

RESEARCH ARTICLE

Analysis of the Choice of Return Mechanism of PPP Model in Rural Human Settlement Improvement under the Rural Revitalization Strategy: Research Based on the Perspective of Evolutionary Game

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Abstract: The improvement of rural human settlement environment is a significant direction of the rural revitalization strategy. Based on the finite rational evolutionary game theory, a cooperative behavior evolutionary game model of rural human settlement environment improvement PPP model with local government, social capital and rural residents as the main game players with the reward mechanism of Government Payment and one with the reward mechanism of Viability Gap Funding are constructed. Comparing the total project revenue of two reward mechanisms, the thesis will obtain the effects of choosing the reward mechanism of rural human settlement improvement PPP. Finally, available suggestions are made to the decision of the reward mechanism of PPP project about rural human settlement environment, thus promoting the application and development of PPP in rural environmental management and to promote sustainable improvement of rural habitat improvement.

Keywords: Rural revitalization strategy, Rural human settlement environment, PPP, Reward mechanism, Evolutionary game theory

1. Introduction

The rural revitalization strategy proposed in the report of the 19th National Congress Party is the main strategy for China's current and future development, and the im-

provement of rural human settlement environment is an important task of China's rural revitalization strategy ^[1]. However, the situation of China's rural settlement environment is severe ^[2], and there are problems that the gap of funds spent in the improvement of rural human settle-

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ment environment is large and there is a lack of a long-term mechanism^[3]. It has become a significant challenge for China's current agricultural and rural development to make up for the shortcomings of the improvement of the rural human settlement environment.

The Chinese central government has widely promoted the public-private partnership (PPP) model to improve the efficiency of waste disposal services since 2013, causing the number of PPP projects increasing^[4]. Since 2014, China has strongly encouraged PPP projects to enter the rural environment field, which obtains great efficiency. Applying the PPP model to rural human settlement environment improvement projects has the advantages of improving the efficiency of project implementation and enhancing the level of project quality^[5]. However, problems such as prominent conflicts between government and enterprises and the difficulties of carrying out projects have existed during the practice of PPP in the rural human settlement environment^[6]. Therefore, it is necessary to promote the smooth implementation of PPP projects. Designing the return mechanism of PPP project is not only the key to advancing the PPP model to implement smoothly^[7], but also the basis and prerequisite for a win-win situation for the government, social capital and the public. Only when the return on investment is reasonable, will social capital have the willingness and incentive to participate in PPP projects, and can the government provide infrastructure and public services at lower cost and higher efficiency than the traditional model, namely the government provides them itself, where it is necessary to implement the PPP model. The public has access to a greater quantity, higher quality and more responsive public services with a reasonable investment return. According to the "Operating Guidelines on PPP (for Trial Implementation)" (CAI Jin [2014] 113), the return mechanism of PPP projects in China, the source of funds where social capital obtains the investment return, including User Charges, Viability Gap Funding and Government Payment.

According to data from the Ministry of Finance's PPP comprehensive information platform, The proportion of the Viability Gap Funding projects among existing rural human settlement environment improvement PPP projects in China is 94%, with Government Payment projects accounting for only 6% and no User Charges projects. However, the reasons for the choice of return mechanism are not specified, only summarizing how this situation is directly related to current PPP policies and the characteristics of the projects. Therefore, there is an urgent need to investigate what factors influence the choice of return mechanism for rural human settlement environment improvement PPP model. Meanwhile, the core of PPP is a partnership, essentially a social game^[8]. PPP projects have a strong public welfare

attribute and problems such as government excessive intervention or giving up regulation, social capital speculation for short-term benefits, and rural residents excluded from the projects are easy to appear^[9]. So it is worth studying that by how to design and choose the return mechanism and how government coordinate the interests of multiple parties to promote a higher quality of rural human settlement environment improvement PPP projects under the circumstance of China and deeply give impetus to the effective conduction of the rural revitalization strategy.

This thesis is novel as it bridges several gaps in the literature. First, in terms of theory, given that the research on the field of rural human settlement environment is still at the beginning, we study the return mechanism of rural human settlement environment improvement PPP to propose suggestions for the choice of the return mechanism of rural human settlement environment improvement PPP by using the literature about the return mechanism of PPP in other fields for reference, which is the first of its kind in the study of rural human settlement environment improvement PPP. Second, in terms of method, based on the previous evolutionary game model, an evolutionary game model for three game players with the reward mechanism of Government Payment and one with the reward mechanism of Viability Gap Funding are respectively constructed and the total revenue of the each return mechanism is calculated. By calculating the balance between the two, we make a decision on the return mechanism, which increases the application scenarios of the evolutionary game method. Third, this thesis provides microcosmic evidence for the decision on the return mechanism of rural human settlement environment improvement PPP. By comparing the total revenue of the two return mechanisms to conclude the influencing factors of the decision on the return mechanism, it is of great practical value to promote the smooth implementation and good operation of rural human settlement environment improvement PPP projects to make great contributions to rural revitalization.

2. Review of the Literature

2.1 The Application of PPP Model in Rural Human Settlement Environment Improvement

Rural human settlement environment improvement is one of the research focuses in academia. Xu Shunqing and other scholars (2018) found that there are problems such as insufficient construction investment and a large regional difference in the construction of sewage and waste treatment facilities in the rural human settlement environment^[10]. However, there are many reasons of rural human settlement environment, such as excessive historical debts,

large investment gap and lack of long-term mechanism^[11]. Because the introduction of PPP model in agricultural and rural areas is the response and support to the rural revitalization strategy^[12], a large number of scholars have done a lot of research on the application of PPP model in rural human settlement environment. Du Yanqiang and other scholars (2018) found that the PPP model of rural environment improvement can solve the problems of insufficient funds, lack of technology and personnel to a certain extent^[3,13]. He (2018) also constructed a framework for analyzing the life cycle costs of PPP model in rural environmental governance and put forward that PPP models in rural environmental governance need to be adapted to local conditions and promoted in a prudent manner^[13].

2.2 The Reward Mechanism of PPP

In recent years, the “Guidelines for Demonstration of Financial Affordability of PPP projects” issued by the Ministry of Finance has restricted the government’s ability to pay for PPP projects. And in order to ensure the smooth implementation of PPP projects, it is particularly important to attract the participation of social capital. Shen Juqin and other scholars (2018) put forward that determining the return mechanism of PPP projects is an important guarantee for successful cooperation between government and social capital parties, and building a reasonable mechanism with risk sharing and investment return is an significant prerequisite for encouraging private capital to enter the PPP market^[14]. It can be seen that the return mechanism of PPP projects is vital to the implementation of PPP model. In the existing literature of the reward mechanism of PPP projects, it involves urban rail transit, forestry etc. Ten Tielan (2016) and other scholars summarize the design points of the return mechanism of PPP project of urban rail transit based on comparative analysis of cases, that is, the government capital support, the driving effect of passenger flow on the project income, the expansion of the profit space of the project, the reasonable benefit distribution mechanism, and the completeness of relevant policies and regulations^[15], but the research on the field of rural human settlement environment is still at the beginning. For instance, Xu Shunqing (2018) and others pointed out that the investment return mechanism in rural pollution governance facilities was unimproved and proposed to innovate its investment return mechanism^[10,16]. However, there is no specific elaboration on how the return mechanism is chosen and the influencing factors of choosing the return mechanism, which this paper wishes to study.

2.3 The Evolutionary Game Model

The PPP model of rural human settlement environment

improvement is a complex system problem, which involves the collaboration of multiple stakeholders. At the same time, evolutionary game has proved to be an effective method to study the stability of complex systems^[16], and it has also proved to be suitable for the research on the problems of rural human settlement environment to a certain extent^[17]. Therefore, some literature uses evolutionary game to study the improvement of the rural human settlement environment. Du Yanqiang et al. (2019) introduce the framework of evolutionary game analysis, design different symbiotic logics and combine typical cases to discuss the conditions met by multiple symbiosis in the PPP model of rural human environment improvement^[6,18]. Zhou Guoliang and other scholars (2022) construct a cooperative behavior evolutionary game model of rural human settlement environment improvement PPP model with local government, social capital and rural residents as the main game players and analyze the influence of the initial willingness of the three parties and government regulation on the evolution of their behavioral strategies by Matlab Software^[18]. However, the choice and design of PPP return mechanism for rural human settlement environment have not been explored among these literatures. Shen Juqin and other scholars (2018) have concluded that the project income is a decisive factor of the decision of the PPP project reward mechanism, so we can make the decision of reward mechanism by comparing the project income of the three players of evolutionary game models under different reward mechanisms.

3. Interpretation of the Concept of PPP Project Return Mechanism

According to the documents issued by the Ministry of Finance, there are three return mechanisms, namely User Charges, Government Payment and Viability Gap Funding. The types of return mechanisms for PPP projects are shown in Table 1.

3.1 Government Payment

Government payments refer to direct government payments to buy public goods and services. Under the government payment mechanism, the social capital undertakes the investment, construction, operation and maintenance of the project, while the government pays the consideration according to the availability of the project facilities, the use of products or services and the quality, so that the social capital can recover the project cost and obtain reasonable benefits. The relationship between the parties to the Government Payment mechanism is shown in Figure 1.

Table 1. Types of return mechanism and income sources of PPP projects

The mechanism of return	Source of income	Income form	The type of project used
User Charges	Consumer	Consumers will pay directly for buying public goods and services	Business projects
Viability Gap Funding	Consumer + government	The government will give financial subsidies to social capital or project companies in the form of financial subsidies, share capital investment, preferential loans and other preferential policies	Prospective business projects
Government payment	Government	The government pays directly for public goods and services, mainly including availability payment and pay for performance	Non-operational projects

Source: [Modern Consulting] Original manuscript (official website: www.cfacn.cn)

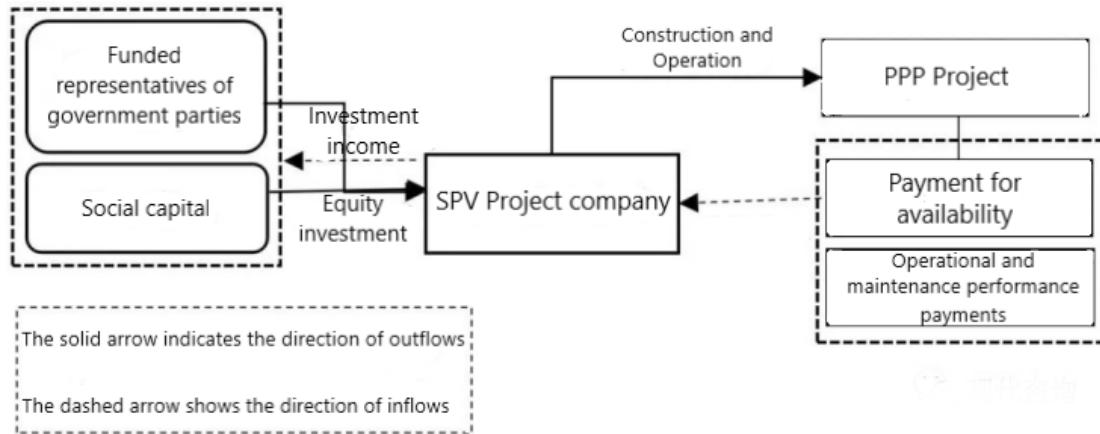


Figure 1. Government payment return mechanism

Source: [Modern Consulting] Original manuscript (official website: www.cfacn.cn)

3.2 User Charges

User charges means that the end-consumer users are directly paid to buy public goods and services, and the project company directly charges fees from the end-users to recover the construction and operating costs of the project and obtain reasonable benefits. Compared with government paid projects, user paid projects do not need the government to bear project demand risks, and do not need the financial expenditure of local governments. It is more in line with the original intention of PPP promotion in China, and is the most important type of PPP model development in the future. The relationship between the parties to the User Charges return mechanism is shown in Figure 2.

3.3 Viability Gap Funding

Viability Gap Funding means that when the user payment is insufficient to meet the cost recovery and reasonable return of the project company, the government will give a certain economic subsidy to the project company to make up for the gap outside the user payment and make the project commercially feasible. It is a compromise between the government and user payment mechanisms, and is usually used for projects with low operational coef-

ficient, poor financial benefits, and direct services to end users, but charges cannot cover investment and operating returns. The relationship between the parties to the Viability Gap Funding return mechanism is shown in Figure 3.

3.4 Distribution of the Return Mechanism of the Three PPP Projects

As can be seen from the Figure 4, the Viability Gap Funding is still the most important return mechanism for the project, followed by Government Payment, and User Charges is the least. The growth rate of the Viability Gap Funding is greater than the other two return mechanisms.

At the same time, the author statistics the data of the rural residential environment reserve list of the official website of the Ministry of Finance, government and Social Capital Cooperation Center, and found that the return mechanism of most rural residential environment PPP projects is feasibility gap subsidy, accounting for 81%, only a small part is paid by the government, accounting for 19%, and the number of user paid projects is 0. The relevant data are shown in Figure 5. Therefore, this model will compare and analyze the overall project revenue under the Government Payment and Viability Gap Funding return mechanism.

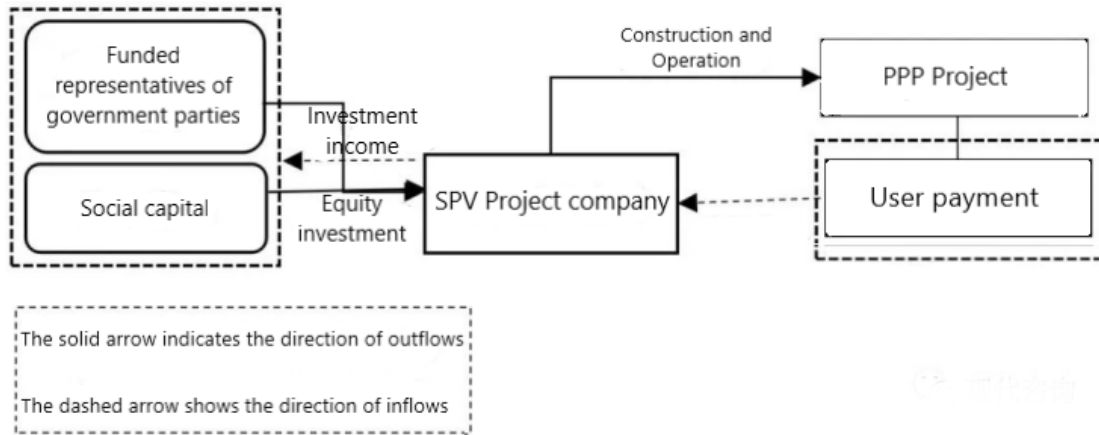


Figure 2. User Charges return mechanism

Source: [Modern Consulting] Original manuscript (official website: www.cfacn.cn)

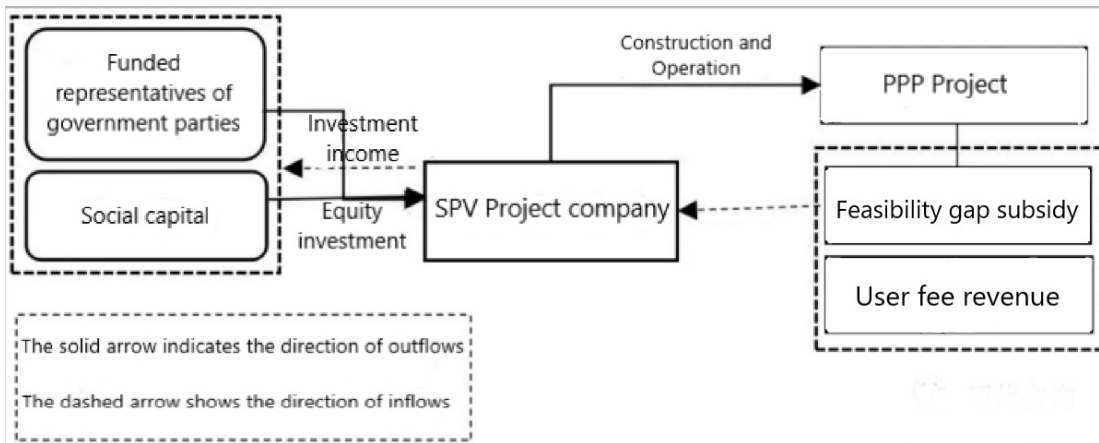


Figure 3. Viability Gap Funding return mechanism

Source: [Modern Consulting] Original manuscript (official website: www.cfacn.cn)

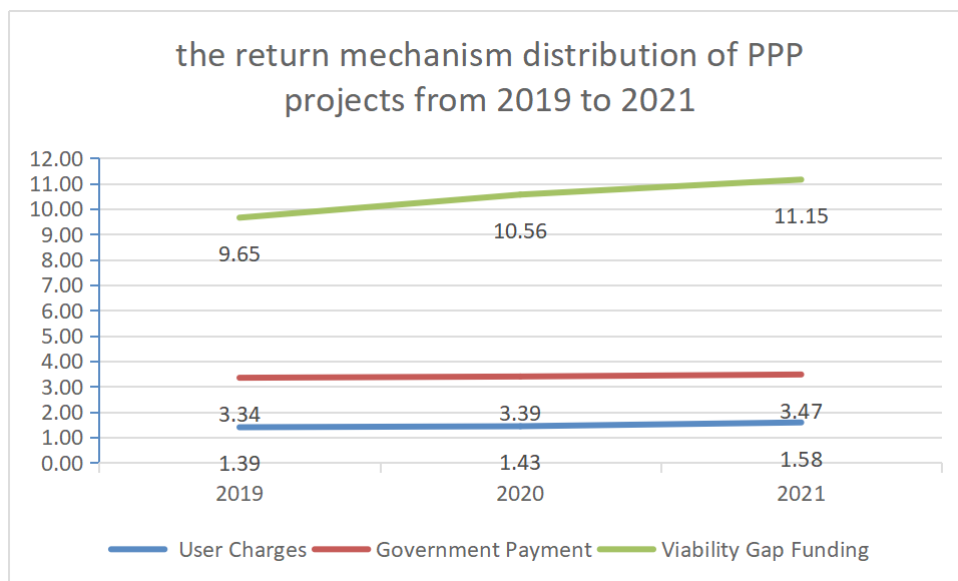


Figure 4. Distribution of project return mechanism of managing database from 2019 to 2021 (unit: one trillion yuan)

Source: Official website of the Government and Social Capital Cooperation Center of the Ministry of Finance

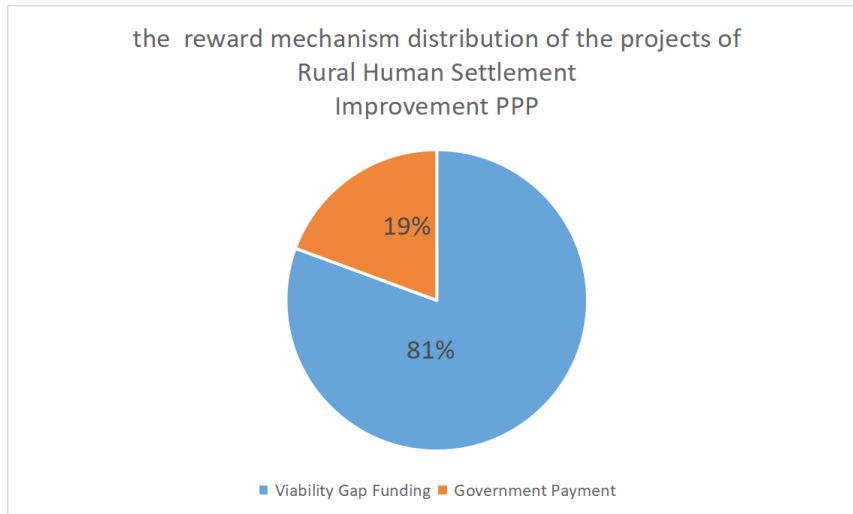


Figure 5. Distribution of project return mechanism of PPP management database

Source: Official website of the Government and Social Capital Cooperation Center of the Ministry of Finance

4. Construction of the Tripartite Game Model of PPP Mode of Rural Environmental Remediation under the Viability Gap Funding Return Mechanism

4.1 Basic Hypotheses

The PPP model of rural human settlement environment improvement involves key subjects such as local government, social capital and rural residents. In order to study the total project income of the three subjects of the PPP model of rural human settlement environment improvement under the Viability Gap Funding return mechanism, the specific assumptions are as follows:

Hypothesis 1: Local government, social capital and rural residents constitute a complete and complex system. The interaction among the three parties is shown in Figure 6. It is assumed that the participants of the three parties are all bounded rational individuals with incomplete information symmetry among them. In the game process, other subjects that may have an impact on the game system in the PPP mode are not considered^[5].

Hypothesis 2: As the purchasers of rural residential environment improvement PPP projects, local governments are responsible for guiding social capital to actively cooperate and supervise their speculation. Their strategic choices are incentive regulation and negative regulation. As a builder of PPP projects, social capital's strategic choice is active cooperation and speculation. As the service recipients of PPP projects, rural residents can actively participate in the construction of environmental remediation projects, or enjoy the benefits of environmental improvement "free riding". Their strategies are to participate

in remediation projects or not to participate in remediation projects. The probability of local government choosing incentive regulation is x , then the probability of negative regulation is $1-x$; the probability of social capital choosing active cooperation is y , then the probability of speculation is $1-y$; the probability of rural residents choosing participation is z , then the probability of not participating is $1-z$.

Hypothesis 3: The income of local government in PPP projects is R_1 ; the regulatory cost is C_1 ; the basic local government expenditure in PPP projects is C_2 ; and the loss of local government when social capital adopts speculation is V .

Hypothesis 4: The basic income of social capital for the project is R_2 ; the cost invested in the project is C_3 ; social capital through fraud, violation of regulations and other speculative activities to gain additional income of R_3 ; the cost of speculation is C_4 ; when the government encourages and regulates and social capital actively cooperates, the reward for social capital according to the completion result of the project is E ; when the government incentives and regulations, the regulatory punishment for social capital violations and other speculative behaviors is P ; if social capital engages in speculative behavior, the loss caused by residents' supervision and reporting is F .

Hypothesis 5: When rural residents do not participate in the project construction, they do not pay the participation cost, but the "free hiking" benefit from the project construction is R_4 ; the income of rural residents participating in the project construction is R_5 ($R_5 > R_4$); the cost of rural residents participating in the project is C_5 ; rural residents shall supervise the speculation of social capital, and the supervision cost is C_6 ; when the government encour-

ages and regulates it, residents participate in the project and supervise it, and the local government rewards it as T .

The interaction between local government, social capital and rural residents under the Viability Gap Funding mechanism is shown in Figure 6.

4.2 Game Payment Matrix and Strategy Solution

According to the above analysis, the three-way evolutionary game payment income matrix of local government, social capital and rural residents is constructed as shown in Table 2 and Table 3.

The expected revenue of local governments in choosing “incentive regulation”:

$$E_{11} = yz(R_1 - C_1 - C_2 - B - E - T) + y(1-z)(R_1 - C_1 - C_2 - B - E) + (1-y)z(R_1 - C_1 - C_2 + P - V - T) + (1-y)(1-z)(R_1 - C_1 - C_2 + P - V) = y(V - B - P - E) - Tz + (R_1 - C_1 - C_2 + P - V)$$

The expected revenue of local governments in choosing “negative regulation”:

$$E_{12} = yz(R_1 - C_1 - B) + y(1-z)(R_1 - C_2 - B) + (1-y)z(R_1 - C_2 - V) + (1-y)(1-z)(R_1 - C_2 - V) = y(V - B) + (R_1 - C_2 - V)$$

The average expected revenue of local governments:

$$E_1 = xE_{11} + (1-x)E_{12} = -xy(P + E) - xzT + x(P - C_1) + (R_1 - C_2 - V) + y(V - B)$$

The expected revenue of social capital in choosing “ac-

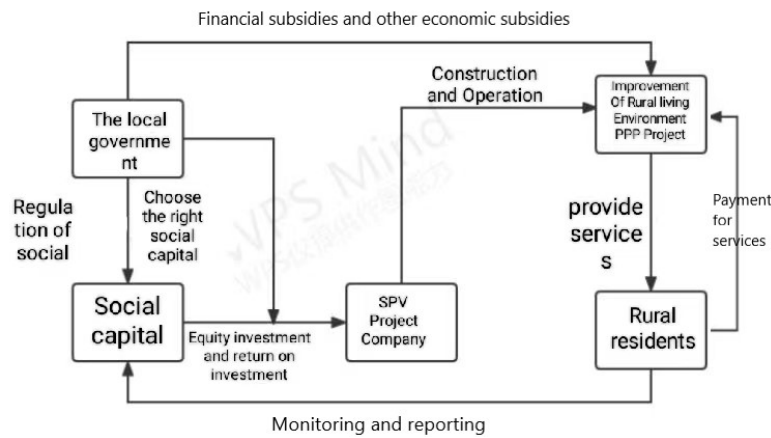


Figure 6. The interaction between local government, social capital and rural residents under the Viability Gap Funding mechanism

Table 2. Three-party game payment income matrix under local government incentive regulation (x)

	Rural residents		
	Participate in (Z)	Not participating ($1-Z$)	
Social capital	Active cooperation (y)	$R_1 - C_1 - C_2 - B - E - T$	$R_1 - C_1 - C_2 - B - E$
		$R_2 - C_3 + B + E$	$R_2 - C_3 + B + E$
		$R_5 - C_5 - C_6 + T$	R_4
	Speculation ($1-y$)	$R_1 - C_1 - C_2 + P - V - T$	$R_1 - C_1 - C_2 + P - V$
		$R_2 + R_3 - C_3 - C_4 - F - P$	$R_2 + R_3 - C_3 - C_4 - F$
		$R_5 - C_5 - C_6 + T$	R_4

Table 3. Three-way game payment income matrix under local government negative regulation ($1-x$)

	Rural residents		
	Participate in (Z)	Not participating ($1-Z$)	
Social capital	Active cooperation (y)	$R_1 - C_2 - B$	$R_1 - C_2 - B$
		$R_2 - C_3 + B$	$R_2 - C_3 + B$
		$R_5 - C_5 - C_6$	R_4
	Speculation ($1-y$)	$R_1 - C_2 - V$	$R_1 - C_2 - V$
		$R_2 + R_3 - C_3 - C_4 - F$	$R_2 + R_3 - C_3 - C_4$
		$R_5 - C_5 - C_6$	R_4

tive cooperation”:

$$E_{21} = xz(R_2 - C_3 + B + E) + x(1-z)(R_2 - C_3 + B + E) + (1-x)z(R_2 - C_3 + B) + (1-x)(1-z)(R_2 - C_3 + B) = E_x + (R_2 - C_3 + B)$$

The expected revenue of social capital in choosing “speculative behavior”:

$$E_{22} = xz(R_2 + R_3 - C_3 - C_4 - F - P) + x(1-z)(R_2 + R_3 - C_3 - C_4 - P) + (1-x)z(R_2 + R_3 - C_3 - C_4 - F) + (1-x)(1-z)(R_2 + R_3 - C_3 - C_4) = -(Px + Fz) + (R_2 + R_3 - C_3 - C_4)$$

The average expected revenue of social capital:

$$E_2 = yE_{21} + (1-y)E_{22} = y[x(E + P) + Fz + B + R_3 - C_4] - (Px + Fz) + (R_2 + R_3 - C_3 - C_4)$$

The expected revenue of rural residents who choose to “participate”:

$$E_{31} = xy(R_5 - C_5 - C_6 + T) + x(1-y)(R_5 - C_5 - C_6 + T) + (1-x)y(R_5 - C_5 - C_6) + (1-x)(1-y)(R_5 - C_5 - C_6) = Tx + (R_5 - C_5 - C_6)$$

The expected revenue of rural residents who choose to “not to participate”:

$$E_{32} = xyR_4 + x(1-y)R_4 + (1-x)yR_4 + (1-x)(1-y)R_4 = R_4$$

The average expected revenue of rural residents:

$$E_3 = zE_{31} + (1-z)E_{32} = z(R_5 - C_5 - C_6) + xzT + (1-z)R_4$$

4.3 Total Project Income of the Three-party Game

$$E_a = E_1 + E_2 + E_3 = R_1 + (y+1)R_3 + (1-z)R_4 + zR_5 - xC_1 - C_3 - (y+1)C_4 - zC_5 - zC_6 + yV + (1-y)B$$

5. Construction of the Tripartite Game Model of PPP Mode of Rural Environment Remediation under the Government Payment Return Mechanism

5.1 Basic Hypotheses

The PPP model for rural human settlements involves key subjects such as local government, social capital and rural residents. In order to study the total project income of the tripartite subjects of the PPP model for rural human

settlements under the government paid return mechanism, the specific assumptions are as follows:

Hypothesis 1: The local government spends C_7 to buy public goods and services, and receives taxes from the social capital party at the tax rate t . The government does not need to pay subsidies and rewards to the social capital party, but when the government encourages and regulates, the regulatory penalty for social capital violations and other speculative acts is P .

Hypothesis 2: The income of the social capital party for the purchase of its own public goods and services by the government is C_7 , and the income from the provision of public goods and services to the government needs to be taxed to the government at the tax rate t .

Other assumptions are the same as those of the tripartite game players under the feasibility gap subsidy return mechanism. The interaction between local government, social capital and rural residents under the Government Payment mechanism is shown in Figure 7.

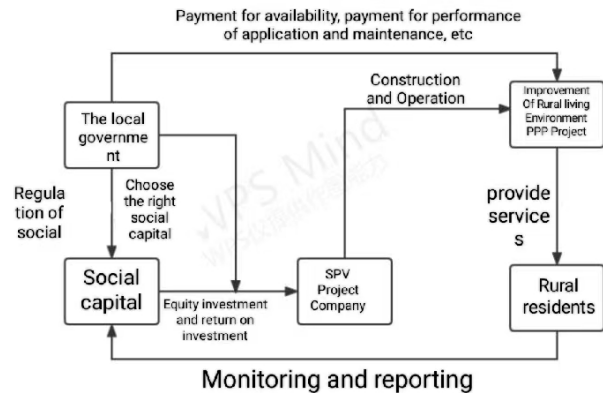


Figure 7. The interaction between local government, social capital and rural residents under the government payment mechanism

5.2 Game Payment Matrix and Strategy Solution

According to the above analysis, the three-way evolutionary game payment income matrix of local government, social capital and rural residents is constructed as shown in Table 4 and Table 5.

Table 4. Payment income matrix of tripartite game under local government incentive regulation (x)

	Rural residents	
	Participate in (z)	Not participating ($1-z$)
Active cooperation (y)	$R_1 - C_1 - C_2 + (t-1)C_7 - T$	$R_1 - C_1 - C_2 + (t-1)C_7$
	$R_2 - R_3 + (1-t)C_7$	$R_2 - R_3 + (1-t)C_7$
	$R_5 - C_5 - C_6 + T$	R_4
Speculation ($1-y$)	$R_1 - C_1 - C_2 + P - V - T + (t-1)C_7$	$R_1 - C_1 - C_2 + P - V + (t-1)C_7$
	$R_2 + R_3 - C_3 - C_4 - F - P + (1-t)C_7$	$R_2 + R_3 - C_3 - C_4 - P + (1-t)C_7$
	$R_5 - C_5 - C_6 + T$	R_4

Table 5. Tripartite game payment income matrix under local government negative regulation (1-x)

		Rural residents	
		Participate in (z)	Not participating (1-z)
Social capital	Active cooperation (y)	$R_1 - C_2 + (t-1)C_7$	$R_1 - C_2 + (t-1)C_7$
		$R_2 - C_3 + (1-t)C_7$	$R_2 - C_3 + (1-t)C_7$
	Speculation (1-y)	$R_5 - C_5 - C_6$	R_4
		$R_1 - C_2 - V + (t-1)C_7$	$R_1 - C_2 - V + (t-1)C_7$
		$R_2 + R_3 - C_3 - C_4 - F + (1-t)C_7$	$R_2 + R_3 - C_3 - C_4 + (1-t)C_7$
		$R_5 - C_5 - C_6$	R_4

The expected revenue of local governments in choosing “incentive regulation”:

$$E_{11}^* = yz[R_1 - C_1 - C_2 + (t-1)C_7 - T] + y(1-z)[R_1 - C_1 - C_2 + (t-1)C_7] + (1-y)z[R_1 - C_1 - C_2 + P - V - T + (t-1)C_7] + (1-y)(1-z)[R_1 - C_1 - C_2 + P - V + (t-1)C_7] = zT + [R_1 - C_1 - C_2 + P - V + (t-1)C_7]$$

The expected revenue of local governments in choosing “negative regulation”:

$$E_{12}^* = yz[R_1 - C_2 + (t-1)C_7] + y(1-z)[R_1 - C_2 + (t-1)C_7] + (1-y)z[R_1 - C_2 - V + (t-1)C_7] + (1-y)(1-z)[R_1 - C_2 - V + (t-1)C_7] = yV + [R_1 - C_2 - V + (t-1)C_7]$$

The average expected revenue of local governments:

$$E_1^* = xE_{11}^* + (1-x)E_{12}^* = x[-yP + zT - C_1 + P] + [yV + R_1 - C_2 - V + (t-1)C_7]$$

The expected revenue of social capital in choosing “active cooperation”:

$$E_{21}^* = xz[R_2 - C_3 + (1-t)C_7] + x(1-z)[R_2 - C_3 + (1-t)C_7] + (1-x)z[R_2 - C_3 + (1-t)C_7] + (1-x)(1-z)[R_2 - C_3 + (1-t)C_7] = R_2 - C_3 + (1-t)C_7$$

The expected revenue of social capital in choosing “speculative behavior”:

$$E_{22}^* = xz[R_2 + R_3 - C_3 - C_4 - F - P + (1-t)C_7] + x(1-z)[R_2 + R_3 - C_3 - C_4 - P(1-t)C_7 + (1-x)z[R_2 + R_3 - C_3 - C_4 - F + (1-t)C_7] + (1-x)(1-z)[R_2 + R_3 - C_3 - C_4 + (1-t)C_7] = [R_2 + R_3 - C_3 - C_4 + (1-t)C_7] - (Px + Fz)$$

The average expected revenue of social capital:

$$E_2^* = yE_{21}^* + (1-y)E_{22}^* = y[R_2 - C_3 + (1-t)C_7] + (1-y)[R_2 + R_3 - C_3 - C_4(1-t)C_7 - Px - Fz] = (y-1)(Px + Fz) + (1-y)R_3 + (y-1)C_4 + [R_2 - C_3 + (1-t)C_7]$$

The expected revenue of rural residents who choose to “participate”:

$$E_{31}^* = xy(R_5 - C_5 + T) + x(1-y)(R_5 - C_5 - C_6 + T) + (1-x)y(R_5 - C_5 - C_6 + T) + (1-x)(1-y)(R_5 - C_5 - C_6) = xT + (R_5 - C_5 - C_6)$$

The expected revenue of rural residents who choose to “not to participate”:

$$E_{32}^* = xyR_4 + x(1-y)R_4 + (1-x)yR_4 + (1-x)(1-y)R_4 = R_4$$

The average expected revenue of rural residents:

$$E_3^* = zE_{31}^* + (1-z)E_{32}^* = z[xT + (R_5 - C_5 - C_6 - R_4)] + R_4$$

5.3 Total Project Income of the Three-party Game

$$E_g = E_1^* + E_2^* + E_3^* = 2xzT + R_1 + R_2 + (1-y)R_3 + (1-z)R_4 + zR_5 - xC_1 - C_2 - C_3 + (y-1)C_4 - zC_5 - zC_6 + (y-1)V + z(x-1)F$$

6. Comparison of the Total Project Income of the Three Parties under the Return Mechanism of Government Payment and Viability Gap Funding

In order to obtain the effects of choosing the reward mechanism of rural human settlement improvement PPP, we compare the total project income of two reward mechanisms by the balance of them.

$$E_a - E_g = -R_2 + 2yR_3 - 2zR_5 + C_2 - 2yC_4 - 2xzT + V + (1-y)B - z(x-1)F$$

The formula above can be regarded as a linear expression affected by a variety of factors including $R_2, R_3, R_5, C_2, C_4, T, V, B$ and F . Therefore, the choice of the reward mechanism of rural human settlement improvement PPP is influenced by the basic income R_2 of social capital, the additional revenues R_3 by the speculation of social capital, the gains R_5 of rural residents participating in the project construction, the basic expenses C_2 in the PPP project of the government, the cost C_4 of social capital speculation, the reward T that the government give to rural residents who participate in the project and supervise the social capital under the circumstance of the government incentive regulation. The loss V of the local government caused by social capital speculation, the government subsidy B obtained by social capital who takes positive actions, the loss F of social capital reported by rural residents participating in supervision. And the coefficient preceded by every factor reflects the influence between the balance of two reward mechanism and every factor. For example, the coefficient preceded by R_2 is -1 , which indicates that

when R_2 is larger, the balance of two reward mechanism is smaller, that is, E_a is smaller or E_g is larger, thus choosing the return mechanism of government payment.

It can be seen from the formula the $x, y, z \in (0, 1)$, so $2y \in (0, 2)$, $-2z \in (-2, 0)$, $-2y \in (-2, 0)$, $-2xz \in (-2, 0)$, $1-y \in (0, 1)$, $-z(x-1) \in (0, 1)v$.

When any factor of the basic income R_2 of social capital, the gains R_5 of rural residents participating in the project construction, the cost C_4 of social capital speculation and the reward T that the government give to rural residents who participate in the project and supervise the social capital under the circumstance of the government incentive regulation is larger, the balance between E_a and E_g is smaller, the return mechanism of Government Payment should be adopted.

When any factor of the loss V of the local government caused by social capital speculation, the additional revenues R_3 by the speculation of social capital, the government subsidy B obtained by social capital who take positive actions, the loss F of social capital reported by rural residents participating in supervision and the basic expenses C_2 in the PPP project of the government is larger, the balance between E_a and E_g is larger, the return mechanism of Viability Gap Funding should be adopted.

7. Conclusions and Suggestions

Based on the evolutionary game theory, this paper constructs an evolutionary game model of cooperative behavior in the PPP mode of rural human settlement environment improvement with local government, social capital and rural residents as the principal part under the mechanism of Government Payment and Viability Gap Funding return. By comparing the total project income of two kinds of return mechanism, this paper discusses the decision design of return mechanism. Under the assumption of bounded rationality of all parties, the following conclusions are drawn:

(1) There is no absolute optimal return mechanism for rural environmental improvement PPP projects. The choice of payback mechanism is affected by multiple factors and needs to be analyzed on a problem-specific basis.

(2) Government Payment return mechanism purchases public commodities and services through direct payment by the government. On the one hand, it can understand the pricing of public services of rural habitat environment, which inhibits the profit-oriented nature of social capital to a certain extent; on the contrary, under the Government Payment mechanism, the government will pay the consideration according to the quality of products and services, and out of the principle of profit maximization of social capital, social capital will improve the quality of products

and services, which reduces the speculative behavior of social capital to a certain extent.

(3) The Viability Gap Funding return mechanism attracts the participation of social capital by providing certain subsidies to social capital to make up for the gap of investment and operating returns that cannot be covered by fees. Due to social capital than the government has a professional, introduce the construction and operation of social capital in rural living environment for the PPP project compared with the traditional government management can improve the efficiency, reduce government spending in the PPP, on the other hand social capital support of the government's financial aid will be more inclined to provide high-quality public services to meet the needs of the rural residents. This makes rural residents more willing to pay for the service, thereby reducing the gap that user fees cannot meet the return on investment and operation, and further reducing the government's financial subsidy.

The return mechanism of PPP projects is still in the initial stage of practice in the field of rural human settlement environment governance. It puts forward decision suggestions for the return mechanism of PPP projects of rural human settlement environment, thus promoting the application and development of PPP model in the field of rural human settlement environment governance according to time and local conditions, and ultimately promoting the sustainable improvement of rural human settlement environment governance. The suggestions are as follows:

(1) Improve the construction of a PPP project database, upload project related data in real time, and provide support for the calculation and research of project return mechanism. The decision-making of the return mechanism is affected by many factors, and a large number of different data need to be obtained. In order to obtain more accurate measurement results and support the decision-making of the return mechanism, it is necessary to establish relevant databases for measurement and research.

(2) The government should take effective regulatory measures to improve its regulatory capacity. Whether adopting the Government Payment model or the Viability Gap Funding model, there are conflicts of interest and value among participants. At the same time, the complexity of rural human settlement environment governance PPP projects has raised higher expectations for the government's regulatory and remediation capacity. The local governments should fairly divide the benefits and responsibilities of relevant stakeholders, formulate effective regulatory policies in combination with their own affordable fiscal expenditures, and improve the defects of the rural environmental governance market mechanism in terms of

supervision.

(3) Improve the investment return mechanism and improve the efficiency and quality of PPP project investment and financing. Local governments, in light of the actual conditions and resource endowment of local governments, carry out rural living environment management and the combined development of other resources to make up for the public welfare income of rural living environment improvement with operating income.

(4) Improve the innovation of the return mechanism of PPP projects in rural human settlements. Accelerate the construction of industry-university-research collaborative innovation mechanism for rural revitalization of human settlement environment, take universities and research institutes as the center, promote the linkage development between multi-disciplines, universities, research institutes and local governments cooperate to strengthen the innovation research of PPP return mechanism, which can make contributions to the research of rural human settlement environment PPP project return mechanism in our country, thus promoting the development of rural revitalization and improving the quality of rural human settlement.

(5) Innovate the issuance mechanism of special bonds for rural human settlements. PPP and special bonds, as government financing tools, are of great significance for alleviating fiscal pressure and thus stabilizing economic growth. Since PPP and special bonds both have the heavy responsibility of “stable growth”, and the issuance mechanism of special bonds is not yet perfect, the PPP return mechanism for rural human settlements has important reference significance for the innovation of special bond issuance mechanism. Improve the trading mechanism of the special bond market, standardize the issuance of special bonds, establish a major news disclosure platform for special bonds, and improve the comprehensive financial reporting system of the government on the accrual basis to provide a reference for the decision-making of the special bond issuance mechanism.

Conflict of Interest

There is no conflict of interest.

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