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LETTER

Policy solution and game analysis for addressing the challenge of developing public–private partnership energy project

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Abstract

Various developing countries have been promoting public–private partnership (PPP) infrastructure projects in recent years. Energy infrastructure project construction, which needs substantial capital investments, is a cornerstone of and supports economic development. A PPP-based energy infrastructure project is beneficial for alleviating developing countries' financial burden and for facilitating the diversified development of the energy market. Therefore, to increase government income and reduce infrastructure project costs, the PPP energy project construction model attracts considerable attention of various industries, especially in developing countries. For example, as gross domestic product growth decelerates and the government debt ratio rapidly increases, many Chinese provinces and cities face financial obstacles to economic development; therefore the Chinese government has issued a series of PPP-based energy policies. However, a number of risk factors associated with PPP projects, and conflicting interests between governments and private investors, have resulted in project failure. This study analyzes the development of PPP in China from the economic and industrial development perspective. It combines the latest PPP energy policies of China to solve problems that stem from the main risk factors involved in constructing and operating PPP energy projects. This research also provides game analysis for achieving maximum benefits as the government and the private investor have conflicting interests.

1. Introduction

A public–private partnership (PPP) is a business model that constructs public assets or provides public services through the cooperation of private investors and the government [1]. Investors rely on private investment fund or management participation of infrastructure projects to gain economic benefits by undertaking various risks under this business model [2–4]. The normal infrastructure project directly constructed and managed by the government often result in project failure due to the lack of risk management and cost control. The advantages of teaming with the private sector include the complete use professional skills, resources, and experiences and effectively increasing project operational efficiency [5]. For example, commercial entities or retail consumers can manage microgrids to balance interests of stakeholders [6]. Several infrastructure projects have been planned and completed through the PPP model to alleviate governement's financial burden; this method is considered effective in various developed and developing countries [7]. Through the investment and management of the private sector, the PPP model enables early availability of public products and services that is particularly attractive in developing countries [8]. The private sector is better able to manage project risks than the government [9]. This is because private sector compenies involved in PPP projects are strongly driven by economic benefits, thereby enabling them to implement highly efficient risk management. In addition, the possibility of project overspending is lower than when direct government management is involved [10]. Governments should initiate PPP investments in clean energy projects in order to move emerging market economies towards a sustainable economic

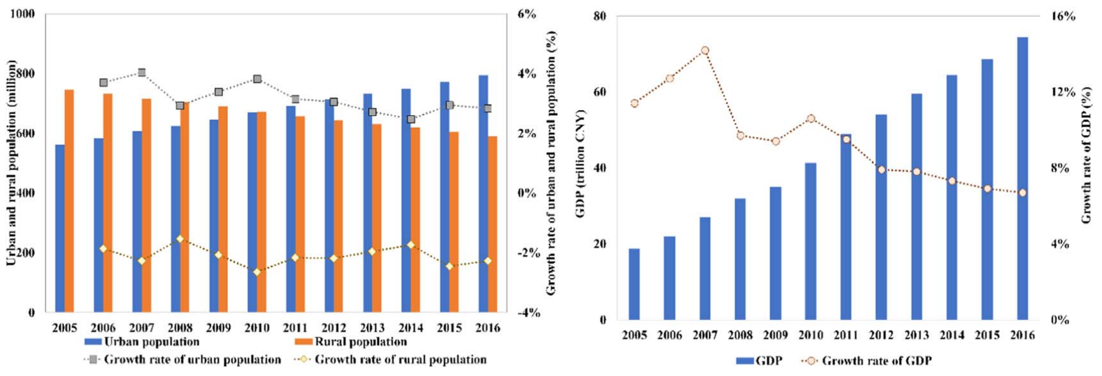

Figure 1. Comparison of urban and rural populations and growth rates (left). Curves of the annual and growth rate of GDP (right). Data source: China Statistical Yearbook (2004–2016).

development [11], and the PPP model is a sustainable energy approach in energy access paradigms [12]. Moreover, private investor participation in electricity network investments is desirable from a government perspective in terms of deregulated electricity markets and integration of renewable energy sources [13]. The PPP model also can be used in semiconductor industry [14], and environmental protection industry [15].

Since the first implementation of the PPP model in the United Kingdom (UK) in the 1990s, this model has been extensively used globally in infrastructure projects in different sectors, such as water supply, medical care, transportation, and energy [16]. There are a number of examples. The European Commission formulated clear policy guidelines to support the PPP infrastructure construction in the Trans-European Transport Networks [17]. Spain has the most large-scale PPP projects compared with the other members of the European Union [18]. Numerous PPP projects are implemented and operated successfully in India [19, 20]. Portugal started a PPP wind power project and put the PPP contract out to tender to attract private capital in 2005 [21]. Energy reform led to the private investor participation in Mexico' energy sector in 2013 [22, 23]. Although the UK, France, and Germany have failed to achieve a satisfying economic effect and the results they expected from applying the PPP model to infrastructure construction, many studies elsewhere have proven that PPP is an ideal model for the effective construction of infrastructure projects [24]. Due to the lack of business management skills of the government, and the long-term operation and high-quality requirement of PPP projects, PPP projects need corresponding supportive policies and strong support by the local government in case of any uncertain risk resulted in project failure. The synergy between government's policy and local traditional system is needed to strengthen PPP [25]. Furthermore, the government aims at achieving a sustainable utility service of PPP projects, and the private investor aims at obtaining more economic benefits. Therefore, how to ensure an effective cooperation between governments and private investors is a huge challenge resulted by the difference between their goals.

Given the comprehensive market-oriented development of developing countries, a delicate balance should be immediately established between private investment and public satisfaction based on the implementation of government policies. Song *et al* [26], Ke *et al* [27], and Shrestah *et al* [28] proposed several methods to achieve this balance, based on their analysis and evaluation of typical cases that avoided various problems sometimes encoutered with PPP projects. Zhao *et al* [29] and Zou *et al* [30] analyzed several factors and management experiences that were found to contribute to PPP project success, thereby offering effective references to draw from to successfully construct PPP projects. However, previous methods and analysis lack the latest data and information on PPP energy project development and do not interpret and consider risks by considering with latest energy policies for PPP energy projects. Therefore, the comprehensive promotion and development of PPP projects should be further analyzed and undergo policy interpretations. This paper presents the main risk factors in PPP energy projects and corresponding policy solution, and game analysis for achieving maximum benefits even if the government's interests conflict with those of private investor. It also provides useful information for other developing countries that expect to develop PPP energy projects.

The remainder of this paper is organized as follows. Section 2 presents the reason for PPP development by analyzing China's national condition. Section 3 analyzes typical PPP energy projects and their main risk factors, and proposes policy solutions. Section 4 demonstrates game analysis that can be used to achieve maximum benefits from PPP projects. Section 5 provides the conclusions.

2. Development of the PPP model in China

2.1. Goals of PPP development

The popularization of the PPP model is an important undertaking to support new urbanization. Urbanization

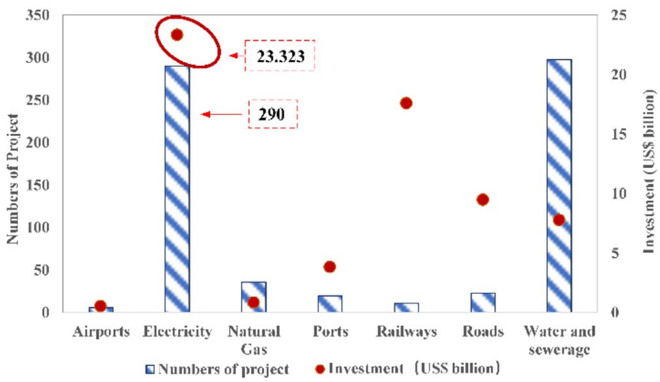

Figure 2. Industrial distribution of the number of and investments in PPP projects.

in China accelerates constantly because of the gradual annual increase of the country's urban population and the decrease of its rural populations (see figure 1). At present, the urban population of China exceeds 0.8 billion, while the rural population has been reduced to 0.6 billion. Meanwhile, the urban population maintains a relative growth rate of 3%, while the rural population has a negative growth rate of approximately 2% in recent years. China's urbanization rate reached 57.35% in 2016, thereby indicating that the country is experiencing pressure on the supply and demand of public facilities and construction peaks of municipal public utilities. Accordingly, the demand for infrastructure services in China is gradually increasing with the country's progressing urbanization and increasing social economic level. However, the government's limited fiscal revenue is insufficient to provide the huge funding necessary for infrastructure construction. The mismatch between the rapid urbanization development and the government's limited discal revenue that results in the increase in the increase in the Chinese government's financial burden. Infrastructure construction using the PPP model mobilizes social resources and private capital to effectively assist urbanization construction and development. The PPP model is recognized as an effective mechanism for ensuring value for money [24]. Thus, the Chinese government focuses considerable attention on this new project financing mode and has implemented a series of supporting policies to accelerate its development.

In addition, China's economic growth is slowing, and the government's financial burden is increasing. Hence, new methods are necessary to stimulate national economic development and relieve debt problems. Although China's gross domestic product (GDP) is continuously increasing, growth rate has declined annually since 2007, thereby indicating the end of the country's rapid economic development (see figure 1). The system of infrastructure construction in a majority of developed countries has taken hundreds of years to develop followed by updating and reconstruction. The Chinese government has attempted to shorten the infrastructure construction and urbanization periods to several dozens of years, thereby resulting in an immense economic pressure. Therefore, the government needs to make an appropriate cut in the expenditure scale of economic construction and optimize the public investment structure.

Furthermore, the debt situations of many local governments in China are affected by the country's financial crisis. Pang and Li [31] determined that the growth rate of the local government debt is higher than the real economic growth rate of China, which is a hypernormal growth trend, and predicted a possible concentrated outbreak of local debt crisis in the next 10 years. The government needs to reduce investments and transfer a part of the market functions to private investors, which helps to properly determine the range of functions of governments, divide the responsibility of governments and private investors, and balance the relation between governments and the market. The Chinese government regards the PPP model as an effective method to alleviate its huge financial burden. Moreover, the PPP model increases investment diversity and provides a reasonable risk-sharing mechanism Overall, PPP is a win–win development mode that gets support from governments and private investors.

2.2. Industrial distribution of PPP

Figure 2 shows the number of PPP infrastructure projects in China from 2007 to the first half of 2017, which is based on World Bank statistics [32]. The 2016 World Bank annual report [33] indicates that the vigorous promotion of the PPP infrastructure construction in China recently has resulted in the average value of PPP project investments reaching US$6.5 billion from 2011–2015 and further increasing by 75% to reach US$11.4 billion in 2016. A total of 684 PPP projects were constructed from 2007 to the first half of 2017 (see figure 2), including 326 PPP projects in the energy industry (e.g. electric power and natural gas projects). The investment amounts in natural gas and electric power projects were US$36 million and US $23.323 billion (ranked first in all investment projects), respectively.

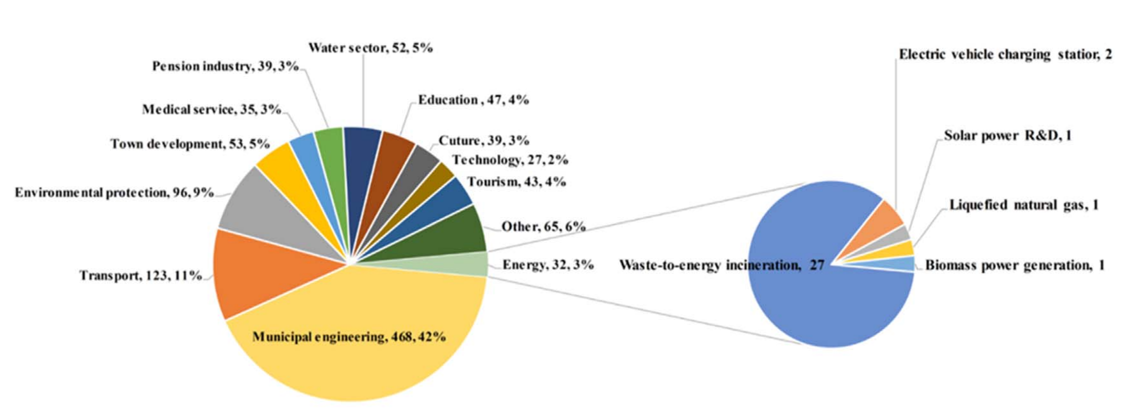

Figure 3. Industrial distribution of the second, third, and fourth batches of PPP demonstration projects and the types of PPP energy projects in China. Data source: [34–36].

However, the effects of implementing PPP energy projects is unsatisfying in China based on the published list of demonstration projects. At present, the Ministry of Finance (MoF) has released the list of four batches of PPP projects. The first batch has small reference values because only 30 demonstration projects, including only 1 PPP energy project, were included. Therefore, this study analyzes the second, third, and fourth batches (i.e. 206, 516, and 396, respectively) of PPP demonstration projects. The PPP demonstration projects represent implementation cases that can be duplicated and popularized. The MoF selected the outstanding projects as the demonstration projects by considering competition in purchasing procedure, authenticity of private investment, reasonability of operation mode, suitability of transaction structure, and sustainability of financial capacity. Figure 3 shows the industrial distributions of the second, third, and fourth batches of PPP demonstration projects from 2015–2018 and there are only 32 energy projects (about 3% of all demonstration projects). According to the World Bank, private investments in PPP energy projects account for a substantially large proportion of the PPP demonstration projects. Although there are large investments, the number of energy projects are small. In addition, these energy projects do not have adequate guidelines and references and enough sustainability for conventional thermal power and renewable PPP energy projects, and also have certain difficulties in using the PPP model in energy projects. As a result, most PPP energy projects in China can barely meet the demonstration project standards and are not strong cases to be duplicated and popularized. This study analyzes and summarizes actual cases, explores the difficulties and risks of promoting and implementing PPP energy projects, and proposes the improvement of schemes by combining the latest relevant PPP policies in China.

3. Project risks and policy solution

3.1. Risk factors of failed cases

Although the first PPP project using build-operate-transfer concessions was constructed 30 years ago in China, the development of the PPP model is still insufficiently mature compared with those in developed countries [37]. Furthermore, major PPP projects in China have experienced a few failures. For example, the construction of the Beijing Olympics venues was completed in 2002, but its operating charges failed to cover investment costs in 2009. Consequently, Citic Union, the main investor, announced that it would abandon its concession agreement, thereby effectively shifting its role from manager to permanent shareholder. In addition, the value of private capitals in winning public tenders of PPP projects and the investment scale of these projects in 2016 were lower than those in 2015 [38]. Furthermore, although the PPP model has been strongly supported by the Chinese government recently, PPP projects have various risk factors that cannot be disregarded. This study investigates and analyzes several typical cases of failed or stagnant PPP energy projects in the world, summarizes the major risk factors and reasons for their failures, and provides recommendations on risk aversion and management. Table 1 presents the details.

All cases presented in table 1 are PPP energy projects and all involved unsatisfactory results caused by various risks. The reasons for project failures were analyzed, specifically those that provided significant references to the development and planning of the PPP energy projects. Figure 4 summarizes the major project risks of PPP energy projects, based on the aforementioned cases. These risks need to be addressed to ensure the successful implementation of a PPP project.

Table 1. Case study of failed PPP energy projects in the world.

Project name	Operation time	Investment amount/concessionaire	Problems
A. Shandong Zhonghua Power Generation Project	1998	16.8 billion CNY/Zhonghua Power Company *et al*	• When the new units started to operate, the Shandong Provincial Price Bureau decreased its electricity price, thereby resulting in the unaffordable cost of the project. • The participation of numerous power generation plants in the power supply prompted the Shandong Development and Reform Commission to decrease the lowest power supply of Zhonghua Power Company and Shandong Electric Power Company from 5500–5100 h in 2003. • Contract constraint forced Shandong Electric Power Company to buy 5550 h of electricity supply at the original price that terminated the unfair contract.
B. Philippines Power Supply projects	The BOT mode was started in 1987	Unknown/Private investors	• During the 1997 Asian financial crisis, the State Power Corporation still singed a BOT agreement with the private sector for a total installed power generation capacity of 2.841 million kW. In 2002, the demand peak of Philippine electricity was only 7.497 million kW, which was equal to 2/3 of the total purchased installed power generation capacity of the power system from the private sector in the Philippines. • The electricity company paid for generated electricity of the power plants rather than the actual dispatched on-grid energy and assumed all risks from market demand fluctuations. The purchase cost of additional electricity was transferred to consumers, thereby resulting in an increase in electricity price.
C. Power generation projects in Colombia	1990s	Unknown/private investors	• To encourage private sector involvement in public services, the Colombian government guaranteed several airports and tollways and signed long-term electricity purchase agreements with independent generators. • Given that the project income was below expectations and many projects have long maturity (30–50 years), the Colombian government had already paid 2 billion USD to the private sector by 2005.
D. Dabhol Power Company	1999	3 billion USD/Enron	• The Southeast Asian financial crisis decreased the exchange rate of Rupee to USD by 40% in 1997. • Agriculture received substantial subsidies from the government but only paid a third of the normal electricity price. • In the beginning of 2001, the dispute between Dabhol Power Company and Maharashtra State Electricity Board (MSEB) on electricity cost escalated and the power plant stopped operation. The government breached the contract by refusing to compensate Dabhol Power Company. • The project construction was continually delayed by the government, thereby resulting in increased project construction cost and electricity price.

Table 1. (Continued.)

Project name	Operation time	Investment amount/concessionaire	Problems
E. Waste incineration power generation projects in the north of Hankou	2011	0.53 billion CNY/Wuhan Hankou Green Energy Co., Ltd	• Urban construction was not completely considered in the project site selection. The new residents around the project was affected as the course of urbanization develops. • The project received public complaints for environmental pollution. The lack of updates in the project feasibility report exacerbated the worsening situation.
F. Zhenzhou Xingjin waste incineration power generation projects	2000	0.245 billion CNY/Hangzhou Jinjiang Group	• Although the power plant started to operate, the business performance was poor, and the plant experienced financial distress. • The shortage of wastes and high transportation costs led to the unaffordable total cost. Meanwhile, the government reduced subsidies for a variety of reasons, such as substandard waste handling methods.
G. Tianjin Shuanggang waste incineration power generation plant	2005	0.54 billion CNY/Tianjin Taida Environmental Protection Co., Ltd	• Site selection for the project lacked a public announcement. The harmful gas production from the operation of the projects caused the residents to panic. • The contract stipulated that the government will provide financial subsidies to the shortage of project benefits. However, no specific amount of the subsidies was provided. For example, the fiscal subsidy in 2012 was below 58 million CNY, which accounted for only 1.25% of the main business income.
H. Chongqing Tongxing waste incineration power generation plant	2005	0.315 billion CNY/Chongqing Steel (Group) Co., Ltd *et al*	• A shortage of wastes was experienced. The basic data of wastes provided by the government failed to match with the actual data. The result was that only one of two incinerators operated and even that cannot meet the demands of the plant. • The process of project approval wasted considerable time. • The government did not construct the supporting facilities as planned. The high costs for transportation, oil, and toll resulted in the supply failing to meet the demand. • Different shareholders have inconsistent benefits. Therefore, a few devices were manufactured by the company of several shareholders or the contract was bundled with other agreements. • During the project construction, the project company lacked strict quality management.

Table 1. (Continued.)

Project name	Operation time	Investment amount/concessionaire	Problems
I. Jiangsu Wujiang waste incineration power generation plant	2009	0.321 billion CNY/WujiangLvzh-ou Environmental Protection Co., Ltd	• Although all project procedures were legal, the project caused strong resident protest, thereby forcing the government to terminate the project by using its administrative power.
J. Kunming Wuhua waste incineration power generation project	2008	0.3 billion CNY/Kunming Xinxin Environmental Resource Industrial Co., Ltd	• The waste incineration technology failed to match the material characteristics of the local wastes. • The government failed to provide sufficient subsidies to the investors, thereby resulting in financial distress to the company. • Policies were imperfect. The government and project companies disagreed on cost adjustment for waste processing, collection, and power line communication. • As investors withdrew funds, no new investors participated in this project.

Project No. Risk (%)	A	B	C	D	E	F	G	H	I	J
	Projects									
Government decision-making risk		X	X	X	X				X	
Government credit risk	X			X			X			
Revenue risk			X			X	X			
Public opposition					X		X		X	
Environment risk					X				X	
Change in market demand	X	X								
Technical risk								X		X
Delay in project approvals and permits				X				X		
Supply risk						X		X		
Exchange rate				X						
Legal and policy risk										X
Payment risk										X
Lack of supporting infrastructure								X		

Figure 4. Summary of the project risks of PPP energy projects in the world.

3.2. Policy solutions for project risks

Major project risks have resulted in failed PPP projects. An effective way to ensure PPP projects success is to eliminate the negative influence of these risks on PPP projects. According to the interpretation of PPP policies, the policy solutions in table 2 are proposed in consideration of the aforementioned risks.

There are brief description about these main risk factors in PPP projects. (1) Government decision-making risk. This risk is typically caused by the improper construction planning of the government. This risk occurred frequently, thereby resulting in the failure of projects. (2) Government credit risk. Government credit should be improved by clear policies and regulations and local governments should be monitored by a third party. (3) Revenue risk and payment risk. Market benefits are mainly determined by cost and profits, thereby making energy projects substantially sensitive to energy materials and market price. (4) Public opposition risk and environment risk. These two risk factors interact in a manner to enable the simultaneous consideration of their prevention. For energy projects, the public opposition comes from environmental factors. (5) Change in the market demand risk. Without adequate market investigations, PPP projects cannot ideally make adjustments in market strategy to respond to changes in the market demand. (6) Technical risks. To eliminate the technical risks, the primary target is to achieve a comprehensive data collection and market investigation. (7) Delay in project approvals and permits. The increasing attention of China's government has resulted in the official issuance of various documents to manage and constraint government departments. (8) Supply risk and lack of supporting infrastructure risk. These two risks can be considered and solved simultaneously for energy projects. The product supply-demand relationship in the market requires advanced planning and prediction. (9) Exchange rate risk. The hedging of this risk is feasible through derivative financial instruments. (10) Legal and policy risk. Local governments should establish the appropriate legislations and policies prior to project construction to prevent unclear responsibility sharing.

4. Game analysis for achieving maximum benefits

The government and the private investor have different demands and functions as the stakeholders in PPP projects. The government mainly focuses on realizing a long-term development of PPP projects and provides policy support. The private investor focuses more on obtaining the economic benefits from PPP projects and improves the operation efficiency of PPP projects. Therefore, effective complementation between the functions of the government and the private investor in PPP projects determines a PPP project's future growth of value. In addition, a reasonable benefits distribution between the government and the private investor facilitates the sustainable development of PPP projects. Based on choosing an optimal effort level and distribution coefficient of governments and private investors, this section demonstrates how to use game analysis to achieve maximum benefits from PPP projects. Three assumptions can be used to analyze the choice process of the distribution coefficient and effort level efficiently:

Assumption 1. The PPP project consists of governments and private investors, and the benefits of the PPP project are closely related to their effort levels. Project benefit is assumed as:

$$E = \alpha\sqrt{e_1} \cdot \sqrt{e_2} + \varepsilon, \tag{1}$$

where, e_1 and e_2 are the effort levels of the government and the private investor respectively. ε is the external uncertainty factor. Additionally, ε is a random variable in Gaussian distribution, whose average value and variance are 0 and $\sigma 2$ respectively, and follows the independent distribution. α is the correlation coefficient between the government and private investor

Table 2. PPP energy policy solutions and interpretations.

Project risks	Policy solution	Policy interpretation
Government decision-making risk	[39–44]	• Authorize the private sector to determine their obligations • Optimize public service and improve decision-making ability • Establish proper project evaluation
Government credit risk	[43, 45–47]	• Governments take responsibility for legal and economic losses because of a change in leadership of local governments • Promote the financial institution to support PPP projects
Revenue risk and payment risk	[41, 43, 48–52]	• Evaluate cost efficiency during the project recognition or preparation stage • Provide a good business investment environment and market coordination • The supervision department implements contract review and follow-up procedures to prevent unspecific responsibilities of payment and violations of contract terms
Public opposition risk and environment risk	[44, 53–55]	• Supervise and examine standard carbon emissions, pollution discharges, and relevant environmental protections • Standardize operation, enhance the public supervision capability, and prevent environmental problems and public opposition • Support the insurance of asset securitization so the public can purchase asset-backed security
Change in the market demand risk	[51, 56]	• Governments establish a coordination mechanism responsible for project review, department coordination, and supervision • Support PPP energy project to realize long-term economic revenue
Technical risks	[57–59]	• Enhance the supply capacity and quality of public products and ensure the technological capacity of private sector
Delay in project approvals and permits	[47, 51, 56, 60–63]	• Stipulate details of approvals, confirm processing time, and increase punishment for delayed approval • Support information disclosure of the approval process and result, and prevent delayed approval
Supply risk and supporting infrastructure risk	[47, 51, 57, 63, 64]	• Alleviate supply risk in the early site selection stage • Governments enhance responsibilities, offer an excellent investment environment, and prevent inadequate supporting infrastructure
Exchange rate risk	[65]	• Develop financial instruments in PPP projects to protect asset value and reduce risks from exchange rate fluctuation
Legal and policy risk	[61, 66, 67]	• Implement specific management methods of investment legislation to prevent legal and policy risks • Prevent local government's inconsistent application of legislation and policy

that represents degree to which effort produces benefits.

Assumption 2. The government and the private investor choose a reasonable effort level based on the benefit distribution. The government's cost is calculated as:

$$C(G) = 0.5\ e_1^2. \quad (2)$$

The private investor's cost is calculated as:

$$C(P) = 0.5\ e_2^2. \quad (3)$$

Assumption 3. The private investor and the government share the total benefits of PPP projects. It is assumed that the distribution coefficient of the government is $\beta (0 < \beta \leqslant 1)$.

The government and the private investor can calculate different effort levels, based on a perspective of individual or collective benefits. Therefore, there are four scenarios in PPP projects.

Scenario 1. The government and the private investor both choose their effort level from an individual benefits perspective.

The government's expected benefits are calculated as:

$$E(G) = \beta\alpha\sqrt{e_1} \cdot \sqrt{e_2} - 0.5\ e_1^2. \quad (4)$$

The private investor's expected benefits are calculated as:

$$E(P) = (1 - \beta)\alpha\sqrt{e_1} \cdot \sqrt{e_2} - 0.5\ e_2^2. \quad (5)$$

Scenario 2. The government and the private investor choose their effort level from a collective benefits perspective. The expected benefits are calculated as:

$$E(e_1; e_2) = \alpha\sqrt{e_1} \cdot \sqrt{e_2} - 0.5\ e_1^2 - 0.5\ e_2^2. \quad (6)$$

Scenario 3. The government chooses its effort level from an individual benefits perspective. The private investor chooses the effort level from the perspective of collective benefits.

Scenario 4. The government chooses its effort level for collective benefits. The private investor chooses its effort level for individual benefits.

According to game analysis, the total benefits can be calculated based on different effort levels in these scenarios (see table 3).

Conclusion 1. If the government chooses its effort level from an individual benefits perspective, based on the comparison between the values of $E(P)_1$ and $E(P)_3$, the result can be calculated as follows:

when $0 < \beta < \frac{11 - \sqrt{13}}{18}$, the private investor chooses its effort level from a collective benefits perspective; when $\frac{11 - \sqrt{13}}{18} < \beta < 1$, the private investor chooses its effort level from an individual benefits perspective.

Conclusion 2. If the government chooses its effort level from a collective benefits perspective, based on the comparison between the values of $E(P)_4$ and $E(P)_2$, the results is the same as that of Conclusion 1.

Conclusion 3. If the private investor chooses its effort level from an individual benefits perspective, based on the comparison between the values $E(G)_1$ and $E(G)_4$, the result can be calculated as follows:

when $0 < \beta < \frac{7 + \sqrt{13}}{18}$, the government chooses its effort level from an individual benefits perspective; when $\frac{7 + \sqrt{13}}{18} < \beta < 1$, the government chooses its effort level from a collective benefits perspective.

Conclusion 4. If the private investor chooses its effort level from a collective benefits perspective, based on the comparison between the values of $E(G)_3$ and $E(G)_2$, the result is the same as that of Conclusion 3.

In summary, there are three situations:

(1) when $0 < \beta < \frac{11 - \sqrt{13}}{18}$, the government chooses its effort level from an individual benefits perspective, the private investor chooses its effort level from a collective benefits perspective;

(2) when $\frac{11 - \sqrt{13}}{18} < \beta < \frac{7 + \sqrt{13}}{18}$, both the government and the private investor choose their effort level from an individual benefits perspective;

(3) when $\frac{7 + \sqrt{13}}{18} < \beta < 1$, the government chooses its effort level from a collective benefits perspective, and the private investor chooses its effort level from an individual benefits perspective.

The government and the private investor would not choose their effort level from a collective benefits perspective simultaneously. Moreover, according to game analysis (see table 3), the relation can be known: $E_3 > E_1$ and $E_4 > E_1$. Therefore, to achieve the maximize benefits for the government and the private investor, the value of β can be set to make the total benefits approach to E_3 or E_4. Consequently, when $0 < \beta < \frac{11 - \sqrt{13}}{18}$ or $\frac{7 + \sqrt{13}}{18} < \beta < 1$, the maximum total benefit can be achieved, and the conflicting interests between the government and the private investor can be eliminated.

Table 3. Game analysis based on optimal effort level in four scenarios.

Private sector government	Individual benefits	Collective benefits
Individual benefits	$E(G)_1 = \frac{3\alpha^2\beta}{8}\sqrt{\beta(1-\beta)}$ $E(P)_1 = \frac{3\alpha^2(1-\beta)}{8}\sqrt{\beta(1-\beta)}$ $E_1 = E(G)_1 + E(P)_1 = \frac{3\alpha^2}{8}\sqrt{\beta(1-\beta)}$	$E(G)_3 = \frac{3\alpha^2\beta}{8}\sqrt{\beta}$ $E(P)_3 = \frac{3\alpha^2}{8}\sqrt{\beta} - \frac{\alpha^2\beta}{2}\sqrt{\beta}$ $E_3 = \frac{3\alpha^2}{8}\sqrt{\beta} - \frac{\alpha^2\beta}{8}\sqrt{\beta}$
Collective benefits	$E(G)_4 = \frac{\alpha^2\beta}{2}\sqrt{(1-\beta)} - \frac{\alpha^2}{8}\sqrt{1-\beta}$ $E(P)_4 = \frac{3\alpha^2(1-\beta)}{8}\sqrt{1-\beta}$ $E_4 = \frac{\alpha^2\beta}{8}\sqrt{1-\beta} + \frac{\alpha^2}{4}\sqrt{1-\beta}$	$E(G)_2 = \frac{\alpha^2\beta}{2} - \frac{\alpha^2}{8}$ $E(P)_2 = \frac{3\alpha^2}{8} - \frac{\alpha^2\beta}{2}$ $E_2 = \frac{\alpha^2}{4}$

Note: G = government; P = private investor; α = the correlation coefficient between the investor and government; β = the distribution coefficient of the government. The subscripts represent the corresponding scenarios.

5. Conclusions

Various developing governments are currently promoting and developing PPP financing projects; therefore, studies on the latest energy policies are needed to analyze the risk factors in PPP energy projects and the reasons for developing PPP projects. In China, as GDP growth decelerates and the government's debt ratio increases, China's government is promoting PPP development of infrastructure construction. The advantages of the PPP model are that it not only improves market vitality and forces the government to share market risk by involving the private sector, but also helps to realize the effective use of special management experience and market means of the private sector, strengthening the possibility of increasing project profits and relieving fiscal burdens and development restrictions of the government caused by the current limited financial resources.

This study analyzes and summarizes the causes and effects of the Chinese government's promotion of PPP infrastructure construction. The issues related to PPP energy projects are identified based on the latest industrial distribution and specific data from demonstration engineering construction PPP projects. The PPP policies related to the energy industry are interpreted and used in an analysis of risk factors inherent in PPP energy projects. Failed PPP energy projects are analyzed comprehensively, and their failure risks are summarized. The occurrences and negative influences of risks could be prevented based on the analyses and interpretations of policies. Moreover, the maximum benefits can be achieved by game analysis, even if interests of the government and the private investor conflict.

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