Game and Simulation of Reasonable Investment Return Mechanism for China's High-Speed Railway PPP Projects

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ABSTRACT
China's high-speed railway PPP project is in the exploration stage, which makes a more benign and efficient interaction between social capital and state-owned capital expected, making the construction of high-speed railway more perfect and more in line with the economic operation trend, and solving the financing problem of high-speed railway construction. This paper first calculates the full investment return range of the high-speed rail PPP project through the capital asset pricing model and the weighted average cost of capital model, establishes a three-stage bargaining game model to analyze the return distribution of the government and social capital in the PPP project, and obtains the theory that the government obtains returns the optimal interval range, combined with the above process, adopts the Monte Carlo simulation method, obtains the reference value of the government's own rate of return through computer simulation, and puts forward suggestions on the investment efficiency of the high-speed rail PPP project according to the game equilibrium result. This paper has certain reference significance for the participants of the high-speed rail PPP project.

Keywords: *PPP project; CAPM model; Game model; Computer simulation.*

1. INTRODUCTION

PPP project is a project operation mode in public infrastructure, which is a cooperation between government and social capital. Under this mode, private enterprises and private capital are encouraged to cooperate with the government for the purpose of project financing. With the rapid development of transportation industry, the financing method of PPP projects is also widely used in the fields of highways and high-speed railways. In order to improve the return mechanism of PPP projects, corresponding regulations have been introduced for the benchmark of "reasonable return on investment", the constraints on the government and the guarantee measures for the return. At present, China is vigorously developing infrastructure projects in the mode of government-social capital cooperation, and a reasonable return on investment is an important guarantee for the successful cooperation between the government and social capital in PPP projects, as well as an important support for the standardization of PPP project management. Looking at the cases of PPP projects at home and abroad, the reasonable setting of investment return mechanism has a significant impact on the success or failure of PPP projects. Therefore, it is necessary to study a reasonable return on investment mechanism.

In recent years, China's high-speed railway has achieved rapid development. Taking Beijing-Shanghai high-speed railway as an example, from 2014 to 2019, the average annual growth rate of Beijing-Shanghai high-speed railway's net profit was as high as 39.4%. Even in 2020, under the severe impact of the new crown pneumonia epidemic, it still achieved a profit of 4.586 billion yuan, which is a veritable benchmark for high-speed rail profitability. Such a high return makes the social parties for open and encourage social capital to participate in major infrastructure construction call gradually high. The construction of the high-speed rail PPP project will reduce the government's financing cost. At the same time, the participation of social capital will make the high-speed rail operation and operation chain more perfect and more adaptable to the needs of the market, and a reasonable financing path is the key to the successful construction and smooth operation of high-speed railway PPP projects. In the field of transportation, the more common is the feasibility gap subsidy type of

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project, which achieves a reasonable level of income through its own operating income and financial subsidies paid by the government. Due to the natural monopoly, capital-intensive [1], public product and long-term revenue characteristics of high-speed railway projects, their asset-specific nature makes it difficult to dispose of railroad lines and equipment with large investment, and the strong position of government departments and national railway groups makes it possible for them to form a "conspiracy" and deliberately "default "[2]. Therefore, it is necessary to explore the "reasonable investment return mechanism" for high-speed railway PPP projects, so as to achieve a win-win situation for the public sector, private sector and banks, and promote the rapid development of China's high-speed railway. This paper first examines the "reasonable return on investment mechanism" for high-speed railway PPP projects by constructing a three-stage boilerplate model.

In this paper, we simulate the process of rate of return allocation between government and social capital by constructing a three-stage game model to obtain the optimal solution of rate of return allocation between them. Computer simulation is used to obtain the estimated value of the government formulated rate of return for the high-speed railway PPP project. This paper has some reference significance for the social capital development and the investment allocation strategy of the government involved in the high-speed railway PPP project.

2. LITERATURE REVIEW

The existing literature on the measurement of returns of PPP projects mainly estimates the returns through models in the fields of technical economics and finance. For example, the paper [3] used the data of PPP projects in the water industry and chose the CAPM model to calculate a reasonable return guideline for private investors in PPP projects in the water line; the paper (Xu, 2019) [4] constructed capital and total investment return measurement models based on the CAPM and WACC models, and empirically derived a reasonable range of capital and total investment return for wastewater PPP projects in recent years.

The research on PPP projects in the existing literature is mainly reflected in the cooperative decision-making and risk assessment of participants. For example, the paper (Wu, 2018) [5] used a combination of binary tree method and Monte Carlo simulation to evaluate the impact of government guarantee policies.

Referring to the existing literature on the measurement model of the return on investment of PPP projects, this paper analyzes the high-speed railway PPP project as an example and studies it from the perspectives of project return, the relationship between the government and social capital, and the government's policy formulation. The innovation points of this paper are mainly reflected in: 1.transportation industry is a key development industry in China recently, and the financing problem becomes an essential research direction, due to the late start of high-speed railway PPP projects, the existing literature on transportation PPP projects is mainly reflected in highways, and there is relatively little research on high-speed railway PPP projects; 2.this paper selects the three-stage game model to explore the government and social capital. In this paper, we choose the three-stage game model to explore the benefit distribution between the government and social capital in PPP projects, and calculate the interval of reasonable benefit return rate of the government by combining the current situation of high-speed railway industry; 3. We use computer simulation method to simulate the benefit distribution of high-speed railway PPP projects, and put forward the reference standard of distribution.

3. GOVERNMENT AND SOCIAL CAPITAL GAME ANALYSIS

An important mechanism for studying PPP projects in the high-speed railway industry is the allocation mechanism of investment returns between the government and social capital, which in turn determines the investment returns of the government and social capital in PPP projects. The allocation of investment returns between the government and social capital is a game process, and the smooth implementation of PPP projects should ensure that both the government and social capital reach a satisfactory state of return. In this paper, we choose a three-stage bargaining game model to study the allocation of investment returns between the two parties and finally find the equilibrium solution of the game between the government and the social capital. Since the government dominates in the game of PPP projects, the government is the last bidder in the three-stage bargaining game [6]. If the social capital and the government do not reach equilibrium in the first two rounds of the game, then according to the agreement of the three-stage bargaining, the social capital must accept the government's proposal in the third round, and the drawn game process between the government and the social capital is shown in Figure 1. Where R represents the rate of return of the high-speed rail PPP project, σ represents the discount factor of each round of the game (i.e., the loss of time and other costs required as each round advances), and the model assumes that the discount factor is the same for each round of the game in order to facilitate the calculation. The conditions for the government to set the rate of return are satisfied.

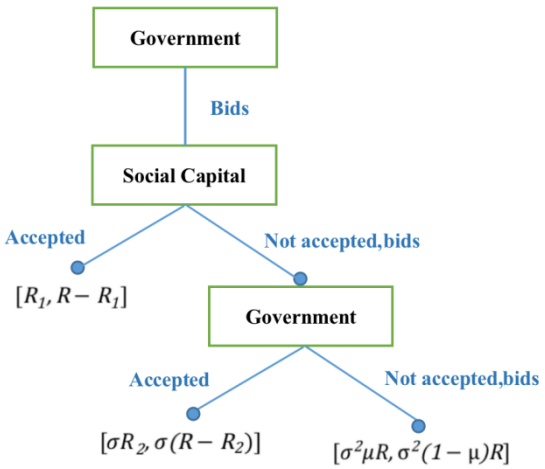

Figure 1: A three-stage bargaining model for government and social capital.

In the three-stage bargaining game model, the reverse induction method is used to analyze the strategies of the government and social capital in the game. In the third round of the game, the government will propose its formulated return on investment scheme, and the social capital can learn about the scheme before the negotiation starts. Suppose the return on investment of the PPP project is R, and the rate at which the government proposes its own share of the return is μ $(0 < \mu < 1)$, then the return on investment that the government can get is μR, and the return on investment of the social capital is $(1-\mu)R$. The three-stage bargaining game model takes into account. The discount factor is taken into account in the three-stage bargaining game model, so in the third round, the actual return on investment that the government can get is $\sigma^2\mu R$, and the actual return on investment of social capital is $\sigma^2(1-\mu)R$. The total benefit obtained by both sides in this round of the game is $\sigma^2 R$.

In the second round of the game, the program proposed by social capital in the second round was for the government to share the return on investment of the project is R_2, then the return on investment of social capital is $R-R_2$. At the same time, considering the discount rate of the second round, the actual return on investment of the project obtained by the government is σR_2, and the actual return on investment of social capital is $\sigma(R-R_2)$. Because social capital can presume that the benefits it obtains in the program proposed in the third round Therefore, in the second round it will propose the scheme that will benefit itself more. In order to make the government accept the ROI in the second round of the game, its ROI scheme for the government satisfies (1) and finally obtains $R_2 \geq \sigma\mu R$, while the decision made by social capital, which satisfies (2), obtains $R_2 \leq (1-\sigma+\sigma\mu)R$. In turn, the project ROI R_2 shared by social capital for the government in the second round of the game is calculated to satisfy $\sigma\mu R \leq R_2 \leq (1-\sigma+\sigma\mu)R$.

$$\sigma R_2 \geq \sigma^2\mu R \quad (1)$$

$$\sigma(R-R_2) \geq \sigma^2(1-\mu)R \quad (2)$$

$$\sigma\mu R \leq R_2 \leq (1-\sigma+\sigma\mu)R \quad (3)$$

In the first round of the game, the government will make the bid, assuming that the government proposes a program that expects its own return on investment in the project is, then the social capital can obtain the benefit is, assuming that the social capital accepts the program developed in the first round of the game, the game is over, and will not carry out the next two rounds, saving the time and cost of the other two rounds of negotiations, so the first round of the game will not involve the discount factor, which will make the government and the social capital as a whole to maximize the available benefits. It will make the government and social capital as a whole to maximize the obtainable benefits. If the government's offer is to make social capital agree in the first round of negotiations, then the government's proposal must make the return on investment that social capital can get not less than the maximum return on investment that social capital can get in the second round of the game, that is, the return on investment that social capital gets satisfies (4).

$$R-R_1 \geq \sigma(R-\sigma\mu R) \quad (4)$$

Solving for $R_1 \leq (1-\sigma+\sigma^2\mu)R$, we get that the maximum ROI that the government itself obtains in the first round of the game is $(1-\sigma+\sigma^2\mu)R$. The ROI that the government sets for social capital is the maximum ROI that it can obtain in the second round of the game, i.e.,$\sigma(R-\sigma\mu R)$. And in practice, the government ROI R_1 set by the government in the first round needs to satisfy both inequalities (4) and (5).

$$R_1 \geq \sigma R_2 \quad (5)$$

Combining (4) with (5) solves for (3), which is brought into the equation and solved for. The critical values of the government and social capital returns for the three games are shown in Table 1.

Table 1: The critical value of the three games government and social capital return.

Number of games	Return to Government	Return to social capital	Overall Return
The first game	$(1-\sigma+\sigma^2\mu)R$	$\sigma(R-\sigma\mu R)$	R
The second game	$\sigma^2\mu R$	$\sigma(R-\sigma\mu R)$	σR
The third game	$\sigma^2\mu R$	$\sigma^2(1-\mu)R$	$\sigma^2 R$

4. MEASUREMENT OF REASONABLE RETURN ON INVESTMENT

Through the above-mentioned game process between the government and the social sector in the negotiation, the reasonable return on investment of the high-speed railway PPP project is measured next, which in turn provides the basic measurement data for the simulation of the rate of return results later on. At present, the mainstream payment calculation methods for PPP project returns include equal principal, equal principal and interest payment formulas. Although the above payment formulas are different, in principle, they all take the construction investment of the project company as the base and calculate the payment that the project company can get in each year of operation according to the annual rate of return of the whole investment, the difference lies in the different amount of principal and interest payment each year.

4.1 Model Construction

The return formula calculated using the WACC model and the CAPM model is as follows:

$$R_e = R_f + \beta_e(R_m - R_f) \quad (6)$$

$$\beta_e = \mathrm{cov}(R_m, R_e) / \partial^2(R_m) \quad (7)$$

In equations (6) and (7), R_e is the return on equity-based investment in the HSR PPP project [7]; R_m represents the return on risk-free assets in the market; R_f is the average return on investment in the market; and β_e is the risk factor, which is related to the systematic risk of the HSR industry.

$$I_c = R_e \times \frac{E}{V} + R_d \times \frac{D}{V} \times (1 - T_c) \quad (8)$$

Here, R_e denotes the cost of equity funds, R_d denotes the cost of debt funds, $\frac{E}{V}$ is the ratio of equity funds to total investments, $\frac{D}{V}$ is the ratio of debt funds to total investments, and T_c is the income tax rate.

4.2 Data selection and calculation

The model was selected from 2015 to 2020, and the data were obtained from the Guotaian database, and the values were taken according to each parameter of the CAPM and WACC models, where R_f represents the return on risk-free assets, and the average yields of 10-year and 30-year Treasury bonds were selected for calculation [8].

R_m represents the average investment return of the market, and the compound growth rate of the SSE Composite Index from 2015 to 2020 is selected to obtain the desired market return (R_m) of 6.95%; β_e represents the risk coefficient, and the values obtained from 8 listed companies in the high-speed railway industry from 2015 to 2020 are selected as samples, and the calculated results are shown in Figure 2. The data of E/V and D/V are based on the Notice of the State Council on Adjusting and Improving the Capital Funding System of Fixed Asset Investment Projects, the minimum ratio of capital funding for fixed asset investment projects is 20%, which is used to set the range of change of debt ratio of PPP projects from 0 to 80%; R_d represents the cost of debt capital, taking the bank medium and long-term loan interest rate of 4.9%; $T_c$represents the income tax rate, according to the income tax rate is 25% according to the relevant provisions of the Income Tax Law of the People's Republic of China.

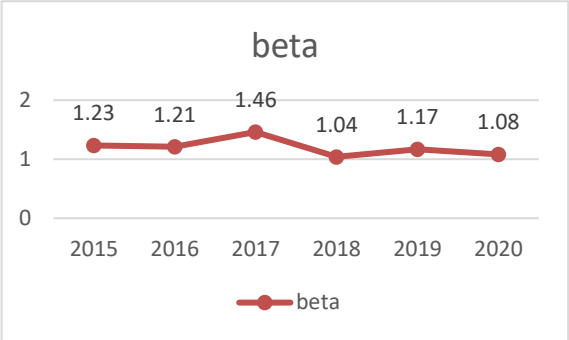

Figure 2: Rail industry listed companies bata value.

The level of return on equity class capital of PPP projects in the high-speed railway industry can be obtained by bringing the parameter values into the CAPM model. When the cooperation period is 10 years and 30 years respectively, the values of return on equity (R_e) are [7.10%, 8.66%] and [7.68%, 8.95%], and the average value is 8.09%, and the plotted curve is shown in Figure 3.

The full return on investment (I_c) of the PPP project in the high-speed railway industry can be obtained by bringing the parameter values into the WACC model. When the debt ratio is between [0%, 80%], the full return on investment of the PPP project in the high-speed railway industry takes a range of [4.56%, 8.09%], and the lower the debt funding ratio is, the higher the expected return is [9].

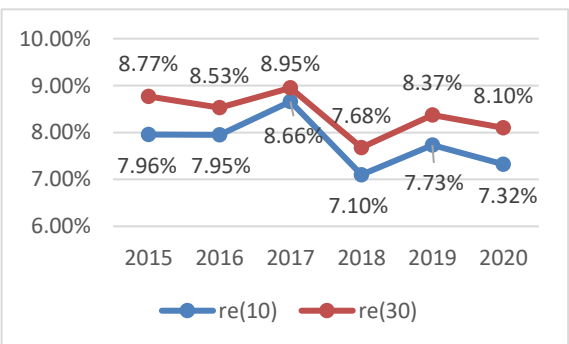

Figure 3: Return on equity funds.

5. PAYBACK ALLOCATION AND COMPUTER SIMULATION

Since the evaluation status of social capital, service performance, and project expectations need to be taken into account in the actual situation, it is more important to be able to estimate an approximate governmental rate of return and thus provide some reference basis for the development of high-speed rail PPP projects. Combined with the above analysis, a computer simulation model is established to calculate the estimated value of the governmental developed rate of return in a large sample situation [10].

5.1 Model Construction

Monte Carlo simulation is a static simulation method, as the previous paper calculated the range of return values of high-speed railway PPP projects, the return rates of different high-speed railway projects are unknown, here the Monte Carlo method is used to simulate a large sample of random values of return values in this range, and then the government return rates that satisfy the conditions are obtained through calculation screening, and then the approximate range of government return rates can be obtained, the specific operation flow chart Figure 4.

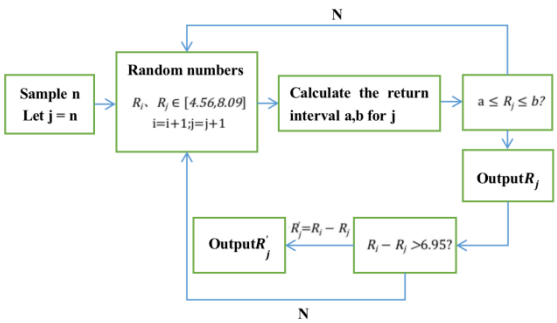

Figure 4: Simulation process of revenue distribution for high-speed rail PPP projects.

Firstly, R_i, R_j satisfying the range of [4.56%, 8.09%] interval is generated, where R_i denotes the rate of return of the HSR PPP project, and the estimated value of the government rate of return interval obtained in the three-stage bargaining model is selected by screening R_j (here, the discount factor σ=20% is assumed), and since the condition for social capital to choose to invest in the HSR PPP project is that at least the rate of return on investment should meet its desired market rate of return, from the previous section, according to the compound growth rate of SSE Composite Index from 2015 to 2020, the desired market rate of return (R_m) is obtained as 6.95%, and then the value of the rate of return that makes the social capital rate of return greater than 6.95% is screened as the rate of return of social capital in the high speed rail PPP project j, i.e. $R_i - R_j > 6.96\%$, by the above calculations, we obtain the rate of return R_i of the high speed rail PPP project in the random large sample case, and the rate of return R_j' obtained by the social capital, and then calculate the expected government return $(R_i - R_j')/R_i$.

5.2 Model Results

The expected government rate of return calculated by the software and averaged to get the government rate of return in the large sample case is 0.30%, where the mean value of the rate of return of the high speed rail PPP project that meets the conditions is 7.39%, and the calculated rate of return that the government can allocate in the PPP project is 4% of the overall project return (0.3%/7.39%). The government can improve its own rate of return by reducing the degree of information asymmetry and financing cost. The government can make more social capital participate in PPP projects by expanding the coverage of social capital, and make higher quality social capital stay through competition mechanism to improve the efficiency and service level of the project, and also improve the government's return in The return rate obtained by the government in PPP projects can also be improved.

6. CONCLUSIONS

This paper analyzes the strategies of the government and social capital in the game by establishing a three-stage bargaining game model and using the inverse induction method to obtain the optimal strategy that maximizes the overall benefit of both parties, and calculates the estimated range of the government's rate of return under the optimal strategy. Finally, computer simulation is used to combine the above processes and simulate using Monte Carlo estimation method to obtain the estimated range of project return and the reference value of government return under the above conditions, and the conclusions of this paper provide some reference suggestions for the participants of high-speed railway PPP projects, and the specific policy suggestions are organized as follows.

1. The government can adjust the return allocation rate of PPP projects to make higher quality social capital participate in the PPP projects.

2. The negotiation process of return allocation is also an important factor to determine the level of return and efficiency of PPP projects, and both parties should fully understand the information in the negotiation process.

3. The government needs to enhance the growth momentum of social capital and stimulate the vitality of all kinds of social capital to make the high-speed railway PPP project more perfect and solve the financing problem.

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