

Government-led rural Infrastructure PPP Project Risk Allocation

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Abstract—The rural infrastructure PPP project can alleviate the government's financial pressure on rural infrastructure construction to a certain extent, and the reasonable allocation of PPP project risks is a key for the progress of the PPP project. This paper based on the principle of government priority bidding, uses the bargaining game theory to establish a bargaining model for risk allocation of PPP projects under incomplete information, and calculates the risk allocation ratio between government and private sector by calculating the Nash equilibrium. Finally, the beautiful villages PPP project in the Shangyu district is taken as an example to provide a reasonable plan for determining the proportion of risk allocation.

Keywords—Rural infrastructure; PPP project; risk allocation; government sector; private sector

I. INTRODUCTION

At present, China's rural areas are in a critical period of "Poverty Alleviation", so it is necessary to develop rural infrastructure as soon as possible. In 2017, General Office of the State Council of the People's Republic of China issued the "Guiding Opinions on Innovating Rural Infrastructure Investment and Financing System and Mechanism" to innovate the rural infrastructure investment and financing system and accelerate the construction of rural infrastructure [1]. The "Guiding Opinions" proposes to improve rural infrastructure construction by establishing a government and personal sector cooperation mechanism (PPP).

The PPP model, Public-Private Partnerships, known as the "public-private partnership", is a new type of partnership between the government and the private sector to share interests and risks. The PPP model not only effectively satisfies the needs of the Chinese government for rural infrastructure, but also brings economic benefits to the private sector [2]. Because the construction of PPP projects is influenced by a variety of risk factors, both parties need to allocate reasonable risk to ensure the development of the project.

At present, scholars mainly use quantitative analysis and qualitative analysis for the risk allocation research of PPP projects. Some scholars have established models to quantitatively analyze risks. Li S, Wei H and Ni X L establish a risk allocation model for PPP projects through AHP and entropy method [3]; Chanetal uses game theory to allocate risks with BOT projects. [4]; Leng Y, Wang H compare the

characteristics of PPP infrastructure project benefit allocation and established the benefit distribution model of PPP infrastructure projects which is based on Shapley value [5]. Other scholars have discovered the risk allocation scheme based on the qualitative analysis. Carlos Oliveira Cruz proposes the risk allocation principle through the bridge project in Lisbon [6]; Sun Hao studies the case of the Handan to Wuhe Expressway project then concluded that the key to the fair distribution of risk is the establishment of the project contract system [7].

The above researches systematically analyze the risk allocation mechanism of project risks, accurately identify the risks of different projects among different participants, and propose risk allocation plans which provide us with valuable theoretical basis and research experience. However, the above studies have treated the status of the participants equally and have not considered the government's dominant position in the risk allocation of rural infrastructure PPP projects. Based on this, this paper studies the impact of the government's dominant position on the risk allocation of the PPP project under the condition of incomplete information, so that it can better reflect the current situation of the rural infrastructure PPP project. The negotiation process analyzes the bargaining model of rotating bids in game theory and calculates the optimal risk allocation both parties to increase the participation of both parties in the project.

II. PRELIMINARY ALLOCATION OF RISKS IN RURAL INFRASTRUCTURE PPP PROJECTS

A. Rural Infrastructure PPP Project

In recent years, the PPP model has gradually been applied to the construction and management of rural infrastructure in China, such as: PPP project has been applied to the construction and management of straw gasification station in Shaling Town, Hong District, Shenyang [8]. The rural drinking water safety project in Dongping County Shandong Province has also applied with PPP project [9]. In general, the current rural infrastructure mainly uses two different PPP models: First, the operation and maintenance in the outsourcing category, which is mainly implemented in rural power generation, rural roads and sewer construction; the other is the construction-operation-transfer model, which is mainly operated in

communication facilities, farmland water conservancy, and rural water.

However, compared with the development of urban PPP model, the rural infrastructure PPP projects are still in a slow development stage. The overall characteristics of the current performance are: small scope and low operational efficiency. First of all, due to the long period of rural infrastructure investment, low profit and high risk, PPP projects are not attractive [10]; secondly, the participation of various entities in the early stages of the project has affected the efficiency of agricultural land consolidation projects [11]. In response to the above problems, the government needs to provide more preferential policies and assume greater responsibilities and improve relevant risk allocation programs to develop the rural infrastructure PPP model.

B. Risk Analysis of Rural Infrastructure PPP Project

The construction of agricultural infrastructure is slow, and the cycle is long, so there are many risk factors that cannot be predicted in the long-term construction process. Foreign scholar Miller R divides the risks into three categories, namely, the risks from technical design and application, construction costs, time extension and operational problems; market-based risks; laws and regulations from income-generating markets and financial markets. [12]; Bing L and Akin Toye A classify risks into micro and macro categories [13]; Khalil Uddin M analyzes the risk allocation in stages, including initial sharing, negotiation sharing and tracking sharing [14]. This paper refers to the above risk classification method, classifies risks into political risk, financial risk, construction risk, operational risk and natural risk.

TABLE I. PRELIMINARY ALLOCATION OF RISKS IN PPP PROJECTS

Risk	Risk factor	Department
Political Risk	Political and legal changes	government
	Delay in government approval	government
	Tax adjustment	government
Financial Risk	Inflation	Share
	Interest rates change	Share
	Foreign exchange change	Share
Construction Risk	Insufficient supervision	Share
	Technical risk	Private sector
	Construction changes	Private sector
Operational Risk	Environmental risk	Sharing
	Market demand changes	Sharing
	Insufficient supply capacity	Private sector
	Charge changes	Sharing
Natural Risk	Force majeure	Sharing

Ling Y and Yang Y use the questionnaire to interview the academic, government and private sectors' views on the reasonable allocation of risk factors. The average method was used to summarize and analyze the data to obtain the risk allocation preference of Chinese PPP projects [15]. Based on the results of this analysis, this paper carries out preliminary risk sharing for the above risks.

For the risks that exist in the construction of rural infrastructure that require mutual commitment, the government and the private sector should determine the corresponding share. Excessive risk sharing will reduce the private sector's responsibility in the project, and too low risk sharing will make the private sector lack implementation enthusiasm, both of which will lead to slow and inefficient project construction, so PPP project participants' negotiations are usually required to arrive at a reasonable risk allocation plan to achieve a win-win situation.

III. ESTABLISHMENT OF A SHARED RISK SHARING MODEL BASED ON BARGAINING GAME THEORY

The most common way of negotiating in risk-sharing negotiations is bargaining. The government first proposes a risk allocation plan in the risk-sharing process. If the private sector agrees, the negotiation ends. Otherwise, the private sector will bid again. Then the government will indicate that if it does not agree, it will bid again. The bid is looped until the negotiation is reached or the negotiation breaks down.

In the actual negotiation process, the two parties cannot fully get the information of the other party, so it is the game of incomplete information. Usually, in the incomplete information static game, the Nash equilibrium result of the game is solved by the Harsanyi transformation, that is, the other participants are aware of the distribution probability of the type of the participant [16]. Based on this, this paper constructs a risk sharing model based on the principle of government priority bidding under incomplete information conditions.

A. Model Hypothesis

- a) There is only a single buyer (referring to government G) and a single seller (referring to private sector P);
- b) Both are completely rational and do not want the negotiations to break down;
- c) For a certain risk, the government assumes the risk ratio is K_i ($0 \leq K_i \leq 1$), then the risk ratio assumed by the private sector is $1 - K_i$;
- d) Because of the strong position of the government, the government gives priority to bidding in the negotiations.

B. Model parameters

(1) Negotiation consumption coefficient

In the negotiations, the time cost, opportunity cost and information fee paid by both parties are the negotiation consumption of both parties. In the process of bargaining, the negotiations are conducted once more, and the negotiation between the two sides is more expensive. Assume that the consumption coefficients of the government department and

the private sector are q_1 and q_2 , respectively. In fact, because the private sector and the government are not equal, the private sector loses more on negotiation costs, $q_1 < q_2$.

(2) Asymmetry in the status of the government and the private sector

In the PPP project, the government provides funds for the project and issues policies, which have a dominant position relative to the private sector. Therefore, in the risk sharing negotiation process, the status of the two parties is not equal, and the government will use its dominant position to transfer the risk a_i to the private sector.

(3) Probability of the government transferring risk in a strong position

Under incomplete information, the government and the private sector do not know each other's information. However, the private sector can estimate the possibility of the government adopting a strategy based on the subjective probability distribution, that is, the government is expected to use the superiority of the probability p_1 to make the private sector take on more risks or to force the private sector to take the risk by $1-p_1$ more risk.

C. Establishment of risk sharing model for PPP projects under incomplete information conditions

The first round: the government quotes k_1 , that is, the risk of k_1 itself, then the private sector bears the risk of $1-k_1$. At the same time, the government requested that the risk share be transferred to the private sector.

If the government has the possibility of p_1 , the private sector is forced to take on more risks. At this time, the risks of the government department G_1' and the private sector P_1' are:

$$G_1' = p_1 (k_1 - a_1) \quad (1)$$

$$P_1' = p_1(1 - k_1 + a_1) \quad (2)$$

When the government does not force the private sector to share the risk with a probability of $1-p_1$, the risks of the government department G_1'' and the private sector P_1'' are:

$$G_1'' = (1 - p_1) k_1 \quad (3)$$

$$P_1'' = (1 - p_1) (1 - k_1) \quad (4)$$

Therefore, the risk expectations of the government G_1 and the private sector P_1 are :

$$G_1 = p_1(k_1 - a_1) + (1 - p_1) k_1 \quad (5)$$

$$P_1 = p_1(1 - k_1 + a_1) + (1 - p_1) (1 - k_1) \quad (6)$$

If the private sector does not accept the offer for the first round, then enter the second round of bargaining.

The second round: the private sector counter-offer k_2 , that is, the government bears the risk of K_2 and bears the risk of $1-k_2$. The government will also impose additional requirements to transfer the a_2 risk share.

If the government forces the private sector to take on more risks with probability p_1 . At this time, the risks borne by the government G_2 and the private sector P_2 are:

$$G_2' = (q_1 p_1) (k_2 - a_2) \quad (7)$$

$$P_2' = (q_2 p_1) (1 - k_2 + a_2) \quad (8)$$

If the government does not force the private sector to share the risk with a probability of $1-p_1$, the risks borne by the government G_2'' and the private sector P_2'' are:

$$G_2'' = (1 - p_1) k_2 \quad (9)$$

$$P_2'' = (1 - p_2) (1 - k_2) \quad (10)$$

Therefore, the risk expectations of the government G_2 and the private sector P_2 are:

$$G_2 = (q_1 p_1) (k_2 - a_2) + (1 - p_1) k_2 \quad (11)$$

$$P_2 = (q_2 p_1) (1 - k_2 + a_2) + (1 - p_1) (1 - k_2) \quad (12)$$

If the government does not agree with the private sector's offer, it will continue to enter the third round of negotiations. In the same way, the risk expectations assumed by the government G_3 and the private sector P_3 in the third round are:

$$G_3 = q_1^2 p_1 (k_3 - a_3) + (1 - p_1) q_1^2 k_3 \quad (13)$$

$$P_3 = (q_2^2 p_1) (1 - k_3 + a_3) + (1 - p_1) q_2^2 (1 - k_3) \quad (14)$$

The bargaining process will continue until the two parties agree on a distribution plan for the risk-sharing ratio, and the negotiations are over.

D. Solution of PPP project risk sharing model under incomplete information conditions

(1) The situation of a limited period of game

The third cooperation in the selection process is the reverse push point. In the third round, the risk assumed by the government is $G_3 = q_1^2 p_1 (k_3 - a_3) + (1 - p_1) q_1^2 k_3$, the risk assumed by the private sector is $P_3 = (q_2^2 p_1) (1 - k_3 + a_3) + (1 - p_1) q_2^2 (1 - k_3)$

k_3). If the quotation G_2 proposed by the private sector in the second round makes the government assume a greater risk ratio than the third round of the risk ratio G_3 , then the government will reject the second round of quotation, when the negotiations can only enter the third round. In order to save the cost of the negotiation process, the risk ratio will be minimized in the second round, and the risk ratio G_2 of the government in the second round will not be greater than the risk ratio G_3 in the third round.

Then, in the second round, the best option for the private sector and the government to negotiate is:

$$G_2 = G_3 \tag{15}$$

At this time, the risks borne by the private sector P_2 are:

$$P_2 = q_1(1 - q_1k_3 + q_1p_1a_3) \tag{16}$$

$$P_3 = q_2^2(1 - k_3) + q_2^2p_1a_3 \tag{17}$$

Since $q_2 > 1$, $q_2 > q_1$, $1 \geq k_3 \geq a_3 \geq 0$, the derivation is obtained, $P_2 < P_3$.

That is, the private sector's risk ratio in the second round is lower than the risk ratio in the third round, so the private sector will negotiate the second round to conclude negotiations.

Next, push back to the first round of the government to first propose the risk ratio. Similarly, under the full information conditions, the government clearly stated that in the second round of negotiations, the government assumed the risk ratio $G_2 = q_1(k_2 + a_2)$, and the private sector assumed the risk ratio $P_2 = q_2(1 - k_2 + a_2)$. Therefore, in the first round, the private sector will accept as long as the government quotation causes the private sector to take risks no greater than the risks involved in the second round. On the contrary, it will extend the negotiation time into the second round. Therefore, at this time, the government's offer k_1 meets the requirements of the private sector and minimizes the risks it bears. In the second round, the best option for the private sector and the government to negotiate is:

$$P_1 = P_2 \tag{18}$$

$$k_1 = 1 + p_1a_1 - q_2(1 - q_1k_3 + q_1p_1a_3) \tag{19}$$

(2) The situation of indefinite game

For an infinite game model, starting from the third round is equivalent to starting from the first round, and the minimum share assumed is the same, then

$$k_1 = k_3 \tag{20}$$

$$k_3 = 1 + p_1a_1 - q_2(1 - q_1k_3 + q_1p_1a_3) \tag{21}$$

Therefore,

$$k_3 = q_2 - 1 + p_1(q_1q_2a_3 - a_1) / (q_1q_2 - 1) \tag{22}$$

$$1 - k_3 = q_2(p_1 - 1) - p_1(q_1q_2a_3 - a_1) / (q_1q_2 - 1) \tag{23}$$

Assuming \bar{a} is a constant, the equilibrium solution of the risk ratios assumed by the government and the private sector is:

$$K = (q_2 - 1) / (q_1q_2 - 1) + p_1\bar{a} \tag{24}$$

$$1 - K = (q_1q_2 - q_2) / (q_1q_2 - 1) - p_1\bar{a} \tag{25}$$

It can be known from (24) and (25) that K is the proportion of risk assumed by the government department, and $1 - K$ is the proportion of risk assumed by the private sector. $p_1\bar{a}$ is the proportion of government risk transfer, so the actual risk assumed by the government is $(q_2 - 1) / (q_1q_2 - 1)$, and the actual risk ratio of the private sector is $(q_1q_2 - q_2) / (q_1q_2 - 1)$.

When $p_1 = 1$, the government must force the private sector to accept additional risk transfer, at which point the risk transfer ratio is the largest. When $p_1 = 0$, it means that the government will not force the private sector to accept additional risk transfer, that is, the risk transfer share is zero. When $0 < p_1 < 1$, it means that the government has not fully played its dominant position because it is not clear about the strength and weakness of the private sector.

IV. MODEL APPLICATION

The beautiful rural PPP project in Shangyu District is a beautiful rural boutique route and a boutique village and rural infrastructure upgrading project implemented in the two years from 2018 to 2019. The total investment of the PPP project is 2.4 billion, of which 2.2 billion belongs to the PPP range. The cooperation period of the project is 12 years (the construction period is 2 years and the operation period are 10 years). The project is currently in the construction stage.

TABLE II. RELEVANT PARAMETERS OF RISK SHARING OF PPP PROJECTS

Risk factor	Corresponding parameter				
	$p1$	$1-p1$	$q1$	$q2$	a
Inflation	0.65	0.35	1.17	1.21	0.15
Interest rate change	0.62	0.38	1.08	1.16	0.11
Foreign exchange changes	0.82	0.18	1.19	1.25	0.08
Insufficient supervision	0.74	0.26	1.06	1.10	0.13
Environmental risk	0.68	0.32	1.14	1.19	0.10
Market demand change	0.9	0.1	1.12	1.17	0.16
Charge change	0.71	0.29	1.21	1.24	0.09
Force majeure	0.76	0.24	1.15	1.09	0.12

The negotiation process is a negotiation under the condition of incomplete information. According to the Delphi research method, this paper uses the questionnaire to analyze the risk sharing ratio of the beautiful rural PPP project in Shangyu District [17]. A total of 53 questionnaires were distributed during the survey, including 48 valid questionnaires. The staff included project operators and technicians. Through questionnaire statistics and data processing, the risk-related parameters p_1 , $1-p_1$, q_1 , q_2 , a , were determined.

Taking inflation risk as an example, the nominal risk ratios of the government and the private sector are:

Government :

$$= (1.21-1) / (1.17*1.21-1) + 0.65*0.15 = 60.27\%$$

Private sector :

$$= (1.17*1.21-1.21) / (1.17*1.21-1) - 0.65*0.15 = 39.73\%$$

The transfer risk ratio is 9.75%, and the actual risk-to-risk ratios of the government and the private sector are:

Government:

$$K' = (1.21-1) / (1.17*1.21-1) = 50.52\%$$

Private sector:

$$1-K' = (1.17*1.21-1.21) / (1.17*1.21-1) = 49.48\%$$

By analogy, the risk sharing ratio of the PPP project in the beautiful villages of Shangyu District is calculated.

TABLE III. RISK SHARING RATIO OF PPP PROJECTS

Risk factor	Risk allocation ratio				
	Government nominal risk ratio	Private sector nominal risk ratio	Transfer risk ratio	Government actual risk ratio	Private sector actual risk ratio
Inflation	60.27%	39.73%	9.75%	50.52%	49.48%
Interest rate change	70.11%	29.89%	6.82%	63.29%	36.71%
Foreign exchange changes	57.84%	42.16%	6.56%	51.28%	48.72%
Insufficient supervision	69.86%	30.14%	9.62%	60.24%	39.76%
Environmental risk	60.08%	39.92%	6.80%	53.28%	46.72%
Market demand change	69.17%	30.83%	14.40%	54.77%	45.23%
Charge change	54.35%	45.65%	6.39%	47.96%	52.04%
Force Majeure	44.62%	55.38%	9.12%	35.50%	64.50%

V. CONCLUSION

Due to the large number of participants in the PPP project, the investment amount is large, and the term is long. There are many unpredictable risk factors in the life cycle of the whole

project. This paper takes the rural infrastructure PPP project as the research object, points out the five types of risks existing in the current rural PPP project in China, and preliminarily summarizes the risks borne by the government and the private sector according to their risk affordability.

For the part of the risk that cannot be independently controlled or undertaken by both parties, the risk sharing plan is calculated by establishing a risk sharing model. The model uses the bargaining game theory to construct a PPP project risk allocation bargaining game model based on the principle of government priority bidding.

According to the analysis of the model, the proportion of the risk sharing between the two parties is related to the negotiation loss coefficient and the probability of the government transferring the risk. The loss coefficient is often related to the information asymmetry of both parties. The more obvious the asymmetry is, the greater the difference of the loss coefficient. The transfer risk refers to the government transferring the risk to the private sector by virtue of its dominant position. The difference in the status of the two parties is greater. The probability of transferring risk is also greater.

Finally, the risk sharing model is used to determine the proportion of risk allocation of rural PPP projects in Shangyu District, and a reasonable risk allocation plan is obtained, which provides reference value for the risk sharing of rural infrastructure construction and PPP mode combination.

In conclusion, through the study of incomplete information dynamic game method in the risk sharing of PPP projects, reasonable risk sharing can cultivate rational behaviors of government departments and private departments during project operation, achieve the lowest risk management costs, and make PPP projects Participants achieve the goal of mutual benefit and win-win.

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