Risk Identification and Risk Allocation in Greenfield Public-Private Partnerships in China

by

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ABSTRACT

With the rapid economic development experienced in China, there is increasing need for more and better public infrastructure. Public-private partnership (PPP), an innovative method for delivering infrastructure projects has been increasingly attractive to both the Chinese government and to the private parties. However, the complex risks inherent in the PPP model have hindered the success of some previous PPP projects in China. This research aims to provide a comprehensive assessment of risks particular to greenfield PPPs in China. A questionnaire survey has been delivered to experts in infrastructure development or in the PPP model. Based on the 41 valid response received, the top 5 critical risks in greenfield PPPs in China are government intervention, difficulty in financing, project price change, construction cost overrun, and conflicting and imperfect contracts. The survey result concludes that government-related risks should be allocated to the public party because these risks can be better controlled by the public party. Risks related to the EPC value chain (engineering, procurement and construction) are suggested to be allocated to the private party. The rest of the risks are preferred to be shared between the public and the private party at some ratio depending on the negotiation between the two parties. The bargaining process for risk allocation between the two parties is analyzed using an alternating offer game with finite rounds. The game shows that the first mover advantage is not guarantee, and the final payoffs for both players depend on the size of the initial pie, the level of patience of each player and number of rounds in the whole process. Based on a qualitative analysis of China's unique economic and political condition, this research aims to provide some suggestions on infrastructure development and public policy for China's PPP implementation.

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I. Introduction

There is massive demand for infrastructure in both developed and developing countries. Emerging countries have more urgent need for infrastructure development as they want to improve their economic performance in the global economy. China, for instance, has developed an aggressive infrastructure plan that includes public/private sector financing aimed at tackling its water quality/quantity problems, air pollution and energy problems, and soil degradation problems[1].

On the one hand is high demand for infrastructure, while on the other hand is a widening global infrastructure funding gap. The world today invests approximately $2.5 trillion a year on transportation, power, water, and telecommunications systems. Yet it is still not enough. A report in 2016 points out that the world needs to invest an average of $3.3 trillion annually just to support currently expected rates of growth. Emerging economies will account for about 60 percent of that need[2]. Also, green infrastructure costs money. Estimation shows that the incremental costs to "green" infrastructures and make them sustainable could be as much as $4 trillion in gross terms, not including operational savings and positive externalities[3]. The accelerating debt growth of Chinese local governments forces the country to seek approaches to finance the infrastructure costs more efficiently.

In recent years, public-private partnership (PPP), an innovative method for financing and delivering infrastructure has been increasingly attractive to both the government and to corporations in China. There is no one standard definition of PPP. According to PPP Knowledge Lab, public-private partnership is "a long-term contract between a private

[1] "Rethinking Infrastructure Finance." Infrastructure Finance Group, Stern School of Business, New York University.
[2] McKinsey Global Institute
[3] The Brookings Institution

party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance"[4]. Compared to the traditional method where the government finances and delivers the project themselves, the PPP model enables the government to transfer some of the responsibilities and risks to the private sectors. The PPP model brings advantages including but not limited to: a competitive bidding process, appropriate balance of project risks, and private sector innovation and expertise. Thus, it helps to improve operational efficiency and optimize the budgetary expenditure structure for the infrastructure projects.

PPP was pioneered by U.K., French and other European governments—took the form of build-operate-transfer (BOT), build-own-operate (BOO) and design-build-finance-operate (DBFO) arrangements. It has been used internationally in more than 85 countries and it has already been successful in countries such as the UK, Australia, US, Spain, and Germany. PPP stages include initiation, design, financing, construction, operation and maintenance. Participants include government, project sponsor, project company, creditors, and contractors, categorized into two groups: public sector (government) and private sector (all others). However, since both sectors need to work together under many stages of a project and the whole process usually takes twenty to thirty years, there must be many risks involved. Previous studies identified risks including macroeconomic risks such as inflation rate volatility and interest rate volatility, construction and operation risks such as completion risk and cost overrun, risks from the government, as well as risks from the conflicts and negotiation between the public and private sectors.

[4] The PPP Knowledge Lab

The PPP model was introduced in China in the late 1970s as an attempt to encourage the country's reform. With increasing demand for more and better infrastructure, the Chinese government started to apply PPP schemes at a large scale in the 1990s by introducing more foreign investment, especially for water, power, and road projects.

There have been many researches studying the risks of implementing PPP in mainland China. Among the studies, most of them focus on traditional infrastructure such as railway and water supply. Since green infrastructure is of great importance for China to meet its goal of sustainable economic and social development, this research aims to study the risks in China's renewable energy infrastructures when adopting the PPP model.

In particular, the research will investigate risk identification and risk allocation in the case of the rooftop solar power project under the auspices of the New Development Bank (formerly known as BRICS Bank). The media reports in April 2016 that the New Development Bank has provided a loan of $81 million in Yuan for a 100 megawatt rooftop solar energy project sponsored by the Shanghai Lingang Hongbo New Energy Development Company[5]. This project is the first recipient in China of a loan from the NDB and it adopts the PPP model.

Using questionnaire survey, the research is intended to estimate the influence of the potential risks financing and delivering the solar power project based on the PPP model. The target respondents include industrial practitioners in the public and private sectors who have been involved in infrastructure projects in China; and academics who have been involved in the research of infrastructure projects or PPPs in China. The participants in the survey were asked to identify the major critical risks in the project. They were also invited to calibrate risk allocation in the project.

[5] China Daily

A game theoretical approach is introduced to analyze the risk allocation process between the public and private sectors. Risk allocation in PPPs can be analyzed using different models. This research uses an alternating offer game with finite horizon to investigate the bargaining process between the two sectors.

With survey results and a game theoretical approach, this research is intended to provide some insights into the risk allocation between the public sector and the private sector in the case of this project and the broader applicability of the findings.

II. Literature review

Public-private partnership (PPP) projects have been pretty successful in places such as Western Europe, the US and Australia. However, due to the various risks inherent in the PPPs and China's immature regulatory environment for PPP implementation, some of the earlier PPP projects in China have not been economically efficient. For instance, the construction of the Beijing National Stadium ("Niao-Chao")—based on PPP financing, suffered from both construction delay and construction cost overrun. According to a case study of the Beijing National Stadium, instead of completing the construction by the end of 2006 as planned, it was actually completed on June 28th, 2008. Moreover, construction costs over-ran the budget by RMB 0.456 billion[6]. This example shows that the need for infrastructure development in China may override concerns around construction and operating efficiency requirements.

Hangzhou Bay Bridge is another example. Five years after the bridge opened to traffic, the bridge's operator faced a huge capital shortfall of 850 million RMB. The actual revenues from toll collection were far lower than expected, mainly due to the huge gap between the amount of traffic forecast by the research team and the actual traffic on the bridge. According to studies, the actual traffic volume fell below the forecast because the local public authorities opened up alternative transportation routes around the bridge.

Based on previous studies, government intervention has been identified as a primary cause of failure of many types of PPPs in China, including water and waste water, power and energy, and transportation sectors. Other critical risk factors in PPP in China have been government corruption, poor public decision-making process, imperfect law and

[6] Ke, Yongjian. "Is Public–private Partnership a Panacea for Infrastructure Development? The Case of Beijing National Stadium." *International Journal of Construction Management* 14.2 (2014): 90-100.

regulation system, followed by risks related to economic viability, the market environment, the construction and operating processes and the state of China's macro economy[7].

Researches have shown that proper risk allocation between the public and private sectors contributes a lot to the success of a PPP project. The risk allocation problems in PPPs have been analyzed in many previous researches using different game theoretical models. A most recent paper was by Yan Li, Xinyu Wang and Yahui Wang. Their study focused on the relationship between risk allocation ratio and alternating offer sequences. In the research, they built an alternating offer game with three rounds of offer to formulate risk management strategies in PPPs. Their result shows that the risk allocation ratio between the public and private sectors is associated with the sequence of alternating offers, the discount factor and the asymmetric degree of knowledge about the other party[8]. However, their research as well as many other previous researches modeled the risk allocation process in PPPs as a three-stage game. In this research, I will generalize the risk sharing model into an n-stage alternating offer game.

This research aims to test the results produced by previous research and to provide a comprehensive assessment of risks particular to PPP in China, based on a qualitative analysis of China's unique economic and political condition.

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[7] Xu, Yelin, John F.y. Yeung, Albert P.c. Chan, Daniel W.m. Chan, Shou Qing Wang, and Yongjian Ke. "Developing a Risk Assessment Model for PPP Projects in China — A Fuzzy Synthetic Evaluation Approach." *Automation in Construction* 19.7 (2010): 929-43.

[8] Li, Yan, Xinyu Wang, and Yahui Wang. "Using Bargaining Game Theory for Risk Allocation of Public-Private Partnership Projects: Insights from Different Alternating Offer Sequences of Participants." *Journal of Construction Engineering and Management* 143.3 (2017): 04016102.

III. Research Design and Data

This research adopts questionnaire survey to estimate the relative importance of different risk factors in the solar power PPP project in China.

i) Questionnaire survey

Based on comprehensive literature review and findings from previous questionnaire survey, my survey listed 17 potential risk factors in this PPP project. See **Appendix 1** for detailed descriptions of the risk factors.

A total of 120 surveys were sent out. The target respondents either have been involved in the management of infrastructure projects in China; or have been working in the infrastructure industry; or have gained in-depth knowledge of the PPP model through their own research or the research of others. The respondents were invited to complete the questionnaire survey on assessing risks in the solar power project in China.

The questionnaire was divided into two parts. In the first part of the survey, the participants were requested to:

1) Assign an estimated probability of occurrence based on a 5-point scale (where 1 = very low probability of occurrence and 5 = very high probability of occurrence);

2) Estimate the severity of the risk described on a scale of 1 to 5 (where 1 = very low influence on PPP project and 5 = very high influence on the project);

3) Identify additional risk factors which are not included in the above;

4) Indicate how the identified risks should be allocated (to the public sector, to the private sector, or shared by both parties).

The second part of the questionnaire solicits the demographic information of respondents. The purpose of this part is to collect the background information of the respondents in order to better understand the risk appetite of the public and the private sectors.

See **Appendix 2** for the complete survey design.

ii) Mean score ranking technique

Using data collected from the survey, the mean score ranking technique provides mean scores for each risk, and it is then used to determine its relative ranking in descending order of importance. The mean score (MS) for each risk factor is computed using the following setup:

$$MS = \frac{\sum(f \times s)}{N}, (1 \leq MS \leq 5)$$

s = Score given to each risk factor by the respondents, ranging from 1 to 5 (1 = Least Important and 5 = Most Important);
f = Frequency of each rating (1-5) for each risk factor;
N = Total number of responses concerning that risk factor.

The impact of each risk factor is calibrated as:

$$Impact = \sqrt{Probability \times Severity}$$

IV. Empirical Analysis

Role of Survey Respondents

Category	Public sector	Private sector	Academic sector	Total
Percentage	*29.27*	*41.46*	*29.27*	*100*

Industrial Experience of Survey Respondents

Category	5 years or less	6-10 years	more than 10 years	Total
Percentage	*51.22*	*21.95*	*26.83*	*100*

120 surveys have been delivered. Most of the target respondents refused to participate or did not give back the survey. Some of the respondents gave back the survey half-complete, and explained that they were actually not familiar with every single risk factor listed and thus were not sure about their answers.

Finally, 41 valid responses have been received. The small sample size might not be qualified for analysis. Yet since PPP practice in China is not mature, participants with comprehensive knowledge and experience are lacking.

The respondents are pretty diversified regarding their background. Around 29.27% are from the public sector and 41.46% are from the private sector. The rest are from the academic sector. The diversification in background helps to minimize selection bias.

11 of the 41 respondents have more than 10 years of working experience in the infrastructure industry. Many of them were previously in the private sector and are now working as government officials. 9 respondents have 6-10 years of working experience in infrastructure. More than half of the respondents have 5 years or less experience. The experience profile is considered acceptable given that PPP projects have only become more popular in China in recent years.

i) Risk Identification Results

Table 1 Overall Results

Rank	Risk Factor	Probability	Severity	Impact	Normalization
1	Government intervention	3.53	3.77	3.65	1.00
2	Financing risk	3.37	3.93	3.64	0.98
3	Price change	3.77	3.40	3.58	0.87
4	Construction cost overrun	3.67	3.47	3.57	0.84
5	Conflicting and imperfect contracts	3.30	3.53	3.41	0.56
6	Poor public decision-making process	3.10	3.70	3.39	0.51
7	Inflation risk	3.47	3.30	3.38	0.50
8	Imperfect law and supervision system	3.20	3.53	3.36	0.46
9	Interest rate fluctuation	3.37	3.33	3.35	0.44
10	Insufficient project finance supervision	3.30	3.40	3.35	0.44
11	Change in market demand	3.10	3.50	3.29	0.33
12	Government corruption	3.00	3.47	3.22	0.20
13	Project/operation changes	3.27	3.18	3.22	0.20
14	Foreign exchange fluctuation	3.20	3.17	3.18	0.13
15	Subjective project evaluation method	3.10	3.23	3.17	0.09
16	Public credit	2.97	3.37	3.16	0.08
17	Completion risk	3.10	3.13	3.12	0.00

Note:

*Impact = (Probability * Severity) ^ 0.5*

Normalization = (Avg. actual value – Avg. minimum) / (Avg. maximum – Avg. minimum)

Table 2 Results from the Public Sector

Rank	Risk Factor	Probability	Severity	Impact	Normalization
1	Interest rate fluctuation	3.38	3.63	3.50	1.00
2	Financing risk	3.13	3.88	3.48	0.97
3	Government intervention	3.50	3.38	3.44	0.91
4	Inflation risk	3.50	3.25	3.37	0.81
5	Insufficient project finance supervision	3.25	3.50	3.37	0.81
6	Change in market demand	3.13	3.63	3.37	0.80
7	Cost overruns	3.50	3.13	3.31	0.71
8	Price change	3.63	3.00	3.30	0.69
9	Foreign exchange fluctuation	3.38	3.13	3.25	0.61
10	Imperfect law and supervision system	3.00	3.38	3.18	0.51
11	Conflicting and imperfect contracts	3.00	3.25	3.12	0.42
12	Subjective project evaluation method	2.88	3.38	3.11	0.41
13	Completion risk	3.13	3.00	3.06	0.33
14	Government corruption	2.88	3.13	3.00	0.23
15	Public credit	2.75	3.25	2.99	0.21
16	Project/operation changes	3.00	2.81	2.90	0.08
17	Poor public decision-making process	2.50	3.25	2.85	0.00

Note:
*Impact = (Probability * Severity) ^ 0.5*
Normalization = (Avg. actual value – Avg. minimum) / (Avg. maximum – Avg. minimum)

Table 3 Results from the Private Sector

Rank	Risk Factor	Probability	Severity	Impact	Normalization
1	Public credit	3.79	3.43	3.60	1.00
2	Completion risk	3.64	3.50	3.57	0.97
3	Insufficient project finance supervision	3.29	3.86	3.56	0.95
4	Cost overruns	3.29	3.64	3.46	0.85
5	Subjective project evaluation method	3.14	3.43	3.28	0.65
6	Inflation risk	3.00	3.50	3.24	0.61
7	Financing risk	3.36	3.07	3.21	0.58
8	Interest rate fluctuation	2.79	3.36	3.06	0.41
9	Project/operation changes	3.07	3.00	3.04	0.39
10	Imperfect law and supervision system	2.71	3.21	2.95	0.30
11	Government intervention	2.93	2.93	2.93	0.27
12	Government corruption	3.00	2.86	2.93	0.27
13	Conflicting and imperfect contracts	2.79	3.07	2.93	0.27
14	Price change	2.93	2.86	2.89	0.23
15	Poor public decision-making process	2.64	3.14	2.88	0.22
16	Foreign exchange fluctuation	2.86	2.79	2.82	0.15
17	Change in market demand	2.64	2.71	2.68	0.00

Note:
*Impact = (Probability * Severity) ^ 0.5*
Normalization = (Avg. actual value – Avg. minimum) / (Avg. maximum – Avg. minimum)

Table 4 Results from the Academic Sector

Rank	Risk Factor	Probability	Severity	Impact	Normalization
1	Imperfect law and supervision system	4.38	4.38	4.38	1.00
2	Government intervention	4.00	4.38	4.18	0.76
3	Poor public decision-making process	3.88	4.50	4.18	0.76
4	Subjective project evaluation method	4.13	4.00	4.06	0.62
5	Insufficient project finance supervision	3.88	4.25	4.06	0.61
6	Interest rate fluctuation	4.13	3.88	4.00	0.54
7	Government corruption	3.50	4.50	3.97	0.50
8	Conflicting and imperfect contracts	3.88	4.00	3.94	0.46
9	Financing risk	3.75	4.13	3.93	0.46
10	Project/operation changes	3.88	3.88	3.88	0.39
11	Price change	3.88	3.75	3.81	0.31
12	Cost overruns	3.88	3.75	3.81	0.31
13	Inflation risk	3.63	3.75	3.69	0.15
14	Public credit	3.63	3.75	3.69	0.15
15	Completion risk	3.50	3.88	3.68	0.15
16	Change in market demand	3.63	3.63	3.63	0.08
17	Foreign exchange fluctuation	3.50	3.63	3.56	0.00

Note:
*Impact = (Probability * Severity) ^ 0.5*
Normalization = (Avg. actual value – Avg. minimum) / (Avg. maximum – Avg. minimum)

According to the overall survey results, the top five critical risk factors are government intervention, financing risk, operating price change, construction cost overrun and conflicting and imperfect contracts.

Government intervention is identified as the most significance risk factor, with mean rating of risk impact equal to 3.65. And it is ranked as the second most severe risk factor for the solar power project in China. This result is pretty consistent with that in previous researches. Based on the analysis of previous researches, government intervention was a primary cause of failure of power and energy projects and transportation projects in China. It is not difficult to understand because PPPs allow the private sector to fully apply their knowledge and experience in project delivery, thus unreasonable government intervention in the design, construction and operation stages would ruin the relationship with the private sector and discourage their interest in future PPP projects.

Financing risk is identified as the most severe risk factor, and it is ranked second regarding the overall risk impact. Financing risk has always been a major concern in large projects, because it can determine whether the construction firm will have enough financial sources to complete the project on time. Successively, it can determine whether the project operator will start making profits as scheduled.

Compared with the survey results on water supply projects and transportation projects, the categories of operating price change and construction cost overrun have a higher impact on the solar power project in China. This might because greenfield PPP projects inherently has higher construction and operation risk due to lack of advanced technology and lack of experience in operating such projects.

The overall survey result also shows that imperfect law and supervision system, poor public decision-making process, and government corruption has a lower impact on

the solar power project. However, imperfect law and supervision system and poor public decision-making process are actually ranked in the top five significant risks according to the results provided by the academic sector. Government corruption is not viewed as a serious threat to the success of PPPs by all three types of respondents probably because of China's high profile anti-corruption campaign by the end of 2012. Some respondents mentioned that corruption is a severe threat to the efficiency of the projects, but it is less likely to happen in PPPs because the private sector can better supervise the government's behavior.

Interestingly, the most significant risk identified by the private sector is public credit, whereas public credit risk is ranked No. 15 by the public sector and is ranked No. 14 by the academic sector. This suggests that the private sector perceives a very low credibility of the Chinese government. Thus, the Chinese government needs to improve its perceived credibility in order to encourage the participation of the private sector in future PPPs.

Respondents also identified risks such as delay in the approval, third party risk, land acquisition and irresistible force, which worth further investigation.

ii) Risk Allocation Results

No.	Risk Factor	Allocated to
1	Government corruption	Public
2	Government intervention risk	Public
3	Poor public decision-making process	Public
4	Imperfect law and supervision system	Public
5	Public credit	Public
6	Change in market demand	Share
7	Financing risk	Share
8	Insufficient project finance supervision	Share
9	Conflicting and imperfect contracts	Share
10	Foreign exchange fluctuation	Share
11	Inflation risk	Share
12	Interest rate fluctuation	Share
13	Price change	Share
14	Project/operation changes	Share
15	Subjective project evaluation method	Private
16	Construction cost overrun	Private
17	Completion risk	Private

The 41 survey responses suggest that risks such as government corruption, government intervention, poor public decision-making process, imperfect law and supervision system and public credit risk should be allocated to the public sector, whereas risks such as subjective project evaluation method, construction cost overrun, and completion risk should be allocated to the private sector. The rest of the risks are preferred to be shared depending on a sharing ratio agreed by both parties.

Also, the responses show that both the public and private sectors are not willing to take more risk share on their own initiatives. However, for some of the risks such as government intervention risk and poor public decision-making process, the public sector is less risk averse than the private sector. The private sector is more willing to take the risks such as completion risk and subjective project evaluation method.

V. Alternating Offer Game – Finite Horizon Case

This session focuses on the risk allocation process between the public and private parties using a game theoretical approach. The bargaining process for risk allocation between the public sector and the private sector can be analyzed using an alternating offer game with finite horizon. And the payoffs for both sectors can be solved using backward induction.

To simplify, assuming that there are two players in the alternating offer game, the public sector and the private sector. When delivering an infrastructure jointly, the public sector wants to transfer some amount of the risks to the private sector.

Suppose that the willingness to accept a specific risk is $W(W \geq 0)$ for the private sector, and the cost to transfer this risk is 0 for the public sector. So that the pie at the very beginning would be $W(= W\text{-}0)$.

The two players move sequentially, making alternating offers. Start in Round 1, Player 1 offers a certain amount of risks r_1 to be transferred to the private sector. The other player (Player 2) chooses to accept or reject the offer. If the offer is accepted, the game ends and each player gets the payoff. If Player 2 rejects the offer, then the game moves on and Player 2 provides an offer of r_2 and Player 1 decides whether to accept or reject. The game continues until an offer is accepted.

I make two assumptions to the alternating offer game between the two players:

First, time is valuable. The pie shrinks by $1 - \delta$ in each round ($0 < \delta < 1$). In other words, the pie is W in Round 1 and it shrinks to $W*\delta$ in Round 2. It shrinks to $W*\delta^{n\text{-}1}$ in Round n. And the pie in each round is equal to the sum of both players' payoff.

Second, there is a deadline. In the final round (Round n), if the offer r_n is still rejected, no deal happens and both players get 0. However, if the offer r_n is accepted, payoff (public sector) $=r_n$ and payoff (private sector) $= W*\delta^{n-1}-r_n$

Therefore, there would be four scenarios:

Scenario 1

The public sector moves first, and the total number of rounds is odd (n is odd).

In Round n, the private sector is willing to accept $r_n \leq W*\delta^{n-1}$. So the public sector offers $r_n = W*\delta^{n-1}$

In Round n-1, the public sector is willing to accept $r_{n-1} \geq W*\delta^{n-1}$. So the private sector offers $r_{n-1} = W*\delta^{n-1}$

In Round n-2, the private sector is willing to accept $r_{n-2} \leq W*\delta^{n-3}-W*\delta^{n-2} + W*\delta^{n-1}$. So the public sector offers $r_{n-2} = W*\delta^{n-3}-W*\delta^{n-2} + W*\delta^{n-1}$

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In Round 1, the private sector is willing to accept

$r_1 \leq W*\delta^{0}-W*\delta^{1} + \cdots -W*\delta^{n-2} + W*\delta^{n-1}$. So the public sector offers

$r_1 = W*\delta^{0}-W*\delta^{1} + \cdots -W*\delta^{n-2} + W*\delta^{n-1}$

Backward induction tells that alternating offer games with costly delay should always end in the first period. Therefore, the final payoffs for both players are as follows:

Payoff (public sector) = $W*\delta^{0}-W*\delta^{1} + \cdots -W*\delta^{n-2} + W*\delta^{n-1}$

Payoff (private sector) = $W*\delta^{1}-W*\delta^{2} + \cdots + W*\delta^{n-2}-W*\delta^{n-1}$

Scenario 2:

The public sector moves first, and the total number of rounds is even (n is even).

Backward induction gives:

Payoff (public sector) = $W*\delta^0$-$W*\delta^1$ $+\cdots+$ $W*\delta^{n-2}$-$W*\delta^{n-1}$

Payoff (private sector) = $W*\delta^1$-$W*\delta^2$ $+\cdots$-$W*\delta^{n-2}$ $+$ $W*\delta^{n-1}$

Scenario 3:

The private sector moves first, and the total number of rounds is odd (n is odd).

Backward induction gives:

Payoff (public sector) = $W*\delta^1$-$W*\delta^2$ $+\cdots+$ $W*\delta^{n-2}$-$W*\delta^{n-1}$

Payoff (private sector) = $W*\delta^0$-$W*\delta^1$ $+\cdots$-$W*\delta^{n-2}$ $+$ $W*\delta^{n-1}$

Scenario 4:

The private sector moves first, and the total number of rounds is even (n is even).

Backward induction gives:

Payoff (public sector) = $W*\delta^1$-$W*\delta^2$ $+\cdots$-$W*\delta^{n-2}$ $+$ $W*\delta^{n-1}$

Payoff (private sector) = $W*\delta^0$-$W*\delta^1$ $+\cdots+$ $W*\delta^{n-2}$-$W*\delta^{n-1}$

Therefore, the four scenarios described above can merge into two:

1. n is odd

Payoff (first mover) = $W*\delta^0$-$W*\delta^1$ $+\cdots$-$W*\delta^{n-2}$ $+$ $W*\delta^{n-1}$ = $W*\frac{1+\delta^n}{1+\delta} > 0$

Payoff (second mover) = $W*\delta^1$-$W*\delta^2$ $+\cdots+$ $W*\delta^{n-2}$-$W*\delta^{n-1}$ = $W*\frac{\delta*(1-\delta^{n-1})}{1+\delta} > 0$

Payoff (first mover) – Payoff (second mover) = $W*\frac{1-\delta+2\delta^n}{1+\delta} > 0$

Since the payoff functions for both the public and private sector are positive, if the private sector is less risk averse, i.e. the initial pie W is larger, both parties get a higher

payoffs. If the private sector is more risk averse to a particular risk, both parties get lower payoffs.

In this case, the first mover always has larger payoff than the second mover. So we can conclude that the first mover always has an advantage over the second mover when there are odd rounds. And the advantage of the first mover increases as the initial pie gets larger.

2. n is even

Payoff (first mover) = $W*\delta^0$-$W*\delta^1$ $+ \cdots +$ $W*\delta^{n-2}$-$W*\delta^{n-1}$ = $W*\frac{1-\delta^n}{1+\delta} > 0$

Payoff (second mover) = $W*\delta^1$-$W*\delta^2$ $+ \cdots$ -$W*\delta^{n-2}$ $+$ $W*\delta^{n-1}$ = $W*\frac{\delta*(1+\delta^{n-1})}{1+\delta} > 0$

Payoff (first mover) – Payoff (second mover) = $W*\frac{1-\delta-2\delta^n}{1+\delta}$

In this case, the payoff functions for both the public and private sector are still positive. Therefore, both sectors get higher payoffs if the private sector is less risk averse, and they get lower payoffs if the private sector is more risk averse.

Different from the previous case where the first mover always has an advantage over the second mover, whether the first mover's payoff exceeds that of the second player in this case depends on the discount factor δ (also known as the level of patience) and number of rounds n in the whole process.

VI. Conclusions

The risks associated with PPP projects in different infrastructure sectors are different. This research has examined some of the most critical risk factors that could occur in greenfield PPP projects in China. The result indicates that government intervention, financing risk, operating price change, construction cost overrun, and conflicting and imperfect contracts are the five most significant risk factors in the solar power project in China. Government intervention has been identified as a primary cause of failure of many types of PPP projects in China. Financing risk has been identified as the most severe among all risk factors. Interestingly, respondents from the private sector considers the public credit risk as the most significant risk factor in greenfield PPP projects in China. Thus, the Chinese government needs to improve its perceived credibility so as to encourage the participation of the private sector in future PPPs.

Optimal risk sharing contributes greatly to maximum project efficiency and minimum total cost. The principles of optimal risk allocation require that the risk should be borne by the party who is capable of influencing and controlling the risk outcome most efficiently. Therefore, risks including government intervention, government corruption, poor public decision-making process, imperfect law and supervision system and public credit risks should be allocated to the public sector, because the government has more ability to influence rules, regulations, policies, and laws, and thus is liable to identify, evaluate, and control these risks. In general, the private sector can utilize lower costs to manage risks in the design, construction, operation and maintenance phases of the projects.

The bargaining process for risk allocation can be analyzed using an alternating offer game with finite horizon. Using backward induction, the result shows that the first player

to make an offer always has an advantage when there are odd numbers of rounds. However, when there are even numbers of rounds in the game, the second player's payoff can exceed the that of the first player. So the first mover advantage is not guaranteed unless the two players pre-set how many rounds of offers will happen during the whole bargaining process.

The use of backward induction is based on the assumption that both players have full information about each other. Yet in reality, this may not be the case. In particular, the public sector might have more information about the private sector while the private sector knows less about the public sector. Further, it has been argued that the public sector has a stronger bargaining power than the private player because the government usually take dual roles as both the participant and regulator in PPPs. So the outcome could be different from what is modeled in this paper.

Bargaining model usually indicates that the more patient player gets the higher payoff. This game assumes that the public and the private sector have the same level of patience. Further research may study how the conclusion might be different when the two bargainers have different levels of patience.

In conclusion, predicting probability, severity, and impact of risk factors is conducive to achieve optimal risk allocation. The findings of this survey may shed some light on both party's attitudes toward risks in greenfield PPP projects in China, and it can help both the public and private sectors to make better decisions in future PPPs.

VII. Implications for infrastructure development and public policy

Countries are putting more emphasis on infrastructure development, especially green infrastructures. The establishment of the New Development Bank, for instance, signals emerging markets' contribution to their infrastructure investment. China is playing an increasingly important role in the global infrastructure industry. In 2016, China issued 255 billion RMB (US$36.9 billion) worth of green bonds, which suggests its determination in leading climate-friendly infrastructure investment.

PPPs can bring benefits such as optimal budgetary expenditure and improved operational efficiency. However, the value of money of an infrastructure project is not assured simply by the decision to deliver it using a PPP. Due to the complexity of the PPP model, a variety of dynamic risks are involved in different stages of a PPP project. The success of a PPP is determined by the quality of the processes through which the PPP is planned and delivered, and the allocation of critical risk factors between the parties.

To ensure the success of PPPs, the public and private parties need to fully understand the objective of each other. In an infrastructure project under the PPP model, in general, the goal of the public sectors is to satisfy public needs with high-quality infrastructure and services. In contrast, the goal of the private sector is to maximize its profit. Research shows that there are risks that the private sector is reluctant to absorb from the public sector. Since the PPP model transfers significant risks to the private party, the government needs to understand the preference of the private sector and make a mutually agreeable contract. A good partnership also requires the public and private participants to understand each other's information and strategies so as to complete the bargaining process of risk allocation quickly.

The risk allocation ratio between the public and private sectors can be specified using enforceable contract written ahead. The dispute between the two sectors can be resolved by clear and enforceable contracts. The problem remains that the government, as one of the PPP parties, is also the regulator of rules and contracts. So the public sector usually has more power to force the private sector to accept unreasonable contracts. As a result, the private sector gets stuck with unacceptable returns on capital or bearing a disproportionate share of the risk.

Compared to those companies who have relatively mature law and supervision system for PPP projects, China needs to perfect its regulatory system when carrying out more PPP projects. The Chinese government has to improve its perceived credibility and provide reliable guarantee for the private participants. The Chinese government should make realistic promises that they intend to and are able to carry out. The government should also increase the transparency in their decision-making in order to encourage the private sectors to participate in future PPPs.

Many people in China talk about PPP today, but few truly understand it. So education on risk assessment and effective contract negotiation is needed. In particular, the public sector should be trained to establish effective risk allocation strategies and develop suitable allocation frameworks for PPPs so as to leverage the overall benefit.

Appendix 1 Description of the Risk Factors

1. Government intervention	Government officials intervene in the project operations directly, which will affect the autonomy of private investors' decision making.
2. Government corruption	The behavior of the corruption of government officials will increase the cost of keeping the relationships between the government and the project company. Meanwhile, it will increase the risk of contract breaking by the government.
3. Imperfect law and supervision system	The damage arising from the current PPP legislation which is low level, low effectiveness, conflict bearing, and poor operability.
4. Poor public decision-making process	Non-standardized procedures, bureaucracy, lacking of PPP project experience and ability, insufficient preparation and information asymmetry, leading to poor decision making.
5. Subjective project evaluation method	Improper evaluation method used will lead to misjudgment of a project's value for money, expertise, time, cost, public satisfaction and so on.
6. Insufficient project finance supervision	Insufficient supervision over project finance can lead to failure in financing.
7. Financing risk	The risk arising from the irrational financing structure, unsound financial market, and difficulty in financing.
8. Change in market demand	Apart from the risk arising from market competition, factors attributed to macroeconomics, social environment, change in population, adjustment of laws, or inflexible to adjust, leading to the revenue of the project company lower than expected.
9. Public credit	The rejection of government to implement the responsibilities agreed in the contract, which brings direct or indirect damages.
10. Project/operation changes	Poor constructability in design phase, design error or vagueness, standards and contracts variation, owners' variation leading to the project, or operation changes.
11. Completion risk	Project delay and construction cost overrun, etc., which cause insufficient cash flow and inability to pay off debts on time.
12. Conflicting and imperfect contract	The risk of the contract with inaccuracy, vagueness, inflexibility, inconsistency, inequitable risk-sharing, unclear division of responsibility, etc.
13. Price change	Price of PPP projects or services are too high, too low, or inflexible to adjust, leading to the revenue of the project company lower than expected.
14. Operation cost overrun	A cost increase, underrated or budget overrun, involves unexpected costs incurred in excess of budgeted amounts due to an underestimation of the actual cost during budgeting.

15. Foreign exchange fluctuation	The risk of the variability of foreign currencies exchange and the foreign currencies exchangeability risk.
16. Inflation	The increase of the price level of the commodities, the decrease of purchasing power of currencies, which cause the increase in the project construction and operation cost and other consequence.
17. Interest rate fluctuation	The loss of PPP projects arising from the uncertainties of the interest rate volatility.

Appendix 2 Questionnaire Survey

Risk Identification and Risk Allocation for Greenfield Public-Private Partnerships in China

Public-private partnership (PPP), an innovate model for delivering and financing public infrastructure projects, has been developing in China since the late 1970s.

Many of the previous studies on PPPs in mainland China have provided risk assessments for brownfield infrastructure projects. This questionnaire is intended for research on the assessment of risks associated with financing a greenfield infrastructure project under the auspices of the New Development Bank (NDB)

According to media reports, the NDB will provide a loan of $81 million in Yuan for a 100 megawatt rooftop solar energy project sponsored by the Shanghai Lingang Hongbo New Energy Development Company.

Part I:
In the first part, you will be requested to estimate both the probability of occurrence and the severity of key risks associated with this project, and to calibrate risk allocation for the greenfield project described above. A five-point Likert scale is used for calibration.

Please answer the three questions for all the 17 risks identified below. Please check (☑) the box that you think is most appropriate under the assumption that the project will use the PPP model.

		1. How likely do you think this risk will occur? 5 = very high probability 4 = high 3 = average 2 = low 1 = very low					**2. How severe do you think this risk is?** 5 = very high severity 4 = high 3 = average 2 = low 1 = very low					**3. How do you think this risk should be allocated?** 5 = wholly allocated to the government 4 = mainly allocated to the government 3 = equally shared 2 = mainly allocated to the private sector 1 = wholly allocated to the private sector				
Evaluation criteria	**Risk factors**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
Macro-economic risk	1. Foreign exchange fluctuation															
	2. Inflation															
	3. Interest rate fluctuation															
Construction and operation risk	4. Project/ operation changes															
	5. Completion risk															
	6. Conflicting and imperfect contracts															
	7. Price change															
	8. Construction cost overrun															
Government maturity risk	9. Government corruption															
	10. Imperfect law and supervision system															
	11. Poor public decision-making process															
Market environment risk	12. Financing risk															
	13. Change in market demand															
	14. Public credit															
Economic viability risk	15. Subjective project evaluation method															
	16. Insufficient project finance supervision															
Government intervention	17. Government intervention risk															

Please identify additional risk factors which are not included in the above and you think might be influential to this specific greenfield project when adopting the PPP model. Please also provide brief description of the additional risks that you have identified and explain why each might be influential.

Part II:

This part of the questionnaire solicits your demographic information, which will help to assess the quality of survey data. The information will be used only for research purposes. Please check (☑) if applicable.

1. Do you have working experience within the construction industry in China?
☐ Yes
☐ No
2. If "Yes" to the 1st question, how long have you been working within the construction industry in China?
☐ 5 years or less
☐ 6-10 years
☐ More than 10 years
3. Have you been involved in the management of PPP projects in China?
☐ Yes
☐ No
4. If "Yes" to the 3rd question, how long have you been involved in the management of PPP projects in China?
☐ 5 years or less
☐ 6-10 years
☐ More than 10 years
5. Have you gained in-depth knowledge of the PPP model through research?
☐ Yes
☐ No

Thank you for your participation. Your confidential response will be of significant help in better understanding the risks of the PPP model in China.

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