Cite this article
Hu QL, Puah CH and Harry E (2025)
Performance of private-public partnership projects: the influence of key determinants.
Proceedings of the Institution of Civil Engineers – Municipal Engineer **178(4)**: 215–231,
https://doi.org/10.1680/jmuen.24.00049

Research Article
Paper 2400049
Received 15/08/2024; Accepted 26/05/2025

Municipal Engineer

Performance of private-public partnership projects: the influence of key determinants

Qi Liang Hu
School of Management, Anhui Business and Technology College, Anhui, China; Faculty of Economics and Business, Universiti Malaysia Sarawak, Kota Samarahan, Malaysia

Chin Hong Puah
Faculty of Economics and Business, Universiti Malaysia Sarawak, Kota Samarahan, Malaysia (corresponding author: chpuah@unimas.my)

Entebang Harry
Faculty of Economics and Business, Universiti Malaysia Sarawak, Kota Samarahan, Malaysia

The success or failure of private-public partnership (PPP) projects in Belt and Road Initiative countries directly impacts infrastructure development and plays a crucial role in national economic growth and UN Sustainable Development Goal 17. This research selected five project specific indicators and three country risk indicators to conduct an empirical analysis using a logistic regression model and moderation effects. Data were sourced from the World Bank and the International Country Risk Guide by the U.S. International Reports Group. The results indicate that multilateral support positively and significantly influences project performance, while investment negatively and significantly influences project performance. Political risk, economic risk, and financial risk negatively impact project performance. In addition, these three types of country risks negatively moderate the effect of project's own factors on the performance of PPP projects. To rephrase, country risks exacerbate the failure of project's own factors on project performance. This research further suggests to policy makers to control the scale of investment and establish a risk platform, and to gain a deeper understanding of the host country's political differences, economic conditions, and policy support. Thus, improving the performance of PPP projects will contribute to the economic development of the Belt and Road Initiative countries.

Keywords: Belt and Road Initiative (BRI)/infrastructure/municipal & public service engineering/performance/private finance initiatives/private-public partnership (PPP)/project management/UN SDG 9: Industry, innovation and infrastructure

Notation

β	regression coefficient
ε	error term

1. Introduction

The 'Belt and Road Initiative' (BRI) is a collective term used to describe the 'Silk Road Economic Belt' and the '21st Century Maritime Silk Road' (Ma and Chen, 2017). The strategic concept was proposed by China in 2013 and aimed at joint development between China and the countries along the BRI (Cao and Li, 2021). Infrastructure ensures smooth social production and orderly daily life for residents. It provides essential services, primarily fixed assets and serves production enterprises and the public (Wang *et al*., 2021). Infrastructure serves production enterprises and the public, forming the material foundation for social reproduction and labour force reproduction. It is a crucial prerequisite for the steady development of the national economy. The World Bank (2008) has classified the following industries as infrastructure: airports, electricity, information and communication technology (ICT), municipal solid waste, ports, railways, roads, and water and sewerage.

Public-private partnerships (PPP) refer to joint participation by public and private sectors in providing public products or managing services (Yu, 2016). The World Bank's Private Participation in Infrastructure (PPI) report indicates that there were a total of 5,010 PPP infrastructure projects along the BRI route by the end of 2023, with a total investment of $1,390.3 billion (World Bank, 2024).

While countries worldwide are adopting PPP models for infrastructure development, such models may not be universally suitable for all infrastructure projects. Governments must assess whether PPP models add more value than traditional approaches (Wahab and Mohamed, 2009). If the added value is low or lacks

feasibility studies, PPP projects may face budget overruns, delays, quality issues, or even project cancellations (Alireza *et al*., 2016). Since PPP projects typically involve partnerships lasting 20 to 30 years, data from 1993 to 2023, spanning 30 years, was selected for analysis (Kukah *et al*., 2024). Table 1 presents the status of PPP projects along the BRI countries to illustrate that the majority of PPP projects were categorised as 'active', indicating ongoing projects that had not reached completion. There were 118 projects categorised as 'cancelled or distressed' during the study period, amounting to $56.18 billion while accounting for 4.04% of all PPP projects. In contrast, only 54 projects were categorised as 'concluded', amounting to $4.1 billion and comprising only 0.29% of total PPP projects. The high failure rate of PPP projects is notable (World Bank, 2024).

Regarding the failure of PPP projects, many experts and scholars believe that various factors lead to the failure of PPP projects. Liu (2019) suggests that different political environments, economic levels and social cultures in BRI countries introduce uncertainties into the PPP model. Wang *et al*. (2021) attribute unsuccessful investments in South-east Asian countries to insufficient market returns, foreign exchange risk, governmental corruption and inaction. Zhang and Xie (2020) highlight political inefficiency, public interest, and revenue risks as reasons for PPP project failures in BRI countries. Sheng (2019) identifies political risks at the national level, including legal and micro level risks such as financing, market, construction, and exchange rate risks in PPP infrastructure projects. Liu (2018) suggests that political instability, high national debt, inflation, and cutthroat competition from foreign firms in BRI countries reduce the likelihood of PPP project success. Based on PPP project data in Africa, Huo *et al*. (2018) indicate that national institutions and multilateral support increase the log-odds of project success.

Therefore, this research aims to address these fundamental questions: the key determinants affecting the performance of infrastructure PPP projects in BRI countries, the intrinsic connection between project performance and project's own factors, the intrinsic connection between project performance and the macroeconomic environment of the BRI country, and how country risks influence PPP project performance. Thereby, it is significant for this study to provide recommendations to firms to improve the performance of PPP projects.

2. Literature review

2.1 Related concepts

'The Silk Road Economic Belt' and the '21st Century Maritime Silk Road' form the BRI. In September 2013, President Xi Jinping proposed the construction of the 'Silk Road Economic Belt' (Xinhua News Agency, 2013a). In October 2013, on the tenth anniversary of China's accession to ASEAN, President Xi Jinping put forward the concept of jointly building the '21st Century Maritime Silk Road' (Xinhua News Agency, 2013b). In November 2013, the People's Republic of China held discussions. It passed the 'Decision of the Central Committee of the Communist Party of China on Some Major Issues Concerning Comprehensively Deepening Reform', marking the formal elevation of the BRI from initiative to concept, ultimately leading to a national strategic height (China News Network, 2013). The China Export Credit Insurance Corporation published the 'BRI National Infrastructure Development Index Report', listing 71 key countries along the BRI (CHINCA, 2023). According to the United Nations regional classification standards, these 71 key countries are divided into seven regions: South-east Asia (10 countries), CIS Six and Mongolia (7 countries), South Asia (8 countries), Portuguese speaking countries (8 countries), West Asia and North Africa (14 countries), Central Asia (5 countries), and Central and Eastern Europe (19 countries).

Currently, there is no definitive consensus on the specific connotation of infrastructure (Ragnar, 1966). Ragnar states that infrastructure cannot simply be summarised as constructing basic facilities and services in individual fields. Infrastructure encompasses macro policies and laws and public services such as public health, education, communication, and water and electricity services. The World Bank divides infrastructure into economic and social infrastructure (Cui, 2020). Economic infrastructure primarily consists of permanent engineering structures, facilities, equipment, and the services they provide for residents' use and economic production. Economic infrastructure includes the following: public utilities such as electricity, communications, piped gas, piped water, sewerage, and solid waste collection and disposal. It also includes public works, such as dams, waterworks, and roads. Other transport sectors include railways, urban transport, ports, rivers, and airports. Economic infrastructure encompasses electricity, gas, and water production and supply sectors, fixed asset investment in transport, storage and postal services, information transmission,

Table 1. PPP project status in BRI countries

Status	Total quantity	Percentage of total	Total investment (billion USD)	Percentage of total
Active	4838	96.57%	1330.03	95.66%
Cancelled/distressed	118	2.36%	56.18	4.04%
Concluded	54	1.08%	4.10	0.29%
Total	5010	100.00%	1390.30	100.00%

Source: World Bank (2024)

computer services and software, water, environment and public facilities management (Liu, 2022).

PPP originated in Western countries. Root *et al*. (1985) refer to PPPs that involve collaborative arrangements where government agencies and private entities jointly plan, finance, and implement projects to address public needs, sharing risks and rewards. PPP refers to any arrangement between the public sector and private enterprises that provide society with public goods or management services. A range of possible cooperative relationships will be established between the public sector and private enterprises during the process (Fleta-Asín and Muñoz, 2020). Partnerships between the public sector and private firms are established with the provision of infrastructure and public services in mind (Keers and van Fenema, 2018). Based on the World Bank's classification criteria, there are four main types of PPPs: management and leasing projects, brownfield projects, greenfield projects, and divestment projects (World Bank, 2024). Stakeholders in PPP projects typically include the public sector, private sector, project lenders, and special project companies.

2.2 Key determinants of PPP project performance

Schepper *et al*. (2015) identified key project's own factors affecting the performance of PPP projects, including investment type, the number of private investors, and investment type. Mona *et al*. (2006) conducted an empirical study on PPP project data from 1990 to 2003, concluding that the performance of PPP projects depends on the nature of the project, market conditions, investment amount, and project type. Oyedele (2013) argued that a critical factor for PPP project performance is the establishment of good cooperative relationships with social capital; in addition, the probability of success varies across different industries.

Schepper *et al*. (2015) indicate that project profile factors influencing the success of PPP projects include investment type, the number of private investors, and the investment amount. Through an empirical study of PPP project data from 1990 to 2003, Mona *et al*. (2006) concluded that the success or failure of PPP projects depends on the nature of the project, the market, the investment amount, and the project type. Oyedele (2013) suggests that the key to PPP project success is establishing effective cooperative relationships with social capital and all parties involved. In addition, the probability of success varies with different investment sectors. Through a survey of PPP projects in Asia and China, Sachs *et al*. (2007) found that PPP project success is not only constrained by the type of investment but also critically influenced by the support of multilateral countries. Yuan *et al*. (2016) demonstrated that a key indicator of PPP project success is reducing residual value risk, which is the risk related to investment amount and type. Examining data from 46 countries along the BRI from 2002 to 2016, Hou *et al*. (2019) found that the more social capital involvement and the greater the support from multilateral countries, the lower the project success rate. Huo *et al*. (2018) examined 552 projects in African countries from 2002 to 2016 and concluded that project success is influenced by multilateral country support, investment scale, and social capital participation. Through a study of 3,466 PPP project data from 1996 to 2015, Liu *et al*. (2019) found that participation in social capital is a crucial factor in project success. Using the entropy method, Xue (2021) showed that investment type, investment amount, and multilateral country support significantly impact the success of PPP projects.

Country risk is an essential factor affecting the success of PPP projects (Biygautane *et al*., 2019; Fleta-Asín and Muñoz, 2020). Country risk impacts economic trade and the construction and development of a nation's PPP projects (Huang *et al*., 2016). The International Country Risk Guide (ICRG) was established by the US International Reports Group in 1980 and conducts risk assessments across 140 countries. ICRG categorises country risk into political risk, financial risk and economic risk, thus establishing three primary risk assessment indicators and 22 secondary risk assessment indicators (PRS, 2015). Regarding political risk, Biygautane *et al*. (2019) suggest that government political commitment is key to the success of PPP projects. Mohamed (2015) indicate that national laws and regulations can promote project development. Percoco (2014) suggests that a low corruption environment and a good political climate are critical factors for project success.

Zhang and Man (2018) divided study samples into low-income, developing, and middle-high-income countries, supplementing studies focusing on high-income countries. Their empirical results indicate that political risk in BRI countries affects their gross domestic product (GDP), thereby hindering Chinese enterprise investments (Zhang and Man, 2018). Ameyaw and Chan (2016) combined political and economic risks to examine their relationship. The results indicate that lower political risk correlates with better economic development and that more developed economies tend to have lower political risk (Ameyaw and Chan, 2016). As such, country risk factors positively attract Chinese enterprises to invest in PPP projects. However, Zhang and Xie (2020) found that political risk deters foreign direct investment.

The macroeconomic stability of BRI countries plays a crucial role in the investment of Chinese enterprises in PPP projects. He and Xu (2018) conducted an empirical study on factors such as economic freedom and strategic assets of BRI countries, leading to several conclusions. Specifically, Chinese foreign investment is economically oriented: the larger the market size and the higher the degree of economic openness, the greater the amount of foreign direct investment. Babatunde *et al*. (2019) selected panel data from 18 African countries and found that a country's economic growth rate and trade freedom can promote foreign direct investment. Aundhe and Narasimhan (2016) concluded from their

empirical research that economic growth rates can promote foreign investment in PPP projects, while actual interest rates and export dependency can hinder foreign direct investment. Wu (2021) suggests that market economic factors significantly affect Chinese enterprises investing in PPP projects: the more open the market and the larger the market size, the more attractive it is for investment. Wang *et al*. (2018) empirically analysed panel data from 112 BRI countries, finding a positive relationship between the economic level of BRI countries and Chinese foreign direct investment. Using the computable general equilibrium model for empirical analysis in the context of BRI, Chen and Yang (2015) concluded that the GDP growth rate positively influences Chinese regional investment in PPP projects. Through research on PPP projects in the transportation sector, Galilea and Medda (2010) found that the economic environment affects project success. If an economic environment has issues, it inevitably leads to fiscal risk, further impacting the development of PPP projects (Lusinyan *et al*., 2009).

Biygautane *et al*. (2020) conducted an empirical study on 97 countries to find a negative relationship between financial risk and foreign direct investment in PPP projects. Xue (2021) examined the relationship between financial development in BRI countries and foreign direct investment in PPP projects. The findings indicate that the higher the level of financial development in BRI countries, the larger the scale of Chinese enterprises investing in PPP projects (Xue, 2021). In contrast, lower financial development restricts China's foreign direct investment. Liyanapathirana *et al*. (2024) focused on North African and Middle Eastern countries to examine the relationship between economic growth rate, trade freedom, and direct investment. They found that high economic growth and trade freedom positively influenced Chinese enterprises to invest in PPP projects (Liyanapathirana *et al*., 2024). Wang (2018) found that China's foreign direct investment is characterised by market driven attraction, and the better the financial environment in BRI countries, the more it attracts Chinese enterprises to invest in PPP projects. Taking the heterogeneity of motivation, Tan and Zhao (2019) examined the relationship between financial development level and structure in BRI countries and Chinese direct investment in PPP projects. They concluded that the scale of financial development in BRI countries significantly promotes investment in PPP projects (Tan and Zhao, 2019). Wang (2021a) examined the relationship between financial scale and efficiency and found a positive impact on the scale of indirect financing and investment in PPP projects. Yang (2021) suggests that the better the financial development structure in BRI countries, the larger the scale of Chinese enterprises investing in PPP projects. After examining 28 PPP projects in China, Nguyen *et al*. (2018) concluded that a sound financial system is key to project success. Luo *et al*. (2017) analysed data from 46 BRI countries' PPP projects and found that financial and political quality risks significantly correlate with project performance.

The literature on the causes of PPP project performance focuses on risk management. In reality, there are many factors influencing the performance of PPP projects, with risk being just one aspect. Few scholars have studied project's own factors such as investment type, investment amount, and investment sector on project performance. Likewise, there is limited research on macroeconomic factors such as GDP and market capacity. Even fewer studies have explored the performance of infrastructure PPP projects in BRI countries. For example, does multilateral support affect the performance of PPP projects? Does the openness of the country and the level of private sector development influence the performance of PPP projects? Under the conditions of country risk, how do project's own factors and macroeconomic factors affect the performance of PPP projects?

Thus, this research makes three contributions. First, it enriches the knowledge system by explaining the relationship between project performance and project's own factors such as investment type, investment amount, and investment sector. Second, it fills the gap in understanding the relationship between PPP project performance and the BRI country's macroeconomic environment. This research reveals the impact of macroeconomic factors on PPP project performance through multilateral support, private sector participation, GDP, and the openness of the country. Finally, the study provides a comprehensive measurement of PPP project performance using rigorous data on political, economic, and financial risks, filling the gap in the understanding of the relationship between country risk and project performance.

3. Materials and methods

3.1 Research hypotheses and framework

The main purpose of this research is to examine the direct relationship between project's own factors and the performance probability of PPP projects, as well as to investigate how country risk, as a third variable, moderates this relationship. Previous studies have generally confirmed the findings on project's own factors and project performance, but country risk remains an unavoidable consideration. Based on the previous theoretical literature study, the hypotheses of this study were set in relation to the objectives of the research.

H_1. Project's own factors significantly explain the performance of PPP project.

H_{1a}. Investment scale significantly negatively correlates with PPP project performance.

H_{1b}. Investment type significantly explains the performance of PPP project.

H_{1c}. The investment sector significantly explains the performance of PPP project.

H_{1d}. Private sector participation significantly positively explains the performance of PPP project.

H_{1e}. Multilateral country support significantly positively explains the performance of PPP project.

H_2. Country risk significantly negatively affects PPP project performance.

H_{2a}. Political risk significantly negatively affects PPP project performance.

H_{2b}. Economic risk significantly negatively affects PPP project performance.

H_{2c}. Financial risk significantly negatively affects PPP project performance.

H_3. High country risk weakens the relationship between project's own factors and performance.

H_{3a}. High political risk weakens the impact of project's own factors on project performance.

H_{3b}. High economic risk weakens the impact of project's own factors on project performance.

H_{3c}. High financial weakens the impact of project's own factors on project performance.

Therefore, this research introduces another moderating variable, country risk, to observe whether it specifically affects the relationship between project's own factors and project performance. The conceptual framework in Figure 1 shows the relationship between the independent variables of project's own factors and the dependent variable of project success, along with the moderating effect of country risk. This research framework also includes macroeconomic factors of PPP projects as control variables, consisting of GDP, the level of national openness, and the degree of private sector development.

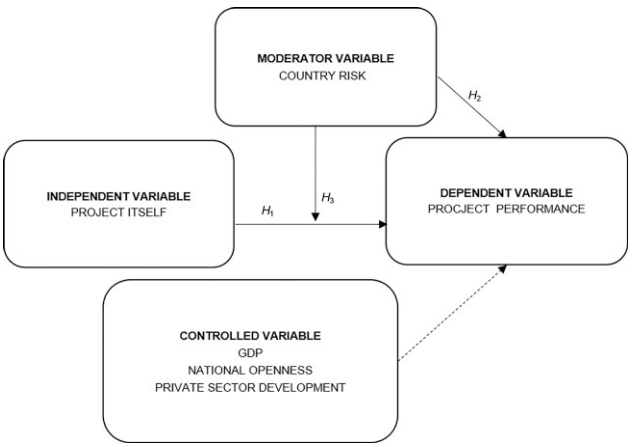

Figure 1. Conceptual framework

These three control variables are chosen to avoid bias and ensure that the expected results of this research are not affected.

3.2 Research variable and data sources

This study examines the relationship between project itself, political risk, economic risk, financial risk, and PPP project performance. It also explores how country risk moderates the relationship between project itself and project performance. The specific variables and assigned values are shown in Table 2.

This research focuses on the key performance factors of infrastructure PPP projects in BRI countries. To evaluate project performance or failure based on actual outcomes, real world data is required to validate the hypotheses (Asadornborikarn, 2021). Therefore, the study adopts a quantitative approach using secondary data. The primary data sources include the World Bank's PPI database, the ICRG by the U.S. International Reports Group, and the World Development Indicators (WDI) database from the World Bank. Data on the number of successful and unsuccessful PPP projects, investment types, investment amounts, investment sectors, multilateral support, and the number of private sector participants are sourced from the World Bank's PPI database. Samples for political risk, economic risk, and financial risk in the country risk category are obtained from the ICRG. The GDP, national openness, and private sector development samples in the macroeconomic environment of PPP projects are drawn from the World Bank's WDI database.

3.3 Logistic regression model

The regression analysis of this study adopted the logistic model, which is a non-linear regression model. Definition $X = (x_1, x_2, x_3 \ldots x_k)$ is a set of factors that affect the success of PPP infrastructure projects, where $x_1, x_2, x_3 \ldots x_k$, respectively, represent independent influencing factors referred to as independent variables. This study used Y to indicate whether the PPP infrastructure project had achieved successful results. As mentioned above, ended/concluded were considered successful and assigned a value of 1. Cancelled and distressed projects failed and were assigned a value of 0. The result is defined as a dependent variable of two categories, namely:

1. $$Y = \begin{cases} 1 \text{ Project success} \\ 0 \text{ Project failed} \end{cases}$$

P is defined as the probability of success of infrastructure PPP projects, namely

2. $$P = P\{Y = 1 \, X = (x_1, x_2, \cdots, x_k)\}$$

Table 2. Variables and assigned values

Variable properties	Variable name	Assignment and interpretation	Scholars
Independent variable	PPP project status	0 = 'Cancelled' or 'Distressed'; 1 = Concluded	Liu (2019); Asadornborikarn (2021); He *et al*. (2021)
Dependent variable	Type	1 = Management and lease contract; 2 = Brownfield; 3 = Greenfield: 4 = Divestiture	Bank (2024); Alireza *et al*. (2016); Xue (2021); Schepper *et al*. (2015)
	Investment	Logarithm of investment amount	Asadornborikarn (2021); Liu (2022); Wu (2021); Schepper *et al*. (2015)
	Sector	1 = Urban solid waste treatment; 2 = Water supply and treatment; 3 = Transportation; 4 = Information and communication technology; 5 = Energy	Bank (2024); Wang (2021b); Williamson (1988)
	Multilateral	2 = Supported by multilateral financial institutions: 1 = Not supported by multilateral financial institutions	Estache (2006); Shen (2016); Liu (2018)
	Sponsors	2 = Multiple private capital participation; 1 = Only one party's private capital participates	Asadornborikarn (2021); Menezes and Ryan (2015); Liu (2018)
Moderator variables	Political risk	0–100	PRS (2023); Ortiz *et al*. (2023); Shen (2016); Wang (2018); Asadornborikarn (2021)
	Economic risk	0–50	—
	Financial risk	0–50	—
Controlled variable	GDPg	(Current period actual GDP − previous period actual GDP)/previous period actual GDP	Han *et al*. (2020); Yuan (2018); Chen and Yang (2015)
	National openness	FDI/nominal GDP (FDI is the international direct investment finance of the host country)	Zhang and Xie (2020); Zhao (2020); He and Xu (2018)
	Private sector development	Domestic credit obtained by the private sector/nominal GDP	Shi and Sun (2017); Ye (2017); Li and Ma (2016)

According to the traditional linear model, the P value greater than 1 or less than 0 may appear, failing to give a reasonable explanation and losing practical significance. Therefore, if P is logically transformed, the logit (P) value range can be any value. Namely:

$$\text{3.}\quad \text{logit(P)} = \text{In}\frac{P}{1-P} = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$

where x_k is the various factors affecting the success of PPP infrastructure projects and β_k is the regression coefficients corresponding to each independent variable. ε is the disturbance term. When the constant term $\beta_0 < 0$, then $\text{In}\frac{P}{1-P} < 0$, that is, $p < 1 - p$. This indicates that the probability of predicting success is less than that of predicting failure. This further suggests that assuming no influence from any success factors, the probability of predicting failure is higher than the probability of predicting success, indicating a high failure rate for the project.

$$\text{4.}\quad \text{logit(P)} = \text{In}\frac{P}{1-P} = \beta_0 + \beta_1 Type + \beta_2 Sector + \beta_3 Sponsors + \beta_4 Multilateral + \beta_5 Investment + \varepsilon$$

In the regression equation, control variables are added, including GDP growth (GDPg), the degree of openness of the country, and the level of private sector development, resulting in:

$$\text{5.}\quad \text{logit(P)} = \text{In}\frac{P}{1-P} = \beta_0 + \beta_1 Type + \beta_2 Sector + \beta_3 Sponsors + \beta_4 Multilateral + \beta_5 Investment + \beta_6 GDPg + \beta_7 Open + \beta_8 Credit + \varepsilon$$

3.4 Moderation effect model

3.4.1 Dimensionality reduction of independent variables

Typically, if the variables are all continuous, principal component analysis (PCA) and factor analysis methods are used (Antosz *et al*., 2023). However, since the influencing factors of PPP projects are mainly discrete categorical variables, we adopt the approach of categorical principal component analysis (CATPCA), as referenced by Avishek *et al*. (2022). The function and purpose of CATPCA are the same as those of PCA, but CATPCA can be used for any type of variable and does not require specific distributions, making it highly versatile (Lazuardi *et al*., 2023). When performing CATPCA, even if some independent variables are not

significant in logistic regression analysis, they can still undergo dimensionality reduction (Hatem *et al*., 2022). On the contrary, using the CATPCA method can reduce model complexity and improve the explanatory power of the model (Yu *et al*., 2024). Therefore, before conducting the moderating effect analysis, this research performs dimensionality reduction on the variables of the PPP project's own factors. The variables for dimensionality reduction include investment type, Investment sector, multilateral country support, the level of private sector participation, and investment amount. These five variables are reduced to one variable, named 'Own'.

3.4.2 Moderating effect

This research examines the extent to which country risk moderates the relationship between project's own factors and project performance. The five variables of project's own factors are reduced to one variable, Own, through CATPCA. The moderating variables are Political, Economic, and Financial.

For the moderating effect of political risk, the moderating effect model is:

$$\text{6.}\quad \text{logit(P)} = \text{In}\frac{P}{1-P} = \beta_0 + \beta_1 Own + \beta_2 Political + \beta_3 Own \times Political + \varepsilon$$

For the moderating effect of economic risk, the moderating effect model is:

$$\text{7.}\quad \text{logit(P)} = \text{In}\frac{P}{1-P} = \beta_0 + \beta_1 Own + \beta_2 Economic + \beta_3 Own \times Economic + \varepsilon$$

For the moderating effect of economic risk, the moderation effect model is:

$$\text{8.}\quad \text{logit(P)} = \text{In}\frac{P}{1-P} = \beta_0 + \beta_1 Own + \beta_2 Financial + \beta_3 Own \times Financial + \varepsilon$$

4. Results and discussion

4.1 Summary of descriptive statistics

This study focuses only on projects classified as 'Completed', 'Cancelled' and 'Distressed', as previously mentioned. Table 3 presents a total of 172 samples. The descriptive statistics primarily include the total number of samples, minimum value, maximum value, mean, and standard error. The variable 'Investment' has a minimum value of −0.52, a maximum value of 3.66, a mean of 1.9479, and a standard deviation of 0.06598. The minimum value of −0.52 for 'Investment' results from using a logarithm with a base of 10 for the investment amount. The value −0.52 corresponds to an investment amount of $0.3 million.

Table 3. Summary of descriptive statistic

Variables	*N*	Minimum	Maximum	Mean	Std. error
Status	172	0.00	1.00	0.3140	0.0355
Type	172	1.00	4.00	2.4244	0.0436
Sector	172	1.00	5.00	2.2849	0.0843
Sponsors	172	1.00	2.00	1.2965	0.0349
Multilateral	172	1.00	2.00	1.1395	0.0265
Investment	172	−0.52	3.66	1.9479	0.0660
GDPg	172	0.34	9.80	2.8550	0.1874
Credit	172	0.59	105.12	19.1083	1.4507
Open	172	0.15	9.66	2.2138	0.1264
Financial	172	20.17	43.46	29.9848	0.3777
Economic	172	20.03	42.42	24.8593	0.4392
Political	172	21.50	69.75	56.2420	0.5241

4.2 Omnibus likelihood ratio test

Firstly, before conducting the Omnibus likelihood ratio test, Pearson correlation analysis, normal distribution test of variables, chi-square test, and multicollinearity test were performed, all meeting the requirements for regression analysis.

Secondly, the logistic regression model was subjected to the Omnibus likelihood ratio test to analyse the overall effectiveness of the model. If the *p*-value is less than 0.05, it indicates that the model is effective; otherwise, it indicates that the model is ineffective. Table 4 shows four models. Model 1 includes the likelihood ratio test for the five independent variables related to PPP projects. Model 2 includes the likelihood ratio test for the PPP project variables and GDP growth rate, totalling six variables. Model 3 includes the likelihood ratio test for the PPP project variables, GDP growth rate, and national openness, totalling seven variables. Model 4 includes the PPP project variables and control variables, totalling eight variables in the likelihood ratio test.

The null hypothesis for the test was that the model quality is the same whether or not the independent variables are included. The *p*-values in Table 4 are all 0.000, far below 0.05. In addition, the Chi-square values are high, leading to the rejection of the null hypothesis. This indicates that the independent variables in the model collectively have a significant explanatory power for the dependent variable, demonstrating the meaningfulness of the model constructed in this study.

Table 4. Omnibus tests of model coefficients

Model	Step	Chi-square	df	Sig.
(1)	Step 1	93.099	9	0.000
(2)	Step 1	111.228	10	0.000
(3)	Step 1	140.618	11	0.000
(4)	Step 1	151.955	12	0.000

4.3 Goodness-of-fit test for model fit

The −2 Log Likelihood is one method used to test a model's goodness of fit. If the −2 Log Likelihood value is relatively small, it indicates that the model has achieved goodness of fit (Edward, 2022). In Table 5, four models are presented. Model 1 includes only the variables related to the PPP projects. Models 2, 3, and 4 sequentially add the variables GDP growth rate (GDPg), Credit, and Open, respectively. The −2 Log Likelihood values range from a minimum of 62.091 to a maximum of 120.947. Lower values indicate a better fit.

The Hosmer and Lemeshow test is another method to assess the goodness of fit of a model. If the *p*-value from the Hosmer and Lemeshow test is greater than 0.05, the null hypothesis is accepted, indicating a good model fit. A smaller Chi-square value also suggests a better fit (Nikola *et al*., 2024). In Table 5, the *p*-values for the Hosmer and Lemeshow test across the four models range from a minimum of 0.653 to a maximum of 0.999. Since all *p*-values are well above 0.05, the null hypothesis is accepted. Therefore, based on the −2 Log Likelihood test and the Hosmer and Lemeshow test, the models exhibit a good fit.

4.4 Logistic regression results

Logistic regression was conducted on the influencing factors of PPP projects. The system processed the variables and fitted the model. In this study, the 'Backward Elimination (Likelihood Ratio)' method was used for binary logistic regression input (Ozgur and Franklin, 2021). The system sequentially eliminated variables that did not meet the criteria through a stepwise method, ensuring the model's validity.

4.4.1 Regression with non-significant hypotheses

The system excluded 'Type', 'Sector' and 'Sponsors' mainly due to the following reasons:

Firstly, for 'Type', which includes Brownfield, Divestiture, Greenfield, and Management and Lease Contract, the type of PPP project operation in BRI countries largely depends on national policies. In addition, the type is influenced by the project itself, such as using Greenfield for transportation projects and Brownfield for energy projects (Almeile *et al*., 2024). Although the significance of 'Type' was 0.000 in the chi-square test and it was included in the model, it was still excluded. Thus, 'Type' is not significantly related to the success or failure of PPP projects. The hypothesis H_{1b}, stating that the investment type significantly explains PPP project performance, does not hold.

Table 5. Goodness-of-fit test

		Hosmer and Lemeshow test		
Model	**−2 Log likelihood**	Chi-square	df	Sig.
(1)	120.947	5.951	8	0.653
(2)	102.818	4.3	8	0.829
(3)	73.429	2.638	8	0.955
(4)	62.091	0.885	8	0.999

Secondly, for 'Sector', the operating range of Chinese enterprises in PPP projects is concentrated in specific fields. Enterprises focus on investment amounts, the country's macro environment, and risk factors. Therefore, enterprises do not choose sectors based on the likelihood of success or failure. 'Sector', as a project itself variable, had a significance of 0.000 in the chi-square test and was included in the model but still excluded. The hypothesis H_{1c}, stating that the investment sector significantly explains PPP project performance, does not hold.

Lastly, regarding 'Sponsors', sponsors refer to the private sector. Current research indicates that 62.125% of projects have only one sponsor. The private sector prefers to involve only one private entity working with the government to avoid multiple leaderships. Naturally, the government, as the main leader, would prefer more private sector participation. Therefore, the number of sponsors does not significantly impact the success or failure of PPP projects. In this model, 'Sponsors' was excluded as it did not meet the variable criteria. Thus, the hypothesis H_{1d}, stating that the number of private sector participants is significantly positively correlated with the success or failure of PPP projects, does not hold.

4.4.2 Regression with significant hypotheses

Table 6 shows the results of the model regression, with four different models. Model 1 is the regression impact of the PPP project's own factors. Model 2 introduces the control variable GDP growth (GDPg) into the regression of the PPP project's own factors. Model 3 further introduces the control variable of the country's level of openness into the regression of the PPP project's own factors. Model 4 further introduces the control variable of the level of private capital openness into the regression of the PPP project's own factors. The specific details are as follows:

Firstly, the regression results of Model 1 show the impact of multilateral support and investment amount on the success or failure of PPP projects. According to the regression results, multilateral support has a positive impact on the success or failure of PPP projects at the 1% significance level, with a coefficient of 2.4140 and a *t*-value of 3.7040. The data indicate that projects supported by two or more countries have a higher success rate. The investment amount negatively impacts the success or failure of PPP projects at the 1% significance level, with a coefficient of −2.523 and a *t*-value of −5.7802. The data suggest that larger investment scales, longer project cycles, and higher associated risks result in a lower success rate. The constant term is −18.8288, indicating that $\ln\frac{P}{1-P} < 0$. According to the logarithmic formula, $p < 1 - p$ which means the probability of success is less than the probability of failure. Why does this occur? Because when all success factors

Table 6. Model regression results

Variable	Model 1	Model 2	Model 3	Model 4
Multilateral	2.4140*** (3.7040)	2.9054*** (4.1621)	2.8235*** (3.3222)	3.7400*** (3.5416)
Investment	−2.5234*** (−5.7802)	−2.2441*** (−4.9091)	−2.4098*** (−4.0688)	−2.5643*** (−3.6835)
GDPg	—	0.4431*** (3.8891)	0.7799*** (4.3489)	0.4747*** (2.3345)
Open	—	—	1.1517*** (3.9961)	0.5762** (1.7887)
Credit	—	—	—	0.1148*** (2.9659)
Constant	−18.8288	−21.0029	−24.0790	−23.824

Note: ***Significant at the 0.01 level, **0.05 level, Z-values are in parentheses

are absent, the intercept of Y equals −18.8288. Without any success factors influencing the PPP project, the probability of success is definitely lower than the probability of failure, leading to a high failure rate.

Therefore, the hypothesis H_{1a}, which states that investment scale is significantly negatively correlated with PPP project performance, holds. In addition, the hypothesis H_{1f}, which states that multilateral support is significantly positively correlated with PPP project performance, also holds. The model expression is:

$$\text{logit(P)} = \text{In}\frac{P}{1-P} = -18.8288 + 2.4140Multilateral - 2.5234Investment \quad (9)$$

Secondly, the regression results of Model 2 show the impact of GDP growth rate as a control variable on the project. The model adds the control variable GDP growth rate to the PPP project's own factors. According to the regression results, after adding GDPg, GDPg has a positive impact on the success or failure of PPP projects at the 1% significance level, with a coefficient of 0.4431 and a *Z*-value of 3.8891. At the same time, the coefficient of Multilateral is 2.9054 with a *t*-value of 4.1621. The data indicate that the success of PPP projects is influenced by the country's GDP growth rate, and multilateral support has a deeper impact on the project performance. The coefficient of Investment is −2.2441 with a *t*-value of −4.9091. The data suggest that the negative effect of investment amount decreases under the influence of the country's GDP growth rate. The constant term is −21.0029, indicating that In $P/(1-P) < 0$. According to the logarithmic formula, $p < 1-p$, meaning the probability of success is less than the probability of failure. Similar to the previous analysis, when all success factors are absent, there are no success factors influencing the PPP project, resulting in a lower success rate compared to the failure rate, that is a high failure rate. Therefore, accelerated GDP growth promotes the performance of PPP projects. The model expression is:

$$\text{logit(P)} = \text{In}\frac{P}{1-P} = -21.0029 + 2.9054Multilateral - 2.2441Investment + 0.4431GDPg \quad (10)$$

Thirdly, the regression results of Model 3 show the impact of GDP growth rate and the degree of national openness as control variables on the project. According to the regression results, Open is positively correlated at the 1% significance level, with a coefficient of 1.1517 and a *t*-value of 3.9961. With the combined influence of GDP growth rate and national openness, multilateral support has an even greater impact on the performance of PPP projects. However, the effect relative to investment scale is somewhat reduced. The constant term is −24.0790, indicating that $\text{In}\frac{P}{1-P} < 0$. According to the logarithmic formula, $p < 1-p$, meaning the probability of success is less than the probability of failure. Similar to the previous analysis, when all success factors are absent, there are no success factors influencing the PPP project, resulting in a lower success rate compared to the failure rate, that is a high failure rate. Therefore, the degree of national openness has a positive impact on the performance of PPP projects. The model expression is:

$$\text{logit(P)} = \text{In}\frac{P}{1-P} = -24.079 + 2.8235Multilateral - 2.4098Investment + 0.7799GDPg + 1.1517Open \quad (11)$$

The regression results of Model 4 show the impact of the three control variables on PPP projects. The macro environment includes the factor of private sector development. According to the regression results, the variable Credit is positively correlated at the 1% significance level, with a coefficient of 0.1148 and a *t*-value of 2.9659. With increased national support for the private sector, the private sector will invest more in national development. Consequently, the coefficient of Multilateral increases to a maximum of 3.7400. The constant term is −23.8235, indicating that $\text{In}\frac{P}{1-P} < 0$. According to the logarithmic formula, $p < 1-p$, meaning the probability of success is less than the probability of failure. Meanwhile, the data indicate that the coefficient for investment scale has also decreased. Therefore, the combined influence of the macro environment reduces the negative impact of investment scale on project performance. Hence, factors in the macro environment, such as national GDP growth, support for

the private sector, and the degree of openness, significantly affect the success and failure of PPP projects.

$$\text{logit(P)} = \text{In}\frac{P}{1-P} = -23.824 + 3.7400Multilateral - 2.5643Investment + 0.4747GDPg + 0.5762Open + 0.1148Credit \quad (12)$$

In summary of the above model analysis, in Model 2, the inclusion of GDPg results in an increase in the Multilateral coefficient, indicating an enhancing effect of the control variable on Multilateral. According to the literature, the Investment coefficient in Model 2 should increase, but it actually decreases. This might be because Model 1 lacks control variables, potentially leading to multicollinearity issues. Adding control variables redistributes the model's explanatory power, bringing it closer to the true situation. Models 3 and 4, respectively, add Open and Credit. The literature suggests that the Multilateral coefficient should increase, but in Model 4, it decreases, although it is still higher than in Model 1. This phenomenon occurs because there is an association between the variables, which reduces the explanatory power of Multilateral. The Investment coefficient increases in both Model 3 and Model 4. According to the literature, when the control variable is positively correlated with the dependent variable, adding the control variable will increase the coefficient of a negatively correlated independent variable. This means that when control variables jointly influence the performance of PPP projects, if the control variables are suddenly reduced or removed, the negative effect of Investment will increase, which aligns with the actual situation.

4.4.3 Receiver operating characteristic analysis

The receiver operating characteristic (ROC) curve is a tool used to evaluate the ability of a logistic regression model to distinguish between positive and negative samples (i.e. classification performance) (Huwaina *et al.*, 2022). It assesses the model's classification ability by showing the trade-off between sensitivity and specificity (1-specificity) at different thresholds (Methasit and Juggapong, 2024). The closer the ROC curve is to the top left corner, the better the model's classification performance (Wang, 2021b). This indicates that the model has a good balance between high sensitivity and high specificity. Figure 2 shows the ROC curves of the predicted probability (PRE). The ROC plot contains curves for four different models. The Area Under the ROC Curve (AUC) represents the area under the ROC curve. The closer the AUC

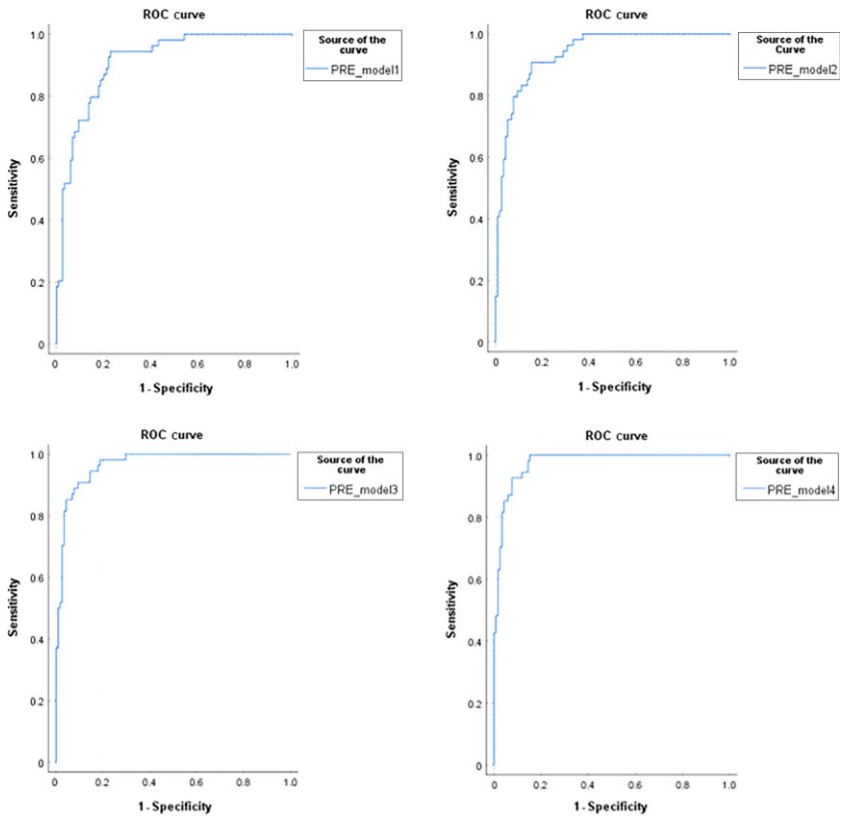

Figure 2. ROC curve for predicted probability

Table 7. Area under the ROC curve

Test result variable(s)	Area
PRE_model1	0.912
PRE_model2	0.938
PRE_model3	0.967
PRE_model4	0.974

value is to 1, the better the model's classification performance. When the AUC value is between 0.9 and 1.0, the model's performance is considered excellent (Gupta *et al*., 2024). Table 7 shows the AUC values for the four models, which are 0.912, 0.938, 0.967, and 0.974. The data indicate that the model improves as more control variables are added.

4.4.4 Pseudo R-squared

Pseudo R-squared is a metric used to assess the goodness of fit of logistic regression models. Since the dependent variable in logistic regression models is binary, the traditional R-squared (R^2) used in linear regression models cannot be directly applied (Singh *et al*., 2024). Pseudo R-squared provides a measure similar to R-squared for evaluating the explanatory power of logistic regression models. Common pseudo R-squared metrics include Cox & Snell R Square and Nagelkerke R Square. The Cox & Snell R Square typically ranges from 0 to 1, with a reasonable range between 0.2 and 0.4. The closer it is to 1, the stronger the model's explanatory power for the dependent variable, indicating better fit (Cara *et al*., 2022). The Nagelkerke R square also typically ranges from 0 to 1, with a reasonable range between 0.3 and 0.5. The closer it is to 1, the stronger the model's explanatory power for the dependent variable, indicating better fit (Eduardo *et al*., 2023). Among the four models in Table 8, the lowest Cox & Snell R Square value is 0.418, which exceeds 0.4, indicating a very good fit. The lowest Nagelkerke R Square value among the four models is 0.587, which exceeds 0.5, also indicating a very good fit.

In summary, although residual analysis is also an important method for assessing model fit and diagnosing outliers in logistic regression models, a more appropriate evaluation method was used in this study. The minimum p-value of 0.659 across the four models in the Hosmer and Lemeshow test indicates a very good fit. The ROC curves of all four models are concentrated in the upper left corner, and the minimum AUC value is 0.912, exceeding 0.9, indicating excellent classification performance. The minimum values of Accuracy, Sensitivity, Specificity, and Precision in the classification table are 84.88, 68.52, 92.37, and 80.43, respectively, indicating high accuracy. The Cox & Snell R Square exceeds 0.4, and the Nagelkerke R Square exceeds 0.5 in the Pseudo R-squared, indicating a very good fit. Therefore, the logistic regression model has good model fit and prediction accuracy.

Table 8. Pseudo R-squared

Model	Cox & Snell R square	Nagelkerke R square
(1)	0.418	0.587
(2)	0.476	0.669
(3)	0.558	0.784
(4)	0.587	0.824

4.5 Moderating effect analysis

4.5.1 Dimensionality reduction of PPP project's own factors

The intrinsic factors of PPP projects include investment scale, investment industry, investment type, the level of private sector development, and the extent of multilateral national support. This paper requires a thorough analysis of the impact of moderating variables on the performance of PPP projects. The five variables representing the intrinsic factors of the projects are combined according to certain weights. In practical research, when the variables are continuous, PCA and factor analysis methods are usually adopted (Zhao and Jia, 2017). However, since the influencing factors of PPP projects are mainly discrete categorical variables, CATPCA is used (Linting and Van der Kooij, 2012). The functionality and purpose of CATPCA are the same as those of PCA, but CATPCA can be used for any type of variable and does not have specific distribution requirements, making it widely applicable (Antosz *et al*., 2023). The combined variables of PPP project intrinsic factors obtained through CATPCA are denoted as 'Own'.

4.5.2 Moderating effects results

Using the macro programme in the statistical software, process was used to analyse the moderating effects. Table 9 shows the results of the moderating effect regression analysis.

In Model 1, the project's own factors have a negative effect on the success and failure of PPP projects. The coefficient is −0.2226, and the t-value is −1.2773. Although it is not significant, it does not affect the subsequent study of the moderating effect. The reason for the negative effect is that the investment scale within the project's own factors is negatively correlated with project performance. Although other variables are positively correlated, the negative effect of the investment scale impacts the other variables, and the investment scale has a high proportion. Therefore, the PPP project itself has a negative effect. The influencing factors of the PPP project itself have already been studied, and the moderating effect is not a study of the project's own factors. Instead, the moderating effect examines how risk factors, as moderating variables, impact the success or failure of PPP projects.

In Model 2, the moderating variable of political risk is introduced. As previously mentioned, according to the International Country Risk Guide by the American International Report Group, the political risk score is out of 100 points. A full score indicates no

Table 9. Moderating effect regression results

Variable	Model 1	Model 2	Model 3	Model 4
Own	−0.2226 (−1.2773)	−4.5338 *** (−2.1321)	−9.9536*** (−2.3967)	−11.7923*** (−2.0036)
Political Risk	—	0.1072*** (3.3010)	—	—
Economic Risk	—	—	1.0907*** (4.9035)	—
Financial Risk	—	—	—	0.8846*** (4.9561)
Own*Political Risk	—	0.0733*** (2.0333)	—	—
Own*Economic Risk	—	—	0.4246*** (2.4672)	—
Own*Financial Risk	—	—	—	0.3870*** (2.1489)
Control variable			Controlled	
Constant	−6.9661	−6.9557	−25.3151	−28.3743
−2 Log likelihood	212.3433	194.3275	64.3129	90.5032

Note:***Significant at the 0.01 level, Z-values are in parentheses

political risk. The higher the score, the lower the risk. Table 9 shows that political risk is positively correlated at the 1% significance level. The coefficient of political risk is 0.1072, and the *t*-value is 3.3010. This indicates that the higher the political risk score (lower risk), the higher the success rate of PPP projects. Therefore, the hypothesis H_{2a} that political risk is significantly negatively correlated with the performance of PPP projects is supported. After the interaction between political risk and the project's own factors is moderated, a positive correlation is found at the 5% significance level. The interaction coefficient is 0.0733, and the *t*-value is 2.0333. The moderation of political risk weakens the negative impact brought by the investment scale. Therefore, the higher the political risk score (lower risk), the higher the success rate of PPP projects. According to Aiken *et al*.'s method, the moderating effect of political risk is plotted in Figure 3. Under conditions of higher political risk, the slope between PPP project's own factors and the performance of PPP projects is greater, indicating a stronger effect of political risk on PPP projects. The higher the political risk score (lower risk), the greater the impact on the success probability of PPP projects. Therefore, hypothesis H_{3a}, that political risk is significantly negatively correlated with the performance of PPP projects, is supported.

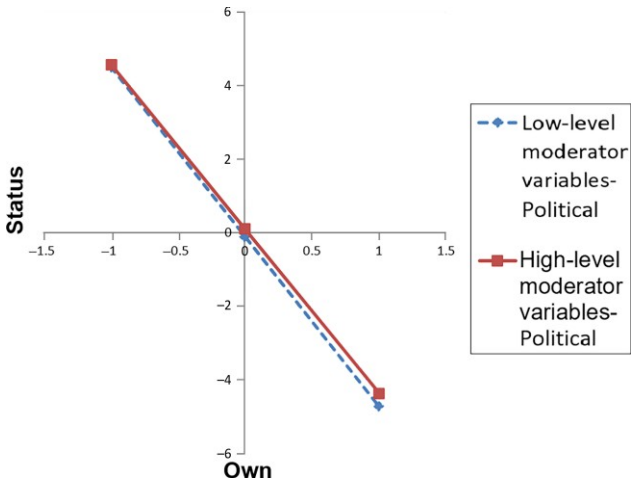

Figure 3. Moderating effect of political risk

In Model 3, the moderating variable of economic risk is introduced. As previously mentioned, according to the International Country Risk Guide by the American International Report Group, the economic risk score is out of 50 points. A full score indicates no economic risk. The higher the score, the lower the risk. As shown in Table 10, economic risk is positively correlated at the 1% significance level. The coefficient of economic risk is 1.0907, and the *t*-value is 4.9035. This indicates that the higher the economic risk score (lower risk), the higher the success rate of PPP projects. Therefore, the hypothesis H_{2b} that economic risk is significantly negatively correlated with the performance of PPP projects is supported.

After moderating the interaction between economic risk and project's own factors, the result is positively correlated at the 5% significance level. The interaction coefficient is 0.4246, and the *t*-value is 2.4672. The moderation of economic risk weakens the negative impact brought by the investment scale. Therefore, the higher the economic risk score (lower risk), the higher the success rate of PPP projects. According to Aiken *et al*.'s method, the moderating effect of economic risk is plotted in Figure 4. Under conditions of higher economic risk, the slope between PPP project's own factors and the performance of PPP projects is greater, indicating a stronger effect of economic risk on PPP projects. The higher the economic risk score

Table 10. Robustness test results

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
MultiLateral	3.759	1.088	11.928	1	0.001	42.906
Investment	−2.933	0.745	15.486	1	0.000	0.053
GDPg-per capita	0.775	0.316	6.017	1	0.014	2.170
Credit	0.118	0.039	9.324	1	0.002	1.125
Open	0.744	0.366	4.130	1	0.042	2.104
Constant	−44.534	56841.662	0.000	1	0.999	0.000

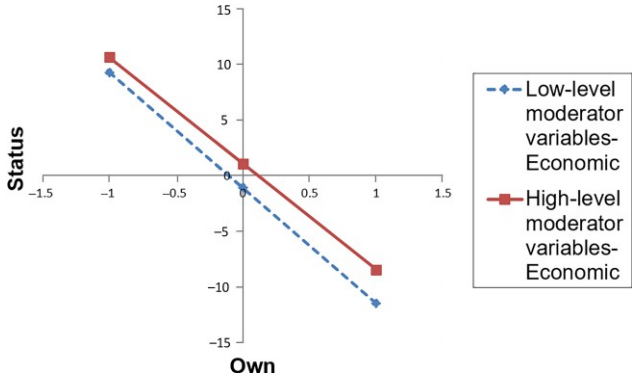

Figure 4. Moderating effect of economic risk

(lower risk), the greater the impact on the success probability of PPP projects. Therefore, hypothesis H_{3c} that economic risk is significantly negatively correlated with the performance of PPP projects is supported.

In Model 4, the moderating variable of financial risk is introduced. As previously mentioned, according to the International Country Risk Guide by the American International Report Group, the financial risk score is out of 50 points. A full score indicates no financial risk. The higher the score, the lower the risk. Financial risk is positively correlated at the 1% significance level. The coefficient of financial risk is 0.9087, and the Z-value is 4.9057. This indicates that the higher the financial risk score (lower risk), the higher the success rate of PPP projects. Therefore, the hypothesis H_{2c} that political risk is significantly negatively correlated with the performance of PPP projects is supported.

After moderating the interaction between financial risk and project's own factors, the result is positively correlated at the 5% significance level. The interaction coefficient is 0.6073, and the Z-value is 2.2282. In PPP projects dominated by the scale of investment, the

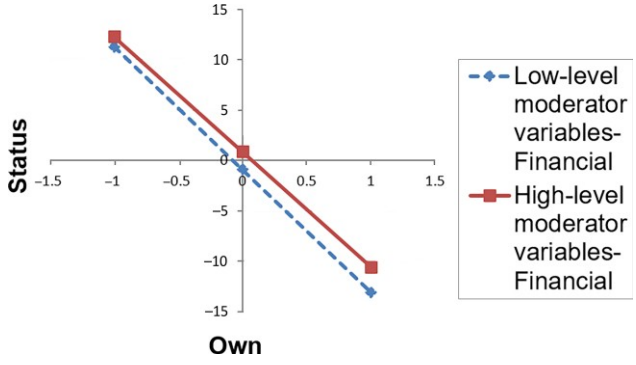

Figure 5. Moderating effect of financial risk

moderating effect of financial risk weakens the negative impact brought about by the scale of investment. Therefore, the higher the financial risk score (lower risk), the higher the success rate of PPP projects. According to Aiken *et al.*'s method, the moderating effect of financial risk is plotted in Figure 5. Under conditions of higher financial risk, the slope of the relationship between the PPP project's own factors and the performance of PPP projects is steeper, indicating that financial risk has a stronger impact on PPP projects. The higher the financial risk score (lower risk), the greater the impact on the success probability of PPP projects. Therefore, hypothesis H_3, which states that when country risk is low, the relationship between the project's own factors and project performance is strengthened, is supported.

4.6 Robustness test

The robustness test can be conducted by splitting the sample, changing the research method, and using alternative variables. To verify the robustness of the model, this paper chooses to replace variables. The per capita growth rate of GDP is used instead of the GDP growth rate to observe changes in the model's results. In Table 10, the method used is the same as in Model 4 of Table 6. Except for replacing the GDP growth rate with the per capita growth rate of GDP, the other variables remain the same. A binary logistic regression with a backward stepwise (LR) method is used. The results of the robustness test are generally consistent with the original model results, with no significant differences. Therefore, the data sufficiently demonstrate that the findings of this study are relatively robust.

5. Conclusions and recommendations

5.1 Conclusions

This study includes three main hypotheses and 11 subhypotheses, tested using methods such as binary logistic regression and CATPCA. The results of the tests for each hypothesis are discussed. The first hypothesis, H_1, states that the intrinsic factors of PPP projects significantly influence project performance. The results show whether these factors have a significant, positive, or negative impact. The second hypothesis, H_2, suggests that country risk negatively affects project performance. The results indicate that country risk has a negative impact on the performance of PPP projects. The third hypothesis, H_3, proposes that country risk significantly moderates the relationship between project intrinsic factors and project performance. The findings show that country risk enhances the effect of intrinsic factors on project performance. In summary, the intrinsic factors hypothesis (H_1) is partially accepted; the country risk hypothesis (H_2) is accepted; and the moderating effect of country risk (H_3) is accepted.

The performance of PPP projects is influenced by various intrinsic factors, including investment scale, investment type, investment industry, private sector participation, and multilateral national

support. Under hypothesis H_1, investment scale is found to be significantly negatively correlated with PPP project performance. The results indicate that larger investment scales negatively impact project performance. As for the investment type, it does not significantly explain PPP project performance. The literature suggests that investment type is not a decisive factor for success, as it depends on the needs of the countries along the BRI. Regarding the investment industry, the results show no significant relationship with project performance. The discrepancy may arise because earlier studies focused on industry selection within PPP projects, while this study focuses on the national environment. The hypothesis that private sector participation is significantly positively correlated with PPP project performance is not supported. The literature suggests that PPP projects must involve collaboration between the government and the private sector. However, having more private sector participants does not necessarily lead to better outcomes, as it can result in fragmented leadership. Therefore, the number of private sector participants should not be excessive. The hypothesis that multilateral national support is significantly positively correlated with PPP project performance is supported, indicating that greater support from other countries leads to higher success rates.

The performance of PPP projects is also influenced by country risks, including political, economic, and financial risks. Under hypothesis H_2, political risk is found to be significantly negatively correlated with PPP project performance. The results show that higher political risk lowers the success rate of PPP projects. According to the definition of political risk by the American International Report Group, it includes government stability, socio economic conditions, investment profile, internal conflict, external conflict, corruption, military involvement in politics, religious tensions, law and order, ethnic tensions, democratic accountability, and bureaucratic quality. These political factors significantly negatively impact the performance of PPP projects. For economic risk, the hypothesis posits a significant negative correlation with PPP project performance. The results indicate that higher economic risk decreases the success rate of PPP projects. The American International Report Group defines economic risk to include per capita GDP risk, GDP growth risk, inflation risk, budget balance risk, and current account risk. Higher economic risks increase the uncertainties for PPP projects, leading to lower success rates. Regarding financial risk, the hypothesis states a significant negative correlation with PPP project performance. The results show that higher financial risk reduces the success rate of PPP projects. The American International Report Group defines financial risk to include external debt risk, current account risk as a percentage of XGS, international liquidity risk, exchange rate stability risk, and debt repayment risk. Greater financial risks lead to increased uncertainties, reducing the success rate of PPP projects.

In hypothesis H_3, the moderating effect of country risk on the relationship between project intrinsic factors and project success is examined. The results indicate that increased political risk strengthens the negative relationship between intrinsic factors and project performance, reducing the success rate. Similarly, increased economic risk weakens the impact of intrinsic factors on project performance, thereby lowering the success rate. Increased financial risk also weakens the impact on PPP projects, reducing the success rate.

Therefore, based on the conclusions of this study, the following recommendations are made for Chinese companies. Chinese companies should leverage their advantages in PPP project industries and select appropriate countries for investment. Since investment scale is negatively correlated with project performance, companies should carefully consider country risks and balance investment scale with project returns. Chinese companies should closely follow China's cooperative initiatives with BRI countries and seek support from multilateral financial institutions. They should pay attention to the political system differences among BRI countries to reduce political risk and respect local religious customs to minimise conflicts. Furthermore, they should adhere to local laws, making appropriate use of common law and civil law systems. Finally, Chinese companies should conduct thorough research on the economic development of BRI countries and carefully choose PPP projects to promote the joint development and progress of BRI countries through their investments.

5.2 Policy recommendations

Enterprises should review the overall scale, development trends, scale conditions, industry layout, and regional distribution of PPP projects in BRI countries, selecting PPP projects that align with their goals. Priority should be given to regions with a strong foundation for PPP project development while controlling the total scale of project investments to comprehensively reduce risks and enhance project success rates.

Chinese enterprises should focus on investing in countries and PPP projects that align with their investment development goals and exhibit economic growth potential. Particular attention should be paid to the openness of trade, investment and finance of the BRI country, making situational and regional decisions on participation in PPP projects.

Enterprises should consider the political system differences among BRI countries to reduce political risk. Thorough research on the political landscape of BRI countries is necessary, including government stability, law and order, internal and external conflicts, government corruption, military influence in politics, religious tensions, ethnic tensions, and the quality of bureaucracy. Respecting local religious customs and traditions can mitigate conflict and political risks. Understanding and adhering to local laws, whether they follow

common law or civil law systems, is crucial. From bidding and financing to contract signing, project implementation and operations, PPP projects involve various legal aspects. Strengthening legal knowledge can help mitigate legal risks.

Enterprises should establish a risk management system. This system should guide the handling of various risks when investing in PPP projects in BRI countries and should be integrated throughout the entire PPP project process.

6. Limitations and future research

A second limitation of this study is the broad range of PPP project industries considered without focusing on a specific infrastructure industry. This study aims to provide direction for Chinese enterprises' investments, so it has not focused on a single industry nor studied one industry in isolation. However, encompassing the variation across industries (energy, ICT, transportation, water supply and treatment, and urban solid waste treatment), the findings and recommendations may not apply to all industries. This study provides a reference to enterprises and governments from the perspective of overall PPP projects, where industry specific understandings should be explored in future research.

Future research should focus on PPP projects of a specific industry to examine the determinants. While studying the determinants of PPP project performance in a specific industry is relatively straightforward, it can allow for thorough research. It can serve as a more specific model for that industry. Therefore, thus study recommends focusing on specific industries in future research while examining these industries individually to elicit a more nuanced understanding of the determinants for each industry.

Funding

This research was funded by Anhui Vocational and Adult Education Society Projects (Grant Nos. AZCJ2024035 and AZCJ2023003); Anhui Provincial Department of Education Quality Project Teaching Research Programme (Grant Nos. 2024jyxm0968 and 2024cyzyq088); Anhui Provincial Department of Education's Research Projects (Grant Nos. 2024AH053342 and 2023AH052667); Anhui Province Chinese Vocational Education Society Planning Project (Grant No. AHZJSc202401); and Anhui Provincial Department of Education's Research Projects (Grant No. 2022AH052786).

REFERENCES

Alireza V, Nordin Y, Norhazilan MN, Mardani A and Antuchevi I (2016) A new hybrid fuzzy cybernetic analytic network process model to identify shared risks in PPP projects. *International Journal of Strategic Property Management* **20(4)**: 409–426.

Almeile AM, Chipulu M, Ojiako U, Vahidi R and Marshall A (2024) Project focussed literature on public-private partnership (PPP) in developing countries: a critical review. *Production Planning & Control* **35(7)**: 683–710.

Ameyaw EE and Chan APC (2016) A fuzzy approach for the allocation of risks in public-private partnership water-infrastructure projects in developing countries. *Journal of Infrastructure Systems* **22(3)**: 784–798.

Antosz K, Kaczmarek MJ, Machado J and Relich M (2023) Application of principle component analysis and logistic regression to support six sigma implementation in maintenance. *Eksploatacja i Niezawodność – Maintenance and Reliability* **25(4)**: 242–259.

Asadornborikarn W (2021) *National Risk, Private Institution Risk Bearing, and Success or Failure of PPP Model Operation*. Master's Thesis, South China University of Technology, pp. 53–67.

Aundhe MD and Narasimhan R (2016) Public private partnership (PPP) outcomes in e-government – a social capital explanation. *International Journal of Public Sector Management* **29(7)**: 638–658.

Avishek C, Satyaki M and Koel D (2022) Functional classwise principal component analysis: a classification framework for functional data analysis. *Data Mining and Knowledge Discovery* **37(2)**: 82–99.

Babatunde SO, Perera S and Adeniyi O (2019) Identification of critical risk factors in public-private partnership project phases in developing countries a case of Nigeria. *Benchmarking: An International Journal* **26(2)**: 334–355.

Biygautane M, Clegg S and Yahya KA (2020) Institutional work and infrastructure public–private partnerships (PPPs): the roles of religious symbolic work and power in implementing PPP projects. *Accounting Auditing & Accountability Journal* **(32)**: 328–341.

Biygautane M, Neesham C and Al-Yahya KO (2019) Institutional entrepreneurship and infrastructure public-private partnership (PPP): unpacking the role of social actors in implementing PPP projects. *International Journal of Project Management* **37(1)**: 192–219.

Cao X and Li ST (2021) The impact of the belt and road initiative on economic growth in countries along the route and China's role. *World Economy Research* **(10)**: 13–24 + 134.

Cara A, Matthew B, Mladen R, Robert P and Christopher U (2022) Predicting student outcomes using digital logs of learning behaviors: review, current standards, and suggestions for future work. *Behavior Research Methods* **55(6)**: 423–443.

Chen H and Yang CY (2015) International economic effects of the belt and road initiative – based on CGE model analysis. *Issues in International Trade* **(10)**: 4–13.

China News Network (2013) The plenary session decided: accelerate the interconnection and interoperability of infrastructure with neighboring countries. See https://www.chinanews.com.cn/gn/2013/11-5509762.shtml (accessed 08/11/2022).

CHINCA (2023) The belt and road infrastructure development index report 2022. See https://www.chinca.org/cica/tbarii/tp/21070513270411 (accessed 08/11/2023).

Cui XS (2020) The impact of business environment in countries along the belt and road on economic development based on the World Bank's business environment indicators. *Journal of Beijing Technology and Business University (Social Science Edition)* **35(3)**: 37–48.

Eduardo A, Nicolás G, Alejandro L *et al.* (2023) Dyspnea severity assessment based on vocalization behavior with deep learning on the telephone. *Sensors* **23(5)**: 329–342.

Edward M (2022) Modes of solid waste management and household health outcomes. *Journal of Environmental Planning and Management* **65(4)**: 629–641.

Estache A (2006) PPI partnerships vs. PPI divorces in LDCs. *Review of Industrial Organization* **29(1–2)**: 3–26.

Fleta-Asín J and Muñoz F (2020) How does risk transference to private partner impact on public-private partnerships' success? Empirical evidence from developing economies. *Socio Economic Planning Sciences* **(31)**: 662–672.

Galilea P and Medda F (2010) Does the political and economic context influence the success of a transport project? An analysis of transport public-private partnerships. *Research in Transportation Economics* **30(1)**: 102–109.

Gupta D, Bhargava A, Agarwal D *et al.* (2024) Deep learning-based truthful and deceptive hotel reviews. *Sustainability* **16(11)**: 4514–4801.

Han Y, Zhang TT and Fang J (2020) Cost-benefit analysis of public parking lot PPP projects from a life cycle perspective. *Transportation Research* **6(2)**: 20–29.

Hatem AS, Essam R and Hassan AH (2022) Categorical principal component analysis (CATPCA) of pedestrian crashes in Central Florida. *Journal of Transportation Safety and Security* **14(11)**: 543–557.

He YP and Xu KN (2018) The impact of economic systems of countries along the belt and road on China's OFDI. *Issues in International Trade* **(1)**: 92–100.

He YL, Zhang Y and Fan YH (2021) Experience, industrial agglomeration, and the success rate of belt and road PPP projects. *International Trade Exploration* **37(3)**: 47–64.

Hou SJ, Long W and Zhou SF (2019) The impact of institutional quality and the participation of multilateral financial institutions on the effectiveness of PPP projects. *Statistics and Decision Making* **35(14)**: 162–165.

Huang LX, Han YH, Wang JL and Li ZJ (2016) China's economic development illuminates the belt and road initiative – an empirical analysis based on night light intensity data. *Economist* **(9)**: 96–104.

Huo WD, Chen RY and Li XY (2018) Institutional quality, multilateral financial institution support, and PPP project effectiveness empirical evidence from African PPP projects. *Research on Economics and Management* **39(3)**: 52–64.

Huwaina RN, Hamimah A, Einur ABH, Azmi BN and Ahmad RZZ (2022) Financial risk in managing public-private partnership (PPP) project. In *Proceedings of IOP Conference Series: Earth and Environmental Science*, pp. 1607–1618.

Keers BBM and van Fenema PC (2018) Managing risks in public-private partnership formation projects. *International Journal of Project Management* **36(6)**: 861–875.

Kukah ASK, Owusu-Manu DG, Badu E and Edwards DJ (2024) Reasons for entering into Ghanaian public-private partnership (PPP) power projects. *Journal of Engineering, Design and Technology* **22(3)**: 854–878.

Lazuardi U, Cory NH, Annisa RV *et al.* (2023) Potentiometry lipid membrane based electronic tongue for the classification of mint in tea by principal component analysis (PCA) and linear discrimination analysis (LDA). *Instrumentation Science and Technology* **51(5)**: 54–68.

Li HL and Ma HX (2016) Economic development opportunities in Bakistan and the belt and road initiative. *Academic Exploration* **(7)**: 36–43.

Linting M and Van der Kooij A (2012) Nonlinear principal components analysis with CATPCA: a tutorial. *Journal of Personality Assessment* **94(1)**: 12–25.

Liu LJ (2018) Main risks and prevention mechanisms for domestic enterprises participating in PPP investments in countries along the belt and road. *Foreign Economic and Trade Practices* **(2)**: 83–86.

Liu XS (2019) *The Impact of National Political Risks on the Effectiveness of Infrastructure PPP Projects*. Master's Thesis, Donghua University, pp. 64–76.

Liu X (2022) *The Impact of Government Governance Factors on Private Investment Willingness in PPP Projects*. Master's Thesis, University of International Business and Economics, pp. 88–92.

Liu HM, Hu SL, Fang K *et al.* (2019) Comprehensive assessment and prevention of political economic social risks in countries along the belt and road. *Geographical Research* **38(12)**: 2966–2984.

Liyanapathirana D, Adeniyi O and Rathnasiri P (2024) Tactical conflict prevention strategies in public-private partnerships: lessons from experts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction* **16(1)**: 996–1012.

Luo Y, Wang F and Chen X (2017) How institutional quality and international financial institutions affect PPP project effectiveness – a study based on experience data from 46 countries along the belt and road. *Financial Research* **(4)**: 61–77.

Lusinyan L, Cebotari A, Velloso R *et al.* (2009) Fiscal risks: sources, disclosure, and management. *IMF Departmental Papers/Policy Papers* **23(24)**: 45–59.

Ma YR and Chen YJ (2017) Discussion on several issues in foreign language education in inner Mongolia under the belt and road initiative. *Journal of Inner Mongolia University of Finance and Economics* **15(2)**: 130–133.

Menezes F and Ryan M (2015) Default and renegotiation in public-private partnership auctions. *Journal of Public Economic Theory* **17(1)**: 49–77.

Methasit P and Juggapong N (2024) Identifying player skill of dota 2 using machine learning pipeline. *Discover Artificial Intelligence* **4(1)**: 22–34.

Mohamed IS (2015) Good governance, institutions and performance of public private partnerships. *The International Journal of Public Sector Management* **28(7)**: 566–582.

Mona H, Francoics RJ and Etienne Y (2006) Determinants of public-private partnerships in infrastructure. *IMF Working Papers* **24(42)**: 33–45.

Nguyen NL, Xiao W and Hoang TT (2018) Financing a PPP project: sources and financial instruments—case study from China. *International Journal of Business and Management* **13(10)**: 76–89.

Nikola SA, Lockhart RA and Loughin TM (2024) A generalized Hosmer–Lemeshow goodness of fit test for a family of generalized linear models. *TEST* **33(2)**: 589–608.

Ortiz R, Contreras M and Mellado C (2023) Regression, multicollinearity and Markowitz. *Finance Research Letters*, **58**: 104550.

Oyedele LO (2013) Avoiding performance failure payment deductions in PFI/PPP projects: model of critical success factors. *Journal of Performance of Constructed Facilities* **27(3)**: 283–294.

Ozgur BE and Franklin D (2021) Multicollinearity in logistic regression models. *Anesthesia and Analgesia* **133(2)**: 362–365.

Percoco M (2014) Quality of institutions and private participation in transport infrastructure investment: Evidence from developing countries. *Transportation Research Part A: Policy and Practice* **70(12)**: 50–58.

PRS (2015) Research and Markets Adds Report: International Country Risk Guide. See https://www.prsgroup.com (accessed 11/11/2022).

PRS (2023) International Country Risk Guide. See https://www.prsgroup.com/exploreourproducts/icrg (accessed 9/11/2023)

Ragnar N (1966) Problems of capital formation in underdeveloped countries. *Punjab University Economist* **2(4)**: 1–23.

Root LS, Brooks H, Liebman L and Schelling CS (1985) Public-private partnership: new opportunities for meeting social needs. *Journal of Policy Analysis and Management* **4(2)**: 302.

Sachs T, Tiong R and Wang SQ (2007) Analysis of political risks and opportunities in public private partnerships (PPP) in China and selected Asian countries: Survey results. *Chinese Management Studies* **1(2)**: 126–148.

Schepper DS, Haezendonck E and Dooms M (2015) Understanding pre-contractual transaction costs for Public-Private partnership infrastructure projects. *International Journal of Project Management* **33(4)**: 932–946.

Shen MX (2016) National risk, multilateral financial institution support, and capital structure of PPP project financing an empirical analysis based on belt and road PPP project data. *Research on Economics and Management* **37(11)**: 3–10.

Sheng WJ (2019) *Game Analysis of Risk Sharing in Belt and Road Infrastructure PPP Projects*. Master's Thesis, Guangdong University of Technology, pp. 37–42.

Shi XM and Sun L (2017) Research on the factors influencing private sector participation in PPP projects under the belt and road initiative. *Research on Financial and Economic Issues* **(5)**: 12–17.

Singh M, Khajuria V, Singh S and Singh K (2024) Landslide susceptibility evaluation in the Beas river basin of North Western Himalaya: a geospatial analysis employing the analytical hierarchy process (AHP) method. *Quaternary Science Advances* **14**: 100180.

Tan J and Zhao ZR (2019) Government and social capital cooperation: China's PPP from an international comparative perspective. *Public Management and Policy Review* **8(3)**: 62–72.

Wahab A and Mohamed S (2009) Reflections on public-private partnerships in Egypt: practical and legal challenges. *Law and Financial Markets Review* **3(3)**: 232–241.

Wang Y (2018) *National Risk and PPP Project Efficiency*. Master's Thesis, Jinan University, pp. 43–51.

Wang W (2021a) *Research on the Impact of Openness of Countries along the Belt and Road on the Efficiency of Their PPP Projects*. Master's Thesis, Sichuan International Studies University, pp. 64–74.

Wang YN (2021b) Research on VAT issues in the construction phase of PPP projects under the BOT model. *Finance and Accounting Learning* **(8)**: 137–138.

Wang PZ, Pan XY and Zhang SY (2018) Institutional factors, bilateral investment treaties, and China's outbound direct investment location choice based on panel data of countries along the belt and road. *Economy and Management Review* **34(1)**: 5–17.

Wang ZH, Bai SJ and Guo YT (2021) Investment risk of belt and road infrastructure PPP projects—taking three Southeast Asian countries as examples. *Journal of Engineering Management* **35(5)**: 88–93.

Williamson OE (1988) Corporate finance and corporate governance. *The Journal of Finance* **43(3)**: 567–591.

World Bank (2008) The World Bank Annual Report 2008. See https://elibrary.worldbank.org/doi/abs/10.1596/978-8213-1 (accessed 08/11/2022).

World Bank (2024) Private Participation in Infrastructure (PPI) database World Bank Group. See https://ppi.worldbank.org/en/ppi (accessed 08/11/2022).

Wu YJ (2021) *Analysis of Key Factors Affecting the Effectiveness of PPP Models*. Master's Thesis, Shanghai University of Finance and Economics, pp. 43–53.

Xinhua News Agency (2013a) Xi Jinping's Important Speech at Nazarbayev University in Kazakhstan. See http://www.gov.cn/ldhd/2013-07/content_2483425.htm (accessed 08/11/2022)

Xinhua News Agency (2013b) Xi Jinping's Speech at the Indonesian Parliament. See http://www.gov.cn/ldhd/2013-03/content_2500118.htm (accessed 08/11/2022)

Xue Y (2021) Economic environment, institutional quality, and PPP project success or failure—based on a study of countries along the belt and road. *Financial Theory and Practice* **(2)**: 58–66.

Yang LL (2021) Social embedding, corporate reputation, and overseas investment economic risk management—a study based on Chinese enterprises' investment in countries along the belt and road. *Journal of Chongqing University (Social Science Edition)* **27(2)**: 8–22.

Ye F (2017) Factors influencing the spatial distribution of investment in infrastructure projects by multilateral development banks—an empirical analysis based on the World Bank's PPI database. *Fiscal Research* **(10)**: 65–75.

Yu QY (2016) *Research on Reform of Urban Public Utilities Regulatory System in China*. Doctor's Thesis, Jilin University, pp. 32–38.

Yu Q, Zhou Y, Xu C, Atumo EA and Jiang X (2024) Temporal instability assessment of motorcyclist injury severities using categorical principal component analysis and random parameter approach with heterogeneity in means. *Journal of Transportation Safety & Security* **16(4)**: 347–374.

Yuan N (2018) *Research on the Impact of Risk Allocation, Market Environment, and Economic Environment on PPP Project Investment and Success*. Master's Thesis, Wuhan University, pp. 55–58.

Yuan J, Chan AC, Xia B *et al.* (2016) Cumulative effects on the change of residual value in PPP projects: a comparative case study. *Journal of Infrastructure Systems* **22(2)**: 111–127.

Zhang CG and Man HF (2018) Comprehensive evaluation and comparison of investment environment in countries along the belt and road an empirical study based on different types of economies. *Finance and Economy* **(2)**: 48–54.

Zhang PF and Xie SY (2020) The belt and road initiative and china's outward direct investment—an empirical analysis based on difference-in-differences. *Investment Research* **39(11)**: 88–95.

Zhao J (2020) Research on the impact of institutional quality and multilateral financial institution support on PPP project performance—empirical research based on asean country PPP project data. *International Trade Issues* **(5)**: 161–174.

Zhao R and Jia RN (2017) Discussion on country risk management in the belt and road strategy—based on the country economic risk assessment model. *Shanghai Finance* **(3)**: 91–95.