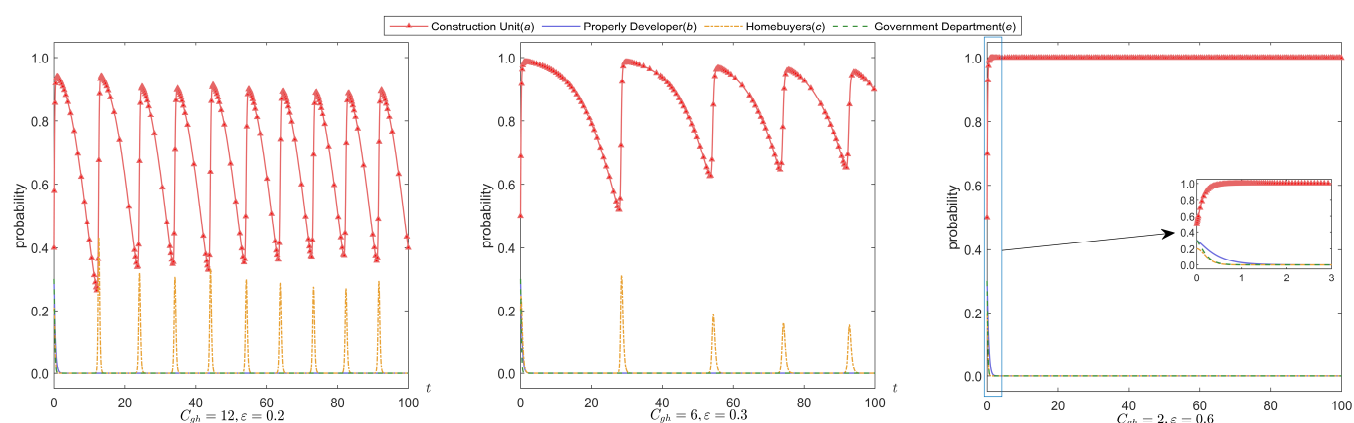


Figure 10. Impact of supervision costs of the government and the involvement of supervision consulting company.

As the supervision consulting company is authorized by the government to supervise the construction project as a representative of non-stakeholders, the changes of the two parameters are related. According to the figure, as the consulting company's review efficiency increases, so does the construction company's compliance with the project's stage acceptance. Finally, it will stabilize to the strategy of completing the project with high quality, which reduces citizens' economic loss and the risk of losing social benefits.

5. Discussion

The model of government regulation's influence on promoting prefabricated building policies comprises multiple stakeholders, each of whom has its unique selection (Lafreniere, 2013; Marshall, 2010) [51,52]. Affected by external and internal factors and their selection strategies, the stable state in the evolution of this model is not unique. In addition, in the evolution process, the changes of each parameter have different effects on the cost and revenue of players. Therefore, when several parameters are changed, one or more players alter their strategy choices to bring the model to a new equilibrium state. However, among the parameters that affect the dynamic evolution model, some can play a decisive role. In this paper, it is found that the government's choice of regulation strategy, the penalty system for non-compliance, the regulatory cost and the supervision companies are vital factors that rebalance the model, which is basically the same as the studies conducted by previous scholars.

The government's supervision system is of great significance, and its prefabricated building policies are aimed at long-term social benefits such as environmental protection and economic development. However, the policies are influenced by the actual price and benefit value. Prefabricated buildings' actual value is equivalent to the amount paid by the homebuyers, while the benefit value comes from homebuyers' long-term possession of the prefabricated houses (King DR, 2003) [34]. Nevertheless, because it is difficult for homebuyers to distinguish the benefit value of cast-in-place buildings from that of prefabricated buildings construction, what determines their choices is the actual value. Therefore, in the case of the same actual value, the public is unwilling to accept new things. For the purpose of obtaining more benefit value, the government should establish a strict supervision system to control the construction quality of construction units and developers to avoid major safety accidents and unnecessary panic in the process of fully promoting the prefabricated building policies, which gives a positive impression of being safe, economical and environment friendly on the public. Only in this way can the policies be promoted successfully. All above are consistent with the study of Raynard M. (2017) [33].

With the development of technology, the correlation between industries has been significantly increased. If a company wants to improve its competitive advantage, it needs to integrate the latest technologies available on the market to undertake more projects, where the control of supervision costs is essential. For construction companies that accept new forms of construction, they have to spend extra money on staff training. However, in this

process, the staff may still follow the old quality control standards for stage acceptance in order to maximize profits, which causes greater safety risks. Therefore, the government needs to regulate the market competition system and strictly control the construction qualification, Song (2020). In previous discussions, the author has put forward some suggestions on this aspect, but it still needs to integrate the decisions of all parties [36].

Supervision companies also play an important role in policy promotion. At present, the homebuyers mostly focus on the influence of developers. If the construction unit and property developers establish the joint venture of interest and risk, the economic losses will inevitably be transferred to the homebuyers. There are three types of losses: First, the public's satisfaction with the government declines, and they believe that the losses are resulted from the government and developers; Second, support for policies melts down. If the public does not understand the promotion policy, once economic losses appear, they will be afraid about the policy. Third, it also hurts the government's long-term social benefits. What government departments pursue is not economic interests, but social benefits. Therefore, the government should improve the supervision mechanism and introduce supervision companies to prevent some players from forming interest groupuscul. This is in line with the suggestions of Wang T (2021) [38] and Zhou JY (2019) [40] on policy promotion.

6. Conclusions and Limitation

6.1. Conclusions

The background of this paper is the policy of striving to develop prefabricated buildings in the 14th Five-Year Plan and National Economic and Social Development and Long-Range Objectives Through 2035 pursued by the Chinese government. It also discusses that with the combination of government regulation mechanisms and the supervision company, how to guarantee the quality and safety of construction projects and avoid losses to the public economy under the premise of valuing the social benefits. The main conclusions are following:

- A reasonable supervision system for the behavior of the construction unit and property developers should be established during the policy promotion to prevent the two subjects from forming a benefit shield, which can effectively reduce the public's economic losses and enhance the support of the policy and the value of social benefits, thus promoting the global strategy of green buildings and environmental protection;
- Apart from establishing the supervision system, the government department should also improve the reward and punishment mechanism. In addition to economic punishment for or the subject who violates regulations, measures such as information disclosure and qualification reduction are necessary to enhance the public's trust in the government. With the increase of punishments, more and more construction units and developers will make strict demands with themselves to ensure safe and stable construction;
- The supervision companies should be massively introduced. On one hand, they can review the low-quality CQPR to avoid the economic losses of the public. On the other hand, it can also encourage people's subjectivity to actively screen the information announced by the developers, thus avoiding the blindness caused by the excessive influence of the developers.

6.2. Limitation

This article analyzed the equilibrium strategy of promoting the prefabricated building policy model under the government supervision system composed of government departments, construction units, property developers and homebuyers. Although it provided enlightenment and draws some conclusions for policy optimization, it is still limited by the following conditions:

First, the cost sources of the supervision company should have been analyzed in the modeling process, but in the model of this paper, it is treated as an agent of the government's

supervision power. The costs of the supervision company and its influences on society can be supplemented in subsequent studies.

Second, the government's incentive to developers is not considered in the cycle. When promoting the prefabricated building policy, not only is there a penalty system, but also a discount on tax or the cost of purchasing for outstanding developers to obtain supports for the policy. Without rewards, developers will likely transfer the benefits of the extra costs or less benefits consumed by choosing assembled buildings to the homeowner community, causing the population to become pessimistic about the policy. Therefore, the corresponding reward and punishment mechanisms can be refined in future studies.

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