

Research Article

Research on Public Rental Housing PPP Project Launching Dilemmas with Dynamic Evolutionary Game

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The public housing PPP projects have encountered a cold reception from the government, which constrained solving the urban housing problem. This paper builds a dynamic game model under incomplete contract conditions, analyzes the key factors affecting the signing of PPP contracts by dynamic evolutionary game analysis, and verifies these factors by simulation. The results show that fiscal spending smoothing, risk transfer, and government performance can promote government to adopt cooperation strategy. Expected project benefits and government performance incentives can promote private capital to adopt cooperation strategy. Changes in transaction cost have a significant impact on the decision of cooperation strategy.

1. Introduction

According to the “2020 New First-Tier Cities Living Report” by Shell Research Institute, the housing prices in most Chinese cities have greatly exceeded the purchasing power of most ordinary people; only Changsha is within a reasonable range among the new first-tier cities. While local governments in China are enjoying land finance dividends, they are also facing a decline in urban competitiveness, increased social stratification, and a lack of movement in consumer demand due to high housing prices. What is more, high housing prices tend to lead to a siphoning effect of the real estate industry on the capital of real enterprises, which hurts the growth potential of economy. A typical example is “ST Ningtong B” which “sold 2 sets of school district houses in Beijing to save its shell” in 2016. The profits of real enterprises after a year of hard work were not even as good as selling a suite to successfully save the shell of the enterprise. This demonstration effect will lead to the funds flow from the real economy to the real estate market.

With the negative impact brought by high housing prices drawing more and more attention from the government and academia, vigorously promoting the construction of rental housing and establishing a rent-to-own housing system has

become an important part of solving the problems of high housing price. Public rental housing is the main body of guaranteed rental housing, and it bears the responsibility of national housing security for low and middle-income urban residents with housing difficulties [1].

Due to the many problems of the traditional construction pattern, adopting PPP to provide public rental housing became a direction encouraged by policy with the resurgence of PPP boom in China from 2014 [2, 3]. In May 2015, the Finance Ministry of China together with six major ministries and commissions issued the Notice on the Use of the Government and Social Capital Cooperation Pattern to Promote the Investment, Construction, and Operation Management of Public Rental Housing, which encourage using PPP to promote the investment, construction, and operation management of public rental housing [4]. However, the development of public rental housing PPP projects is not optimistic in reality; the launching rate and implementing rate are both low. According to the latest data from the project management database of China PPP comprehensive information platform, as of September 17, 2021, the cumulative number of projects in projects management pool reached 10,082, of which 180 are guaranteed housing projects, accounting for 1.78%. Among the 19 major

categories of industries, the amount of municipal engineering project ranks first, and the number of guaranteed housing project ranks 11th with only 4% of municipal engineering projects. Furthermore, more than 90% are shantytown renovation projects among guaranteed housing projects. The number and investment amount of public rental housing projects only account for 0.17% and 0.11% in the projects pool; the launching rate of public rental housing PPP project is very low. In terms of implementation rate, by comparing the names of public rental housing projects in the PPP project management pool with the project reserve list, and searching the information of public rental housing PPP projects by project bulletin time, it is found that most of the public rental housing projects listed in the project reserve list are not in the PPP project management pool; the project implementation rate of public rental housing PPP project is lower than the average implementation rate. Therefore, researching the reasons for the “low” launching rate and implementing rate of public rental housing PPP projects and providing effective solutions has become an urgent problem to be solved for the development of housing security.

2. Literature Review

Since PPP projects are mostly launched by governments, there are many literature researches on the motivation of governments to adopt PPP. Maskin and Tirole [5] and Spackman [6] argue that the greatest attraction of PPP for governments is that the government can use social capital to mask debt. According to the research of Fourie and Burger [7], an important reason for the rise of PPP in South Africa is the low management capacity of the government. Lindqvist [8] argues that when the service quality cannot be met, the government chooses private agencies to represent projects with high service quality requirements but correspondingly needs to take higher risk, so allowing social capital to participate in projects with lower service quality meets the government's expectation. Maskin and Tirole [5] focused on explaining the rent-seeking phenomenon of government officials in PPP projects; they argue that “fixed-price” contracts in the case of private partial financing can effectively prevent officials from rent-seeking activities. According to Jeskobi [9] and Guo and Ho [10], the government adopts PPP considering three relative advantages: firstly, PPP is more efficient than traditional procurement; secondly, PPP can help the government break through fiscal constraints to supply public infrastructure; thirdly, PPP is a catalyst for public sector reform. On this basis, some scholars have studied the motivation of governments to launch PPP projects at different levels of economic development using questionnaire survey and concluded that the preferences of governments are heterogeneous across economic development stages [11, 12]. Kou [13] applied a modified S-CAD approach to deconstruct the premise position, objectives, means, and expected outcomes of governments launch PPP projects.

It has also been argued in the literature that, in addition to the government's own factors, the government's willingness to launch PPP projects is also closely related to the responsiveness of social capital and the external

environment. Koppenjan [14] and Vanham and Koppenjan [15] argue that initiating PPP projects is a complex process of cooperation between the governments and enterprises. During cooperation, the characteristics of government-enterprise interaction and the content characteristics of project may exert influence on the process. Wang et al. [16] argue that less attractive local governments that realize initiating PPP project is difficult to get response from social capital are more likely adopt traditional patterns, so as to save organizational costs. Yang et al. [17] argue that stable market expectations, financial accessibility, and complete institutional guarantees can motivate governments to choose PPP pattern. Hammami et al. [18] argue that PPP are more likely to be adopted in countries with macroeconomic stability. Bertelli [19] analyzed the possible impact of leaders' tenure on PPP launch from a political economy perspective.

In the study of public rental housing PPP project launch, studies have concluded that institutional environment, government capacity, and project characteristics are the main factors affecting local governments' willingness to launch public rental housing PPP projects. Brown et al. [20] applied PPP-related theories to investigate government departments and private sector in China; their results show that it is feasible to implement PPP to supply subsidized housing in China, but institutional constraints must be overcome to achieve full benefits. Kwofie et al. [21] studied the factors for the successful implementation of subsidized housing PPP projects by distributing questionnaires to professionals; they concluded that a well-developed public operating department, comprehensive feasibility studies, and effective procurement procedures are key success factors. Chen et al. [22] argue that the greater the government's financial constraints, the greater the risk of the project and the greater the government's incentive to bring in private capital for PPP cooperation in building public rental housing.

According to Xu et al. [23], as the limiting of the selling price or rent of subsidized housing is affected by residents' payment capacity, the price set by the government is usually lower than the market price, and the willingness of social capital to participate in investment and construction is greatly reduced. Coupled with its long construction and operation period, slow funds withdrawal, and lacking of certain exit paths, some social capitals are discouraged. Zhao et al. [24] studied the investment decision of the private sector in public rental housing PPP projects based on the investment risk evaluation index system of private sector. Yang and Xia [25] conducted a study on improving the enthusiasm and sustainability of social capital participating in public rental housing construction from the perspective of tax planning. Duan [26] studied the investment decision of private sector participating in public rental housing PPP projects by real options approach.

The inherent reasons of “low” start-up and implementation rates of public rental housing PPP projects have been studied by scholars from the government and private capital perspectives. Studies from the government perspective mostly took the lack of government financial resources as the starting point and focused on the impact of government financial resources on whether the government adopts the PPP or the

traditional approach to provide public goods or services. Unfortunately, the conclusions of existing studies have not yet been unified [27]. Some scholars also argue that unsound institutions, unreasonable deal structures, and substandard project performance reduce the motivation of local governments to launch public rental housing PPP projects. Studies from the social capital perspective mainly focused on the impact of government financial resources, institutional environment, risk and benefit distribution, government credit, incomplete contracts, and information asymmetry on the participative motivation of private capital [28–30]. Some scholars have done more detailed qualitative analysis. For example, Fu [31] found that profitability, improving government-enterprise relationship, and policy preference are the main motivations for private capital to participate in the construction of guaranteed housing through a questionnaire survey. Wang [32] and Yao argue that public sector support, risk management capability of private sector, economic value of subsidized housing projects, stability of the subsidized housing market, and fairness and efficiency of bidding have the most significant impact on the motivation of private sector participating in the construction of subsidized housing.

In summary, existing studies have fruitfully explored the factors that influence governments launching public rental housing PPP projects and have achieved quite rich results; these literatures provide useful references for the design of control variables in this paper. However, there are still shortcomings in the existing studies: firstly, the existing studies have analyzed the dilemma of initiating public rental housing PPP projects from the perspective of government and social capital, respectively, lacking the analysis of the interaction between public and private behaviors, and failing to consider the combination of government interests and social capital interests in an integrated manner; secondly, the existing studies have mostly focused on normative discussions; few studies made empirical analysis of the difficulties in initiating PPP projects. Therefore, based on the existing research results, this paper establishes the initial decision model of government and social capital in the launch stage of public rental housing PPP projects from the perspective of cost-benefit and analyzes the decision-making behavior of government and social capital by evolutionary game analysis and simulation analysis. Specifically, apply the system evolutionary stability analysis to get the evolutionary stability state of government and social capital decision-making strategy and then explore the cooperation status between government and social capital through analyzing the evolutionary stability state. Finally, analyze the impact of changes in factors on the system evolutionary strategy and simulate based on a real case to identify and verify the key factors affecting the launch of public rental housing PPP projects.

3. Modeling

3.1. Concept Definition.

- (1) Social capital decision function. From the contractual perspective, the public rental housing PPP project is essentially a long-term contractual

relationship between the government and social capital on the provision of public rental housing. Social capital is willing to conclude a PPP contract with the government because it can generate benefits, at least greater than the opportunity benefits of the elements it provides; otherwise it will give up cooperation. Therefore, the decision of social capital is based on comparing project benefits with opportunity costs.

- (2) Government decision function. At present, there are three main supply patterns of public rental housing: public build public operate, private build public operate, and public-private partnership (PPP). Table 1 is a summary of characteristics of three public rental housing supply patterns. The main feature of public build public operate is that the construction of public rental housing is carried out in a planned manner and the government dominates everything. Due to the lack of competition and autonomy, the public build public operate pattern suffers from certain efficiency loss, which poses a hidden danger to the long-term sustainable operation of public rental housing [33]. Due to the single supplier, the government has great financial pressure; it is prone to expanding supply conflicts [34].

Private build public operate refers to the public rental housing built by social capital and managed by the government; the public rental housing is transferred to the government at no cost after completion. As in the additional construction mode, when the developer is granted land by the government, it is agreed in the contract that a certain number of public rental housings must be built. Compared with public build public operate, the additional construction mode achieves compatibility between government guarantee and the market-oriented land [35]. However, abruptly making different groups of people live together spatially not only increases the difficulty of neighborhood management, but also is not conducive to social integration [36], and the developer's additional construction is not free of charge; the allotted public housing will be taken back or bought back by the government after completion if there is no preferential land policy [1]. Therefore, although there are differences between public build public operate mode and private build public operate mode, the essence of them will involve a large amount of financial capital expenditure [37], and both can be classified as the traditional construction pattern, which is the government-led pattern. The PPP pattern refers to the competitive procurement of social capital by local governments, social capital responsible for project design, financing, construction, and operation, so it is the social capital-led pattern. The government's decision is based on comparing the cost-benefit of two supply patterns.

3.2. Basic Assumptions of the Model.

- (1) Cooperation subject assumptions: both public and private parties are finite rational; both of them have only two strategies. The strategy choices of

TABLE 1: Characteristics comparison of public rental housing supply patterns.

	Public build public operate (government-led pattern)	PPP (social capital-led pattern)	Private build public operate (government-led pattern)
Operating pattern	Agent construct/BT	BOT/TOT	Bundled construction
Participation degree	Build/financing + build	Financing + build + operation	Financing + build
Funding sources	Government	Government + social capital	Real estate developer
Land	Land appropriation	Land appropriation	Land transfer
Profit mode	Agent construct fee/fixed profit	Gap grant + franchise	Land income compensation
Construction subject	Government platform company	Social capital	Real estate developer
Contract	Administrative contract	Public and private contracts	Business contract
Procurement method	Lack of competition	Competitive procurement	Lack of competition in construction stage
Development tendency	Forbidden	Encouraged	—
Performance	Insufficient supply, poor quality, remote housing location, high rent, poor capital efficiency	Shorter construction periods, lower costs, higher quality, better service	Serious shortage of supply, medium quality, longer cycle, poor management, medium social evaluation

government are (launch, nonlaunch), and the probabilities of launch and not launch are X and $1-X$, $X \in [0, 1]$. The launch strategy and nonlaunch strategy, respectively, represent the government's adoption of PPP pattern and traditional pattern for building public rental housing. The strategy choices of social capital are (participation, nonparticipation), and the probabilities of choosing participation and nonparticipation strategies are Y and $1-Y$, $Y \in [0, 1]$. The participation strategy means that social capital responds positively to the construction of public rental housing, and the nonparticipation strategy means that social capital invests in other more profitable commercial real estate projects. Table 2 summarizes the optional strategies of government and social capital and their probabilities, as well as the corresponding pattern for each strategy.

- (2) Government's strategy choices: the basic benefit of public rental housing construction is G_0 . Compared with the traditional pattern, the incremental benefits of adopting PPP pattern include the fiscal expenditure smoothing benefit G_1 and the benefit from cost reduction and efficiency gain G_2 . The reason for such a division is mainly to consider that the core demands of local governments to adopt PPP pattern are, firstly, to use social capital's funds to reduce the government's financial pressure; secondly, to use the professional advantages of social capital to improve the quality of supply [38]. The comparison between the traditional pattern, in which the government input resources are G_3 , and the PPP pattern, which generates incremental benefits while increasing transaction costs, becomes a constraint for the application of PPP projects. Studies have shown that relational contracts can significantly reduce transaction costs [39]. For this reason, the increased transaction cost

TABLE 2: Optional strategies of government and social capital and their probabilities.

Subject	Strategy	Probability	Corresponding patterns
Government	Launch	X	PPP pattern
	Nonlaunch	$1-X$	Traditional pattern
Social capital	Participation	Y	PPP pattern
	Nonparticipation	$1-Y$	Other investments

while governments adopting launch strategy is $(1-\beta)C_g$, and β is the relationship savings coefficient. The government's adoption of the launch strategy will incur necessary organizational cost, which is recorded as C_0 . Table 3 shows the benefit parameters and cost parameters for the government under the PPP pattern and the traditional pattern.

- (3) Social capital's strategy choices: the project revenue includes rental income, property service income, and operation income of infrastructure facilities. The rental income and property service income are contractually agreed fixed income and operation income depends on the degree of social capital's efforts, which is difficult to be clearly defined in the contract. Correspondingly, the project revenue is divided into fixed revenue S_1 and contract surplus Q . The allocated proportion of government in the contract surplus is λ , and the allocated proportion of social capital is $1-\lambda$. Table 4 shows the benefit parameters and cost parameters for the social capital under the PPP pattern and the traditional pattern.

In the traditional pattern, the benefit of social capital is S_0 . In PPP pattern, the social capital will get the policy support benefit S_2 in addition to the expected benefit. Compared with the traditional pattern, the PPP pattern

TABLE 3: Benefit parameters and cost parameters for the government under two patterns.

	Basic benefits	Incremental benefits	Basic investments	Transaction costs	Organizational costs
PPP	G_0	G_1G_2	G_3	C_g	C_0
Traditional pattern	G_0	---	G_3	---	---

TABLE 4: Benefit parameters and cost parameters for social capital under two patterns.

	Fixed revenue	Policy support benefits	Implicit benefits	Contract surplus	Transaction costs
PPP	S_1	S_2	S_3	Q	C_H
Traditional pattern	S_0	---	---	---	---

increases the operation and maintenance responsibility of the social capital. If the project is well operated and maintained, it can generate great public recognition, thus gaining implicit benefits such as brand enhancement, the implicit benefits recorded S_3 . Compared with the traditional pattern, the PPP pattern also increases the transaction cost of social capital, which is recorded as $(1 - \beta)C_H$. Drawing on successful experiences, the government can take certain punitive measures for social capital that adopts a nonparticipation strategy, which is denoted by F. Accordingly, the evolutionary game matrix is shown in Table 5.

4. Evolutionary Game Analysis of Public and Private Parties

4.1. Replication Dynamic Equations of the Evolutionary Game Model. According to Table 5, the replication dynamic equation for the local government to adopt the launch strategy is

$$\begin{aligned}
 F(X) &= \frac{dX}{dt} \\
 &= X(E_X - \bar{E}_1) \\
 &= X(1 - X)\{Y[G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0] - C_0\}.
 \end{aligned} \tag{1}$$

When $Y = C_0/G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0$, we have $F(X) = 0$; i.e., the game behavior of the local government is a stable equilibrium no matter what strategy it chooses.

When $Y \neq C_0/G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0$, let $F(X) = 0$; we get $X = 0$ and $X = 1$ are two stable equilibrium points of X .

Finding the partial derivative of $F(X)$ with respect to X , we get

$$\frac{dF(X)}{dX} = (1 - 2X)\{Y[G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0] - C_0\}. \tag{2}$$

The evolutionary stabilization strategy ESS requires an antiperturbation feature that must satisfy $dF(x)/dx < 0$.

When $Y > C_0/G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0$ has $dF(Y)/dY|_{X=1} < 0$ and $dF(Y)/dY|_{X=0} < 0$, there is an equilibrium point $X = 1$.

When $Y < C_0/G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0$ has $dF(Y)/dY|_{X=1} < 0$ and $dF(X)/dX|_{X=0} < 0$, there is an equilibrium point $X = 0$.

Similarly, the replication dynamic equation for social capital to adopt the participation strategy can be obtained as

$$F(Y) = \frac{dY}{dt} = Y(E_Y - \bar{E}_2), \tag{3}$$

$$= Y(1 - Y)\{X[S_1 + S_2 + S_3 - (1 - \beta)C_H + (1 - \lambda)Q - S_0] + S_0 + F\}.$$

When $X = S_0 + F/S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q$, we have $F(Y) = 0$.

TABLE 5: Benefit matrix of the evolutionary game between local government and social capital.

Participant	Social capital		
		Participation	Nonparticipation
Local government	Launch	$G_0 + G_1 + G_2 - G_3 - (1 - \beta)C_g + \lambda Q$ $S_1 + S_2 + S_3 - (1 - \beta)C_H + (1 - \lambda)Q$	$G_0 + F - G_3 - C_0$ $-F$
	Do not launch	$G_0 - G_3$ S_0	$G_0 + F - G_3$ $-F$

When $X \neq S_0 + F/S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q$, let $F(Y) = 0$, we can get $Y = 0$ and $Y = 1$ are two stable equilibrium points of Y .

Finding the partial derivative of $F(Y)$ with respect to Y , we get

$$\frac{dF(Y)}{dY} = (1 - 2Y)\{X[S_1 + S_2 + S_3 - (1 - \beta)C_H + (1 - \lambda)Q - S_0] + S_0 + F\}, \quad (4)$$

and when $X > S_0 + F/S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q$ has $dF(Y)/dY|_{Y=1} > 0$ and $dF(Y)/dY|_{Y=0} < 0$, there is an equilibrium point $Y = 1$.

When $X < S_0 + F/S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q$ has $dF(Y)/dY|_{Y=1} > 0$ and $dF(Y)/dY|_{Y=0} < 0$, there is an equilibrium point $Y = 0$.

Let $a = S_0 + F/S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q$, $b = C_0/G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0$; we can get the five equilibrium points of the system as $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$,

(a,b). The stability of the equilibrium points of the equations will be discussed below in the plane $M = \{(x, y) | 0 \leq x \leq 1, 0 \leq y \leq 1\}$.

4.2. System Evolutionary Stability Analysis. According to the local stability analysis method, the Jacobi matrix of the equilibrium point of the system is obtained as

$$\begin{aligned}
 J &= \begin{bmatrix} \frac{\partial F(X)}{\partial X} & \frac{\partial F(X)}{\partial Y} \\ \frac{\partial F(Y)}{\partial X} & \frac{\partial F(Y)}{\partial Y} \end{bmatrix} \\
 &= \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}, \\
 M_{11} &= \frac{\partial F(X)}{\partial X} \\
 &= (1 - 2X)\{Y[G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0] - C_0\}, \\
 M_{12} &= \frac{\partial F(X)}{\partial Y} \\
 &= X(1 - X)[G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0], \\
 M_{21} &= \frac{\partial F(Y)}{\partial X} \\
 &= Y(1 - Y)[S_1 + S_2 + S_3 - (1 - \beta)C_H + (1 - \lambda)Q - S_0], \\
 M_{22} &= \frac{\partial F(Y)}{\partial Y} \\
 &= (1 - 2Y)\{X[S_1 + S_2 + S_3 - (1 - \beta)C_H + (1 - \lambda)Q - S_0] + S_0 + F\}.
 \end{aligned} \quad (5)$$

The determinants $\det J$ and trace $tr J$ of Jacobi matrix are, respectively,

$$\begin{aligned}\det J &= M_{11}M_{22} - M_{12}M_{21}, \\ \text{tr} J &= M_{11} + M_{22}.\end{aligned}\quad (6)$$

If $\det J > 0$ and $\text{tr} J < 0$, it indicates that the equilibrium point has asymptotically stable nature; i.e., it is the ESS point, at which the game steady state is reached. The stable points of the equilibrium state in the model are shown in Table 6.

Let $t_1 = G_1 + G_2 - (1 - \beta)C_g + \lambda Q$, $t_2 = S_1 + S_2 + S_3 - (1 - \beta)C_H + (1 - \lambda)Q$.

In Table 6, t_1 represents the net return of the government launching the public rental housing PPP project, and t_2 represents the net return of the private capital participating in the public rental housing PPP project. Theoretically, cooperation can be reached only if the net returns of both the government and social capital are greater than 0. So the stability of the evolutionary game is independent of policy support. Considering the difference in the order of action and decision-making approach, the government chooses the construction way first, and social capital decides whether to participate after the government's choice. The government's decision-making approach is to compare the incremental benefits and incremental costs generated by PPP pattern and select to adopt PPP pattern if the incremental benefits are greater than the incremental costs, and vice versa for the traditional pattern. The social capital decision-making approach is to compare the participation benefits and participation costs, and due to the existence of penalty costs, social capital is likely to choose the participation strategy in the case of participation losses. Under the above constraints, the local stability analyses of each equilibrium point are shown in Tables 7–10.

As can be seen from Figure 1, the system exhibits a variety of evolutionary stable states as the factors affecting the decision-making of both public and private parties change. Case ① and case ③ show evolutionary stable state (c), case ② and case ⑤ show evolutionary stable state (d), case ⑥, case ⑧, case ⑩, and case ⑫ show evolutionary stable state (a), and case ⑦, case ⑨, and case ⑪ show evolutionary stable state (b). The cooperation status between the public and private parties in each evolutionary stable state is discussed in Tables 8–10.

4.2.1. State (a). The incremental benefit of the government adopting the launch strategy is greater than the incremental cost, the benefit of social capital participation is less than the participation cost, and the loss value is greater than the penalty cost of nonparticipation. At this time, the rational

social capital will choose the nonparticipation strategy. In the case the social capital adopts nonparticipation strategy, the government will be forced to adopt the traditional supply pattern, which is case 6. If the incremental benefit of the government taking launch strategy is less than the incremental cost, the government will choose the nonlaunch strategy. The rational social capital will choose the nonparticipation strategy because the loss of participation is greater than the penalty cost of nonparticipation, i.e., case ⑧, case ⑩, and case ⑫.

4.2.2. State (b). The incremental benefit of the government's launch strategy is less than the incremental cost, so the government will not choose launch strategy. In this case, the participation loss of social capital is less than the nonparticipation penalty cost; then the social capital will still adopt participation strategy, i.e., case 7, case 9, and case 10.

4.2.3. State (c). The incremental benefits of both public and private parties adopting cooperation strategy are greater than the incremental costs, i.e., case ①. If only the government's launch benefit is greater than the launch cost, social capital will still adopt the participation strategy as long as the participation loss of social capital is less than the nonparticipation penalty cost, i.e., case ③.

4.2.4. State (d). When $t_1 > 0, t_2 > 0$, $S_0 + F < 0$ and $t_1 > 0, t_2 < 0$, $S_0 + F < 0$, $t_2 + F > 0$, there are two evolutionary stable states of the system strategy, namely, (0,0) and (1,1), and the specific evolutionary direction depends on the initial state of the system. The system will evolve toward (1,1) when their initial states fall into quadrilateral BECD. The system will evolve toward (0,0) when their initial states fall into quadrilateral ABEC.

5. Parameter Variation Analysis and Simulation

5.1. Influence of Parameter Changes on the Convergence of the Evolving System. To further analyze the influence of factors change on the evolutionary strategy of the system, the area of the quadrilateral BECD is represented by S_A , which indicates the probability that the game system converges to (1,1). The larger S_A is, the greater probability that the public and private parties will adopt a cooperative strategy, calculated as follows:

$$S_A = 1 - \frac{1}{2} \left[\frac{S_0 + F}{S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q} + \frac{C_0}{G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0} \right]. \quad (7)$$

To simplify the analysis, the factors that can directly affect the probability of cooperation between public and private parties are selected for analysis, and case ② is discussed first as an example.

(1) Gain-type factors: since there are $\partial S_A / \partial G_1 > 0$, $\partial S_A / \partial G_2 > 0$, $\partial S_A / \partial S_1 > 0$, $\partial S_A / \partial S_2 > 0$, $\partial S_A / \partial S_3 > 0$ at the saddle point, S_A is positively correlated with the government revenue indicators G_1 and G_2 . Namely,

TABLE 6: Local stability of social capital’s cooperation degree in public rental housing PPP projects.

Equilibrium point	Jacobi matrix determinant	Jacobi matrix trajectory	Existence condition
A(0,0)	$-C_0(S_0 + F)$	$S_0 + F - C_0$	---
B(0,1)	$-t_1(S_0 + F)$	$t_1 - S_0 - F$	---
C(1,0)	$C_0(t_2 + F)$	$C_0 + (t_2 + F)$	---
D(1,1)	$t_1(t_2 + F)$	$-(t_1 + t_2 + F)$	---
E(a,b)	$-a(1 - a)(t_1 + C_0)b(1 - b)(t_2 - S_0)$	0	$0 < a < 1, 0 < b < 1$

TABLE 7: Local stability of each equilibrium point in the range of different parameter values.

Equilibrium point	① $t_1 > 0, t_2 > 0, S_0 + F > 0$	② $t_1 > 0, t_2 > 0, S_0 + F < 0$	③ $t_1 > 0, t_2 < 0, S_0 + F > 0, t_2 + F > 0$
A(0,0)	Saddle point	ESS	Saddle point
B(0,1)	Saddle point	Unstable	Saddle point
C(1,0)	Unstable	Unstable	Unstable
D(1,1)	ESS	ESS	ESS
E(a,b)	Inexistence	Saddle point	Inexistence

TABLE 8: Local stability of each equilibrium point in the range of different parameter values.

Equilibrium point	④ $t_1 > 0, t_2 < 0, S_0 + F > 0, t_2 + F < 0$	⑤ $t_1 > 0, t_2 < 0, S_0 + F < 0, t_2 + F > 0$	⑥ $t_1 > 0, t_2 < 0, S_0 + F < 0, t_2 + F < 0$
A(0,0)	Saddle point	ESS	ESS
B(0,1)	Saddle point	Unstable	Unstable
C(1,0)	Saddle point	Unstable	Saddle point
D(1,1)	Saddle point	ESS	Saddle point
E(a,b)	Inexistence	Saddle point	Inexistence

TABLE 9: Local stability of each equilibrium point in the range of different parameter values.

Equilibrium point	⑦ $t_1 < 0, t_2 > 0, S_0 + F > 0$	⑧ $t_1 < 0, t_2 > 0, S_0 + F < 0$	⑨ $t_1 < 0, t_2 < 0, S_0 + F > 0, t_2 + F > 0$
A(0,0)	Saddle point	ESS	Saddle point
B(0,1)	ESS	Saddle point	ESS
C(1,0)	Unstable	Unstable	Unstable
D(1,1)	Saddle point	Saddle point	Saddle point
E(a,b)	Inexistence	Inexistence	Inexistence

TABLE 10: Local stability of each equilibrium point in the range of different parameter values.

Equilibrium point	⑩ $t_1 < 0, t_2 < 0, S_0 + F > 0, t_2 + F < 0$	⑪ $t_1 < 0, t_2 < 0, S_0 + F < 0, t_2 + F > 0$	⑫ $t_1 < 0, t_2 < 0, S_0 + F < 0, t_2 + F < 0$
A(0,0)	Saddle point	ESS	ESS
B(0,1)	ESS	Saddle point	Saddle point
C(1,0)	Saddle point	Unstable	Saddle point
D(1,1)	Unstable	Saddle point	Unstable
E(a,b)	Inexistence	Inexistence	Inexistence

the greater the project financing income and efficiency gain, the more active the government in adopting PPP, and the greater the probability of public-private cooperation. Generally speaking, the stronger the comprehensive strength of social capital, the lower the financing cost and the higher the

efficiency benefit. Thus, the strength of social capital is crucial to the choice of public rental housing supply pattern. Meanwhile, it can also be seen that S_A is positively correlated with the social capital revenue indicators $S_1, S_2,$ and S_3 ; i.e., the greater the project rental income, policy support, and implicit revenue,

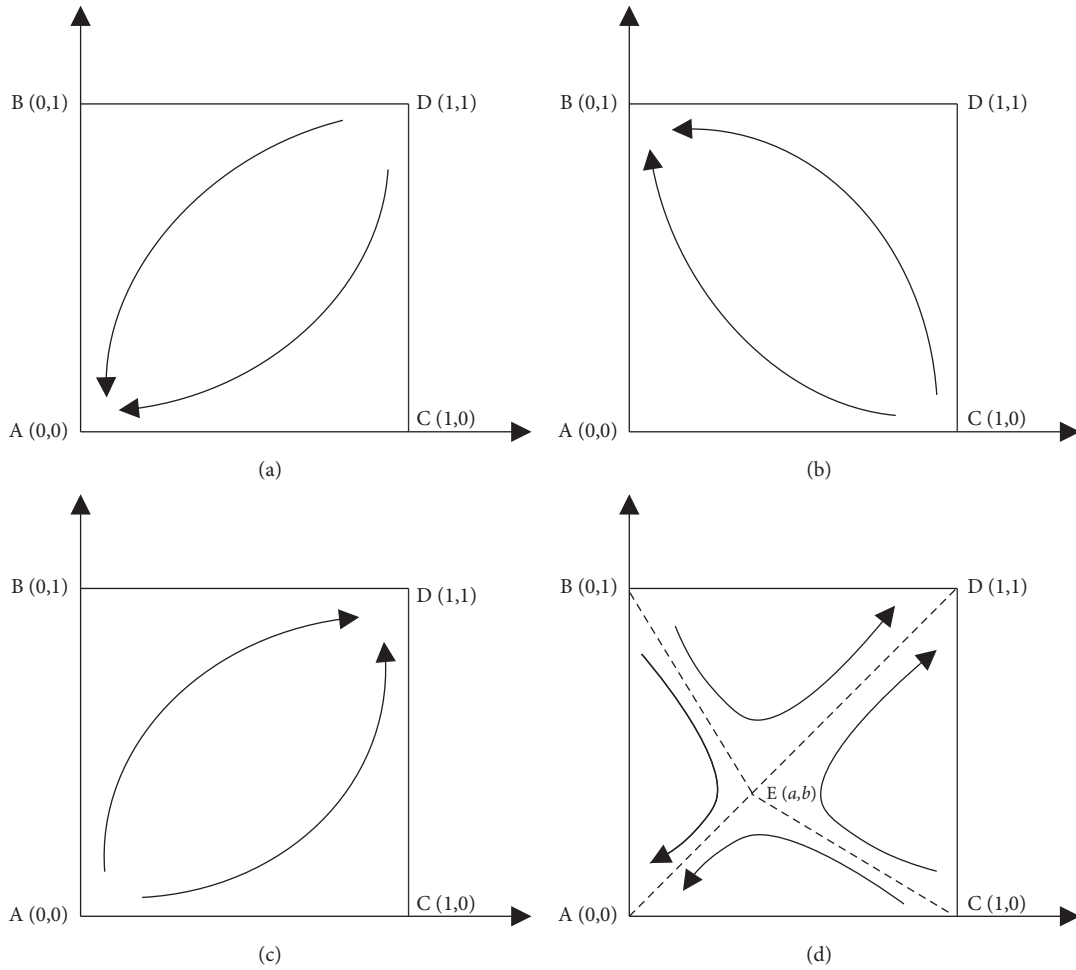


FIGURE 1: System evolution steady state phase diagram. (a) Evolutionary stable state is (nonparticipation, nonparticipation). (b) Evolutionary stable state is (nonparticipation, participation). (c) Evolutionary stable state is (participation, participation). (d) Multiple evolutionary stable state.

the easier it is for both parties to reach cooperation intention. Therefore, strict project justification process, optimization of the taxation system of guaranteed housing, and improvement of reputation incentive mechanism are conducive to improving the cooperation probability of public rental housing PPP projects.

- (2) Cost-type factors: since there are $\partial S_A / \partial C_H < 0$ and $\partial S_A / \partial C_g < 0$ at the saddle point, S_A is negatively correlated with C_H and C_g ; i.e., the larger the project transaction cost, the smaller the probability of cooperation. To this end, on the one hand, we should accelerate the improvement of relevant systems to control the generation of transaction costs at source by simplifying project approval procedures and

establishing a competitive cost discovery mechanism. On the other hand, build a good relationship governance mechanism and give full play to the role of trust, communication, and other relationship governance factors in reducing project transaction costs.

- (3) Regulation-type factors: cooperation residual allocation is the core of the public-private game, which requires repeated communication and bargaining between two sides. The two sides are most likely to have conflicts in this link, which eventually leads to the project end in the beginning.

From equation (7), we have

$$\frac{\partial S_A}{\partial \lambda} = -\frac{1}{2} \left\{ \frac{-(S_0 + F)Q}{[S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q]^2} + \frac{-C_0Q}{[G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0]^2} \right\}. \quad (8)$$

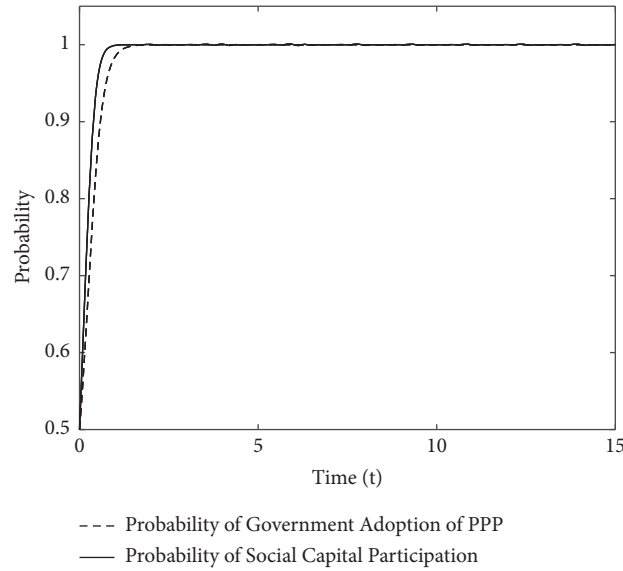


FIGURE 2: The evolution path of the stable strategy for the example.

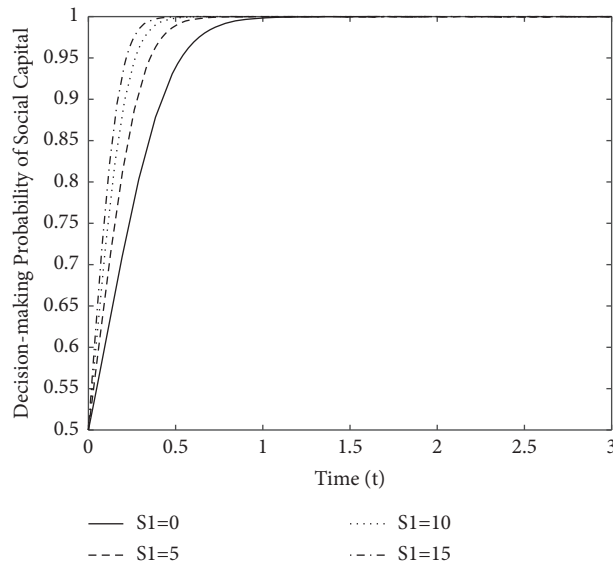


FIGURE 3: Evolutionary path of S_1 impact.

From the above equation, it can be seen that the effect of the contract residual allocation ratio on the probability of cooperation is always in dynamic change due to the

influencing factors and its situations are various. Taking the second-order partial derivative of λ , we get

$$\frac{\partial^2 S_A}{\partial \lambda^2} = -\frac{1}{2} \left\{ \frac{2(S_0 + F)Q^2}{[S_0 + (1 - \beta)C_H - S_1 - S_2 - S_3 - (1 - \lambda)Q]^3} + \frac{2C_0Q^2}{[G_1 + G_2 - (1 - \beta)C_g + \lambda Q + C_0]^3} \right\} < 0. \quad (9)$$

According to the extreme value principle, there exists an optimal contractual residual allocation ratio λ^* for the project that maximizes the probability of cooperation between two sides. Therefore, in order to avoid the consulting

scheme to be ungrounded, the implementation agency should consult the social capital at the stage of scheme preparation. At the same time, hire a high-level consulting agency. The main factors affecting the benefit allocation,

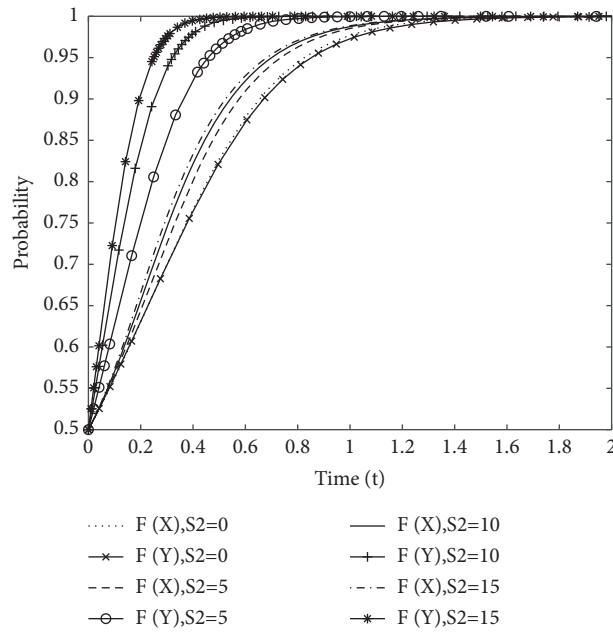


FIGURE 4: Evolutionary path of S_2 impact.

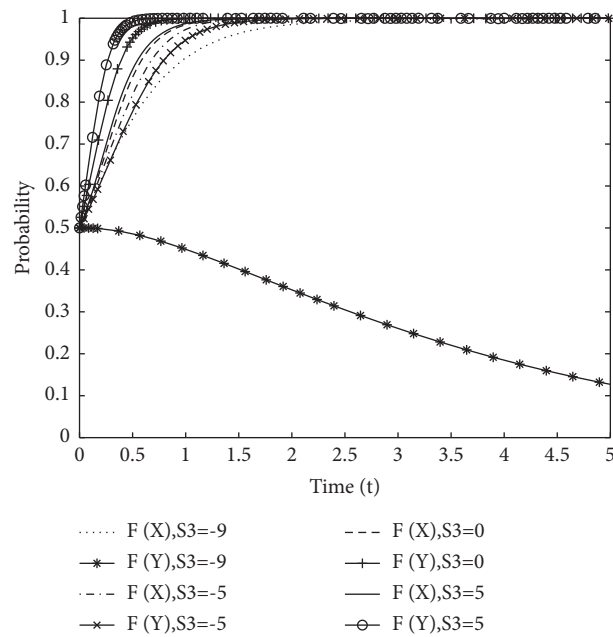


FIGURE 5: Evolutionary path of S_3 impact.

such as the project input proportion, risk sharing coefficient, equity structure, willingness to cooperate, and degree of effort, should be comprehensively considered. And construct a suitable benefit allocation pattern to make the benefit distribution more objective and reasonable, so as to reconcile the differences in benefit distribution between two sides and ensure the success of the project.

After calculation, case ⑤ is the same as case ②.

5.2. Evolutionary Game Pattern Arithmetic Analysis. For further analysis and verification, we take a PPP project of public rental housing in China as a case to conduct an example analysis of the sample game model. The case is a prefecture-level city's public rental housing PPP project covers a total area of 4.27 hectares, with a total construction area of 627901 m^2 and a total investment of 2.413 billion yuan, all funded by the social capital. On October 16, 2019, the

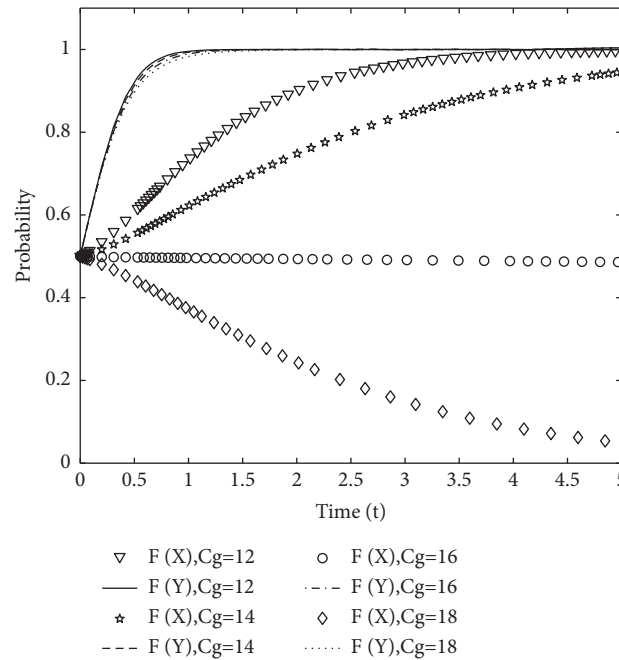


FIGURE 6: Evolutionary path of C_g impact.

public and private parties signed the PPP project contract, and the project has entered construction stage in present. On October 12, 2020, while participating in the first round of performance evaluation of the project, the authors conducted face-to-face interviews with the project consulting agency, the head of the private capital Jiangxi Fuzhou Investment Development Co., and the implementing agency Fuzhou Real Estate Administration, respectively. The interviews mainly covered the project's policy support, the project's investment plan, and the project's revenue allocation. According to the preproject program and interviews with implementing agencies and consulting agencies, we get that the main leaders of the municipal party committee attach great importance to the project, and the higher government and the National Development Bank of China have corresponding policy support, according to which it is determined that $G_0 = 18$, $G_1 = 2$, $G_2 = 1.29$, $G_3 = 16.47$, $S_0 = 0.46$ (taking 2 points as the surrogate construction fee), $S_1 = 0.81$, $S_2 = 4.23$, and $Q = 5$. S_1 is calculated by operating cost and internal rate return of financial after-tax, S_2 is calculated by total government subsidy minus total project investment, and Q is estimated based on project construction content and social capital strength.

Considering that the social capital of the project is a municipal wholly state-owned enterprise, it is determined that $S_3 = 0.06$ and $F = 0.02$. According to the implementation plan, the preproject costs are borne by the implementing agency, and it is determined that $C_g = 0.13$, $C_0 = 0.05$, and $C_H = 0.01$. Considering that the core of the preproject work is to improve the cooperation enthusiasm of two sides, the document does not make any agreement on the contract residual allocation, and there is no mechanism for sharing the excess revenue, so we focus on the effects of S_1 , S_2 , S_3 , C_g in the analysis of the calculation case.

As can be seen from Figure 2, with the increase in the number of evolutionary iterations, the strategies of both public and private parties stabilize at the cooperation strategy, which is in line with the actual situation of the project. From Figures 3 and 4, it can be seen that, with the increasing of S_1 and S_2 , the rate of public and private parties who tend to cooperate also increases rapidly, indicating that the increase of fixed benefits and policy support can accelerate the cooperation progress but does not affect the evolutionary results, which is consistent with the conclusion of theoretical analysis. From Figure 5, it can be seen that the implicit benefits can only change social capital's strategy if they reach a certain level. As can be seen from Figure 6, with the increasing C_g , the cooperation probability of local government gradually shifts from launch strategy to non-launch strategy, indicating that the government's upfront transaction cost has a significant impact on its decision.

6. Conclusions and Implications

6.1. Conclusions. This paper aims to study the key factors that influence the government and social capital to launch public rental housing PPP projects. We establish an initial decision model containing both government and social capital in the start-up stage of public rental housing PPP projects from the perspective of cost-benefit and then using the dynamic evolutionary game analysis to analyze the system evolutionary stability of the decision-making behavior of government and social capital and analyze the impact of changes in various factors on the system evolutionary strategies. Finally, conduct simulations based on a real case to further validate the analysis results. Through the study, we can draw the following conclusions from this paper: Firstly, the unilateral launch strategy and unilateral

participation strategy of both public and private parties are unstable results of the evolutionary game. Only win-win can ensure the project is implemented successfully. Secondly, the increase of fiscal expenditure smoothing benefits, risk transfer benefits, and performance benefits is conducive to the government to adopt launch strategy. Thirdly, reasonable expected project benefits and government performance incentives are conducive to the social capital to adopt participation strategy, but too high return will have the consequence of “beyond is as wrong as falling short.” Fourthly, the transaction cost has a significant impact on the decision of cooperation strategy. The research results of this study have important application significance. The findings presented in this paper can provide reference for local governments to improve the incentive way of attracting social capital to participate in PPP projects and provide guidance for the design and improvement of the residual control rights allocation mechanism of public rental housing PPP projects. It can also provide a reference for social capital to establish the right concept about participating in public rental housing PPP projects and provide some reference for the central government departments to carry out the policy of PPP standardized management, especially for the start-up management of PPP projects.

However, our research also inevitably has some limitations. As mentioned in the literature review, there are numerous factors that influence the government’s willingness to launch PPP projects, including microlevel factors such as project characteristics, mesolevel factors such as government capacity and contract design, and macrolevel factors such as institutional environment. This study only considers the microlevel costs and benefits of both public and private parties in the construction of model parameters and without considering the influence of meso- and macrolevel factors on public and private decisions and does not identify the importance of factors by empirical analysis, which affects the accuracy of policy recommendations. The differences in the spatial distribution of public rental housing PPP projects are not considered. In fact, there is a serious regional imbalance in the distribution of public rental housing PPP projects in China; the public rental housing PPP projects are overly concentrated in less developed regions with serious user fee revenue shortage and government credit risk, which are not analyzed in the study.

6.2. Implications. Firstly, reasonably determine the cooperation period to improve the project operation and maintenance revenue space. Generally speaking, the longer the project cooperation period, the better it is to improve the government’s fiscal expenditure smoothing revenue, but accordingly it lengthens the capital recovery cycle of social capital. Considering that operation and maintenance are the core of PPP pattern and the key to achieve price to value for PPP projects, appropriately lengthening the project cooperation cycle is more conducive to take the advantage of social capital’s experience and technical advantages. To this end, it is recommended to do the following. ① Rationally allocate project operation resources and broaden the project profit chain. Specifically, the construction content of public

rental housing projects should be enriched as much as possible when designing the project transaction structure. In addition to welfare housing for low-income people, it can also include some talent housing that can be rented in the market and even some real estate projects that can be sold. At the same time, improve the development rights of relevant supporting commercial and residential land, encourage project companies to develop by-products and extend the project value chain, create cash flow through supporting services, and increase project companies’ operation and maintenance income. ② Increase the residual percentage shares by social capital in project contracts and allow social capital to enjoy more project dividend rights as their efforts increase and project performance improves.

Secondly, reform the housing security assessment mechanism to improve the endogenous motivation of local governments. One important reason for local governments being not enthusiastic about public rental housing projects is that local governments need to deal with many urban construction and management tasks, and the benefits of public housing can be seen only in the long term. It leads local government officials to believe that the construction of public housing is not only “make dowry for others”, but also crowding out local limited financial resources. Therefore, in order to improve the launching willingness of local governments, the first step is reforming the incentive mechanism for promotion and including the goal of public rental housing in the performance and promotion assessment of local governments. For example, make the coverage of public rental housing supply and the satisfaction of low-income residents as key indicator in the promotion assessment of officials, and include them in the important work of the government as a basic evaluation of the government’s performance. The evaluation results should be organically integrated with the management of cadres to increase the willingness of government officials to launch public rental housing PPP project. The second step is accelerating the legislation about housing, adding “housing security” to the responsibilities of local governments, and strengthening the housing security responsibility of governments at all levels according to the law. At the same time, a special chapter should be set out to clearly define the land supply plan, construction standards, and development planning for public housing, so as to steadily promote the construction of public housing through mandatory laws.

Thirdly, build risk sharing mechanism for the project and scientifically allocate risks between public and private parties. Public rental housing PPP project has the characteristic of large investment amounts, high asset specificity, and blurred boundaries of government intervention during the project implementation. Therefore, public rental housing PPP project has high investment risk. For this reason, the contracting cost of both public and private parties is high, which affects forming cooperation strategy. So the introduction of standardized public rental housing PPP agreement texts at the national level is crucial to the successful implementation of the project. Specifically, on the one hand, a normative contract for public rental housing PPP projects should be issued as soon as possible. The government should

introduce the operation points of public rental housing PPP project contract combined with the characteristics of public rental housing. When establishing the project contract standard, the normative contract should be drafted with the full help of the professional power of consulting agencies. On the other hand, give full play to the role of external brain and big data in project risk management. Because of the strong professionalism of risk identification and sharing, when formulating PPP project contracts, the government can determine the basic types of risk factors and risk sharing framework with the help of big data analysis. Risk allocation should be within the limits of ability, and the results of risk allocation should be reflected in the rights and obligations terms and the return mechanism of benefits.

Fourthly, improve the reputation evaluation system and increase the implicit return of social capital. According to the 2015 Analysis Report of China's Top 500 Private Enterprises, the return on net assets of the Top 500 Private Enterprises in 2014 was 14.04%, but the rate of return on investment of public rental housing projects is only around 6%–8%. Therefore, it is very important to improve the reputational return of private capital. Specifically: Firstly, a reputation data disclosure platform should be established to improve the reputation value. The implementation agency is responsible for assessing the performance of social capital and then informing the information service agency, which can be a government-appointed media or a third-party intermediary service agency. The information service agency establishes a special information disclosure platform to regularly disclose the performance status of social capital. At the same time, the government regards the data as reference indicator for the process of purchase service from social capital. For example, investors with outstanding reputation may no need to be prequalified. And the weight of bidders' historical performance scores can be increased in the bid evaluation process, which not only helps to save transaction costs, but also increases the value of reputation. Secondly, widen the range of channels to increase the value of social reputation. It can be considered to award various honors to business leaders and enterprises with good reputations and increasing publicity and coverage through the media to motivate them to reduce unreasonable profit-seeking behaviors. In addition, the project approval process can be appropriately simplified for enterprises with good reputation in subsequent projects. Under the same conditions, give priority to reputable enterprises so as to increase the value of reputation. At the same time, the implicit income of social capital can be increased by selling the title rights of public rental housing and adding value to the reputation capital of social capital, thus increasing their enthusiasm in participating public rental housing PPP project.

Data Availability

All the data used to support the findings of the study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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