



# Public–Private Partnerships and Financial Performance of Infrastructure Projects

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## Abstract

Public–Private Partnerships (PPPs) have emerged as a central mechanism for financing infrastructure amid fiscal constraints, yet evidence on their financial performance remains mixed and insufficiently explained at the project level. This study examines how PPP project structure influences the financial performance of infrastructure projects, with particular emphasis on the mediating role of risk allocation and sectoral heterogeneity. Adopting a layered mixed-methods design, the study combines project-level panel data analysis with a structured risk allocation assessment, complemented by embedded case studies and comparative sector analysis. Using longitudinal data on PPP projects across transport, energy, water, and social infrastructure sectors, the empirical analysis employs fixed-effects panel models, mediation specifications, and sector interaction terms to capture performance dynamics over time. The findings show that PPP project structure—especially private capital participation and availability-based payment mechanisms—has a positive and statistically significant effect on financial performance, proxied by debt service coverage and profitability indicators. Importantly, risk allocation efficiency partially mediates this relationship, confirming that balanced risk sharing enhances revenue stability and debt sustainability. Sectoral results reveal pronounced heterogeneity, with transport projects being more sensitive to demand risk and social and energy infrastructure benefiting from revenue-stabilising contractual arrangements. By moving beyond aggregate analyses and explicitly modelling risk allocation as a mechanism, the study advances PPP and project finance literature and offers practical insights for policymakers, PPP units, investors, and lenders seeking to improve the financial sustainability of infrastructure partnerships.

**Keywords:** Financial performance, Infrastructure finance, Project-level panel data, Public–private partnerships, Risk allocation, Sectoral heterogeneity.

## 1. Introduction

### 1.1. Background to PPPs and Infrastructure Finance

Public-Private Partnerships (PPPs) have been recognized as an essential tool for infrastructure finance and delivery, especially under conditions of financial constraints, rapid urbanization, and escalating requirements for resilient infrastructure. The integration of public control with private financial support and expertise is likely to improve efficiency, accelerate delivery, and optimize value for money in sectors such as transportation, energy, water, and social infrastructure. In the past few years, multilateral development agencies and national governments have increasingly encouraged PPPs as an approach for bridging infrastructure gaps while minimizing public sector exposure (World Bank, 2023; OECD, 2021). Despite the popularity of PPPs, the financial performance of PPP projects has been mixed, raising questions about the viability of PPPs as a sustainable model for infrastructure finance.

### 1.2. Motivation: Financial Performance Variability in PPP Projects

Empirical studies suggest a significant degree of variability in the financial performance of PPP projects, even for projects in the same sector or institutional environment. Some PPP projects experience stable cash flows, good internal rates of return, and timely debt service, while others face cost overruns, revenue problems, renegotiations, and financial difficulties. Recent studies suggest that the differences in financial performance are no longer fully explained by the sectoral characteristics of the projects and the macro-environment, but are often linked to project-specific factors, including the contractual, financial, and risk structures of the projects (Carbonara & Pellegrino, 2020; Roumboutsos & Saussier, 2021). This ongoing diversity of financial performance requires a deeper, project-by-project analysis of the relationship between the structure of PPPs and financial performance outcomes.

### *1.3. Research Problem and Knowledge Gap*

Despite the extensive literature on PPPs, three interrelated gaps are particularly prominent. Firstly, the majority of the empirical literature focuses on country-level or sector-level aggregated data, and therefore lacks project-level financial information. Secondly, the literature on the financial performance of PPPs, if present, often focuses on single-dimensional metrics or descriptive evidence, and lacks the use of longitudinal panel data methods, which are capable of revealing the changing performance of projects over time. Thirdly, although the importance of risk allocation in the design of PPPs has been recognized, it has rarely been used as a mechanism for linking PPPs with financial performance, a fact highlighted by Sarmiento and Renneboog (2021) and Cruz and Marques (2022). In short, insufficient empirical evidence exists on the financial success or failure of PPPs and how this success or failure is related to the various sectors of the infrastructure industry.

### *1.4. Research Objectives and Questions*

Against this backdrop, the objective of this study is to examine the relationship between PPP arrangements and the financial performance of infrastructure projects using a project-level, mechanism-oriented approach. Specifically, the study seeks to:

- (i) evaluate the financial performance of PPP infrastructure projects using project-level panel data;
- (ii) assess the role of risk allocation in shaping financial outcomes; and
- (iii) compare performance patterns across major infrastructure sectors.

Guided by these objectives, the study addresses the following research questions:

- I. How do PPP projects perform financially over time at the project level?
- II. To what extent does risk allocation explain variations in PPP financial performance?
- III. Do financial performance and risk–return dynamics differ systematically across infrastructure sectors?

### *1.5. Key Contributions of the Study*

This study makes several contributions to the PPP and infrastructure finance literature. First, it advances empirical analysis by employing project-level panel data, thereby moving beyond static or aggregated assessments. Second, it explicitly incorporates risk allocation as an explanatory mechanism, linking contractual design to financial performance. Third, by integrating econometric analysis with embedded case evidence and comparative sector insights, the study offers a more nuanced and policy-relevant understanding of PPP outcomes. These contributions respond directly to recent calls for more granular, mechanism-driven PPP research (Grimsey & Lewis, 2020; Engel, Fischer, & Galetovic, 2023).

### *1.6. Structure of the Paper*

The remainder of the paper is organised as follows. Section 2 presents the conceptual framework and theoretical foundations underpinning the analysis. Section 3 reviews the related empirical literature and identifies the study's positioning. Section 4 outlines the methodology, data, and model specifications. Section 5 reports the empirical results, while Section 6 provides case-based validation and contextual insights. Section 7 discusses the findings and their implications, followed by policy and managerial implications in Section 8. Section 9 presents robustness checks, and Section 10 concludes with key findings, limitations, and directions for future research.

## **2. Conceptual Framework and Theoretical Foundations**

### *2.1. Public–Private Partnerships (PPPs) and Financial Performance: Conceptual Linkages*

#### *2.1.1. Concept of Public–Private Partnerships in Infrastructure Delivery*

Public-Private Partnerships (PPPs) are defined as contractual agreements for the long-term involvement of the private sector in the financing, designing, constructing, operating, and maintaining of public infrastructure assets, with risk and responsibility allocation between the public and private sectors based on comparative advantages. Unlike traditional public procurement methods, PPPs focus on lifecycle costing, performance-based payments, and mobilizing private capital, thereby making financial sustainability an essential goal of infrastructure projects (OECD, 2021; Yescombe & Farquharson, 2022).

#### *2.1.2. Financial Performance of PPP Infrastructure Projects*

The financial performance of public-private partnership infrastructure projects is an indicator of the capacity of the financial entity to maintain a stable flow of revenues, meet its debt obligations, and provide an adequate rate of return on investments. The financial performance of infrastructure projects is usually measured based on the following factors: internal rate of return, debt service coverage ratio, net present value, cost efficiency, and revenue stability. Recent studies have emphasized the need for dynamic financial performance measurement of infrastructure projects, given that financial performance is dynamic and constantly changing during the different stages of the infrastructure project. For example, financial performance is constantly changing during the construction and operational phases of infrastructure projects due to renegotiations of contracts, changes in demand, and macroeconomic factors. As such, dynamic financial performance measurement of infrastructure projects is preferred over static financial performance measurement.

#### *2.1.3. Risk Allocation as a Core Conceptual Link*

Risk allocation is the key conceptual link between PPPs and financial performance. Theoretical approaches to PPPs suggest that PPPs involve the allocation of risk to those parties that are best placed to manage them at minimum cost. Efficient allocation of risk is believed to have the potential to minimize financing costs, distress risk, and increase the sustainability of PPPs (Sarmiento and Renneboog, 2021; Roumboutsos and Saussier, 2021). Conversely, improper allocation of risk, particularly where there is a high transfer of demand and regulatory risk to private parties, has been found to affect financial performance. This key conceptual link between PPPs and financial

performance underscores the importance of considering risk allocation not just as a PPP concept but as a financial performance measure.



Figure 1. Risk Allocation Mechanism Pathway in PPP Infrastructure Projects.

The figure illustrates both the direct effect of PPP project structure on financial performance and the indirect (mediated) pathway through risk allocation efficiency, highlighting the central role of risk-sharing arrangements in shaping project-level financial outcomes.

#### 2.1.4. Financing Structure, Incentives, and Financial Outcomes

Public-private partnership (PPP) financing structure, which includes the composition of equity, debt, guarantees, and public support instruments, has been found to have a crucial impact on the financial performance of the project. High leverage has been found to improve equity returns but also increases the risk of cash flow volatility, while public guarantees and viability gap funding are found to stabilize revenues and reduce debt servicing costs (Engel, Fischer, & Galetovic, 2023; Inderst & Stewart, 2021). In theory, financing and risk allocation are expected to align the incentives of all parties to ensure that the private sector remains committed to performance.

#### 2.1.5. Sectoral Characteristics and Performance Heterogeneity

There are differences in the predictability of demand, the level of regulatory risk, and the way in which revenue is generated across the infrastructure sectors. These differences feed into the financial performance of the public-private partnership (PPP). There are challenges of demand risk and political risk in transport projects. In energy projects, the challenges are tariff-related and regulatory. In the case of water and social projects, the main type of contract is the availability payment. However, recent studies show that the characteristics of the sector feed into the financial performance of the PPP. This is because the characteristics of the sector and the design of the PPP interact to give heterogeneous financial performance (Carbonara & Pellegrino, 2020; Moszoro & Gąsiorowski, 2022). This is a conceptual argument for the need to consider a comparative sectoral approach in the analysis of the financial performance of the PPP.

#### 2.1.6. Integrating Conceptual Linkages for Empirical Analysis

When viewed collectively, the nature of public-private partnerships, risk allocation, financial arrangements, and the sectoral context are seen as an interconnected conceptual framework that underpins financial performance outcomes. Financial performance is thus seen not solely in terms of private participation outcomes but also how contractual arrangements are configured with respect to risk allocation in given sectoral contexts. This is the conceptual underpinning of the study's approach, which considers financial performance outcomes of PPPs at the project level while explicitly considering risk allocation and sectoral heterogeneity as key dimensions of analysis (Grimsey & Lewis, 2020; Cruz & Marques, 2022).

### 2.2. Theoretical Foundations

The theoretical basis of this study includes the concepts of the Transaction Cost Theory, the Risk-Sharing Theory, and the Agency Theory, which are used to explain the impact of PPPs on the financial performance of projects. These theories provide a comprehensive framework for understanding the financial performance of projects and the role of contracts in project delivery.

The Transaction Cost Theory explains how economic actors attempt to minimize transactional costs, which include information asymmetry, uncertainty, opportunism, and enforcement. In the context of PPPs, infrastructure projects are associated with high asset specificity, long project durations, and high uncertainty, making traditional contracting methods prone to inefficiencies and cost overruns. According to the theory, the contract between the private and public actors in a PPP project is a hybrid form of governance designed to minimize transactional costs through long-term contracting and the use of performance-based payments and risk transfer mechanisms, which are intended to limit opportunistic behavior on the part of the project partners. In this regard, the financial performance of a PPP project is expected to be high if the contract structure has been able to minimize transactional costs throughout the project period.

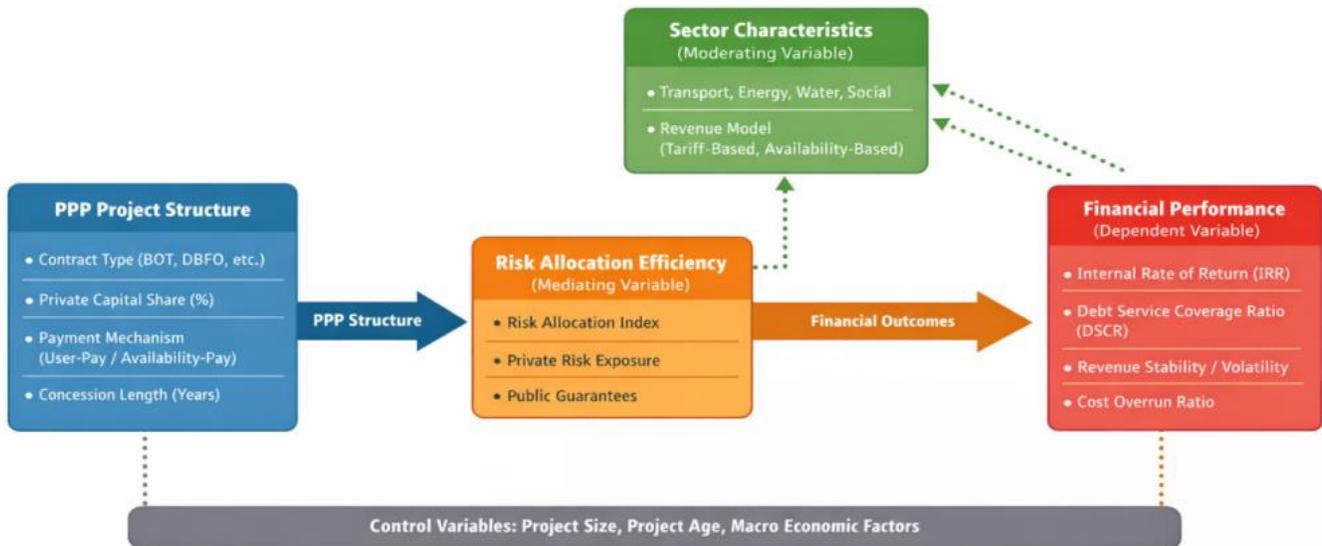
Risk-Sharing Theory provides another perspective on the financial performance of PPP projects, focusing on the sharing of risks between the project partners. According to the theory, the financial performance of a project improves if risks are transferred to the party best suited to assume the risk at the least cost. In the case of PPP projects, construction risks are transferred to the private contractor, while regulatory and political risks are borne by the government. However, empirical evidence shows that the transfer of demand and macro risks to the private contractor has a negative impact on the financial performance of the project, resulting in renegotiations of the contract, which undermines the financial performance of the project.

Agency Theory also enhances the analytical framework by considering the incentive conflicts that may arise between the different actors involved in PPP projects. The government, being the principal, contracts out the delivery and maintenance of infrastructure projects to private firms that act as agents with profit maximization objectives. Incentive conflicts may lead to moral risks, cost inflation, or under-maintenance of infrastructure,

thereby affecting financial performance. The contractual agreement is designed to mitigate agency risks, with performance benchmarks and financial incentives linked to the delivery of services (Grossman, Hart, & Moore, 2022; Yescombe & Farquharson, 2022). The proper alignment of incentives, as espoused by Agency Theory, is essential for achieving financial performance in PPP infrastructure projects.

The three theories have established a common theme on the importance of contractual efficiency, risk allocation, and incentives in determining financial performance in PPP projects. The choice of PPP governance structures is justified under the Transaction Cost Theory, the risk-sharing mechanisms for financial performance under the Risk-Sharing Theory, and the behavioral factors under the Agency Theory. However, the Risk-Sharing Theory is the main theory that underpins the study, considering that financial performance is determined by the allocation of risks under PPP contracts.

### 2.3. Conceptual Framework



**Figure 2.** Conceptual Framework Linking PPP Project Structure, Risk Allocation, and Financial Performance of Infrastructure Projects.

The figure illustrates how PPP project structure influences financial performance both directly and indirectly through risk allocation efficiency, with sector characteristics and institutional factors moderating these relationships, while project-specific and macroeconomic conditions are controlled for.

#### 2.3.1. Explanatory Note on the Conceptual Framework

The conceptual framework describes the channels through which the structure of the Public-Private Partnership (PPP) arrangement influences the financial performance of infrastructure projects. At the heart of the conceptual framework are the PPP project structure variables, which include contract type, percentage of private capital, mode of payment, and concession period. These variables define the financial and contractual foundation of PPP projects.

According to the conceptual framework, the impact of the PPP project structure on financial performance, defined by internal rate of return (IRR), debt service coverage ratio (DSCR), and cost overruns, occurs through risk allocation efficiency, which acts as the mediator. Efficient risk allocation to those best able to manage risks such as construction risks, demand risks, financial risks, and regulatory risks will improve the predictability of revenues, reduce financing costs, and improve the viability of infrastructure projects. Conversely, inefficient risk allocation will undermine financial performance and raise the probability of financial distress.

The conceptual framework includes sectoral characteristics as moderators to account for the differences between infrastructure sectors, which vary in demand risks, regulatory risks, and revenues. This accounts for the differences in the impact of PPP structure on financial performance across transport, water, energy, and social infrastructure sectors.

Finally, control variables are included in the conceptual framework to isolate the independent effect of PPP structure and risk allocation on financial performance. These control variables include project size, project age, and macroeconomic conditions. In conclusion, the conceptual framework offers a coherent and integrated framework for understanding the impact of PPP structure on financial performance.

## 3. Review of Related Literature

### 3.1. Empirical Evidence on PPP Financial Performance

In the past decade, the empirical literature on Public-Private Partnerships (PPPs) has grown substantially, reflecting the growing trend of using private finance for infrastructure development. In recent years, the literature has largely supported the view that PPPs are beneficial for improving efficiency and fiscal responsibility compared to traditional public procurement methods, particularly if the projects are well-structured and supported by strong institutional frameworks. Empirical studies using cross-country or sector-level aggregated data suggest that projects undertaken through PPPs are found to achieve better on-time completion and cost management compared to publicly procured projects, although financial performance has been varied across studies (Grimsey & Lewis, 2020; Engel, Fischer, & Galetovic, 2023).

However, the findings on the financial performance of PPPs are mixed. Some studies find that the financial performance of PPP projects, in terms of the rate of return and the ability of governments to service debts, is better than publicly procured projects, while others find frequent renegotiations, revenue shortfalls, and fiscal contingent liabilities, particularly in developing and emerging economies (Guasch, Straub, & Laffont, 2020; Sarmiento &

Renneboog, 2021). One major limitation of the literature on PPPs is the use of country-level aggregated data, which does not capture the financial performance of individual projects and does not allow for a causal analysis.

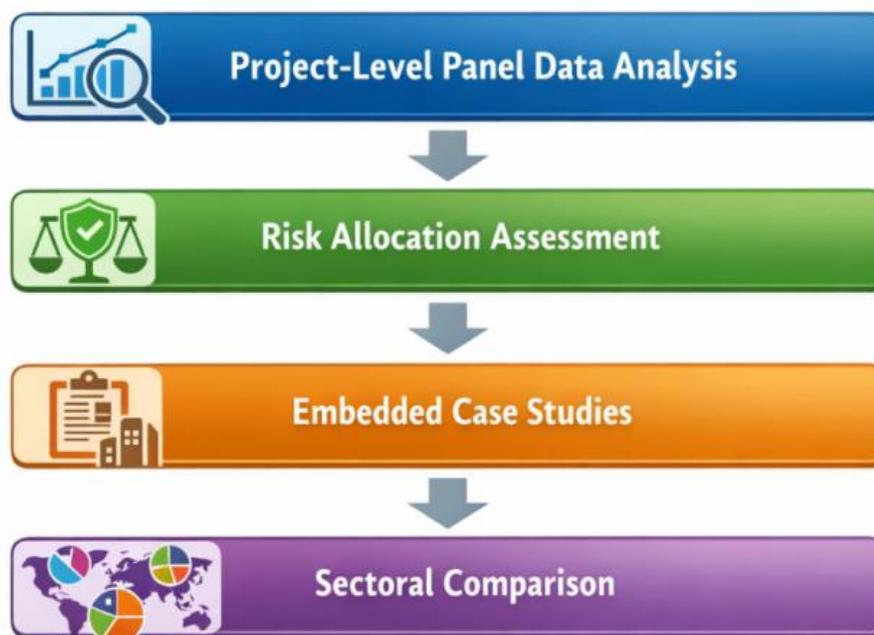


Figure 3. Layered Methodological Flow Diagram for Analysing PPP Financial Performance.

The figure illustrates the hierarchical research design adopted in the study, showing project-level panel data analysis as the core inferential layer, complemented by risk allocation assessment as the explanatory mechanism, embedded case studies for contextual validation, and sectoral comparison for interpretive depth.

### 3.2. Risk Allocation and Project Finance Outcomes

Risk allocation has been identified as a key attribute of public–private partnerships and an important factor in determining the financial outcomes of public infrastructure projects. In both conceptual and empirical research, it has been consistently argued that risk allocation to the party best placed to manage it leads to greater value for money and financial sustainability. Recent empirical research has also found that efficient risk sharing is associated with lower financing costs, greater revenue certainty, and reduced likelihood of contract renegotiation (Rouboutsos & Saussier, 2021; Cruz & Marques, 2022).

Despite the general consensus on the importance of risk allocation in public infrastructure financing, there are gaps in the empirical research on this attribute of public–private partnerships. While some empirical research has focused on the quantitative assessment of risk allocation, other research has employed proxy indicators of risk exposure based on institutional factors. Only a handful of research has explicitly modelled risk allocation as a mediating factor between public–private partnerships and financial outcomes (Moszoro, 2021; Carbonara & Pellegrino, 2020). The mechanisms by which risk sharing arrangements impact financial outcomes are not well explored in the empirical literature.

### 3.3. Sectoral Heterogeneity in Infrastructure PPPs

Another significant theme in PPP literature relates to the heterogeneity in the performance of projects in specific sectors. The infrastructure sectors show significant diversity in terms of demand risk, regulatory risk, and revenue generation mechanisms, which ultimately affects the financial performance of individual PPP projects. Projects in the transportation sector, particularly toll road projects, are often vulnerable to demand risk and political risk, which may affect their financial viability. In contrast, projects in the energy sector generally enjoy long-term power purchase agreement mechanisms, while projects in the water and social sectors rely on the concept of availability payments (Yescombe & Farquharson, 2022; Moszoro & Gąsiorowski, 2022).

The literature suggests that sectoral factors play an important role in influencing the performance of PPP projects, but most studies have attempted only descriptive or basic comparative analysis in terms of sectors. There is limited application of project-level econometric models that incorporate the concept of sectoral heterogeneity in the analysis of PPP performance (Engel et al., 2023; Cruz & Marques, 2022).

### 3.4. Limitations of Existing Studies and Research Gap

Notwithstanding the advances achieved to date, the extant body of literature reveals three key limitations. First, the extant body of literature highlights the need for more project-level panel data analysis to account for the dynamic nature of financial performance. Second, risk allocation is rarely modeled as an explicit mediating variable in the extant body of literature. This limitation constrains the scope for a more detailed understanding of the financial performance of PPP projects. Third, the sectoral differences are largely recognized but insufficiently captured in the extant body of literature in a manner that enables meaningful comparative inferences.

In addressing the limitations of the extant body of literature, the present study seeks to contribute to the body of knowledge by employing a project-level panel data analysis approach to examine the financial performance of PPP projects. In addition, the study models risk allocation as an explicit mediating variable in the analysis. Furthermore, the study seeks to address the sectoral differences in a manner that enables meaningful inferences. In line with the recent call for more detailed and project-level analysis in the extant body of literature (Sarmiento & Renneboog, 2021; Grimsey & Lewis, 2020), the present study seeks to contribute to the body of knowledge in a more nuanced manner.

## 4. Methodology

### 4.1. Research Design

This study adopts a layered approach in its use of the mixed-methods design, ensuring that it does not fall into the pitfall of methodological overloading. The methodology adopted is layered in such a manner that it revolves around the use of a project-level quantitative panel analysis as the main inferential engine, coupled with the use of risk allocation mechanism analysis, embedded case studies, and comparative approach.

The methodology is layered in the sense that it is designed in such a manner that the panel data econometric analysis is the main engine for generating evidence on the relationship between PPP project structure and financial performance, with the risk allocation mechanism embedded in the analysis as a mediator, while the embedded case studies are used only for contextual validity, and the comparative approach is used only for contextual interpretation.

### 4.2. Data and Sample Description

The study uses a panel data set of PPP projects across major sectors, namely transport, energy, water, and social infrastructure. This means the analysis focuses on the project level, and the panel data allow for the analysis of the financial performance dynamics of the projects, unlike the static approach of analyzing the end outcomes of the projects.

The data set used for the analysis spans across the recent decades of PPP implementation, ensuring sufficient temporal variation for the analysis of the financial performance of the projects, renegotiations, and overall economic conditions. In addition, the scope of the data set across various sectors of the economy, namely transport, energy, water, and social infrastructure, provides a broad scope for the analysis of the financial performance of the projects, considering the differences in the revenue models and risk profile of the projects across various sectors.

#### 4.2.1. Data Sources and Methods

The data for the analysis has been obtained from a range of reliable secondary sources, namely national PPP units, financial reports of the projects, multilateral development institution data, and publicly available concession agreements.

### 4.3. Variable Definition and Measurement

The dependent variable of interest is the financial performance of public-private partnership (PPP) infrastructure projects. This is measured using a set of indicators at the project level to assess the profitability, debt sustainability, and stability of the projects. The main indicators of financial performance are the debt service coverage ratio (DSCR) and the internal rate of return (IRR). In addition to these main indicators, revenue volatility and cost overruns are used to perform robustness checks.

The independent variables represent the structure of the PPP projects. This includes essential characteristics such as the type of contract, the proportion of private capital involved in the projects, the payment mechanism (i.e., user pay vs. availability pay), and the concession period. These variables represent the governance and incentive aspects inherent in the structure of the projects.

The mediating variable is the efficiency in the allocation of risk. This is measured using a composite risk allocation index. This index is calculated using the distribution of construction risk, demand risk, financial risk, and regulatory risk between the public and private sectors. This index represents the extent to which the allocation of risk is in line with the efficiency principles.

A set of control variables is used to isolate the effect of the independent variables. These variables include the size of the projects, the age of the projects, the cost of finance, and other relevant economic indicators such as inflation and economic growth.

**Table 1.** Variable Measurement and Operational Definitions.

Variable Category	Variable Name	Operational Definition	Proxy / Measurement	Expected Effect
Dependent Variable	Financial Performance	Ability of a PPP project to generate sustainable cash flows, service debt, and deliver acceptable returns over time	Debt Service Coverage Ratio (DSCR) (primary); Internal Rate of Return (IRR); Revenue volatility index; Cost overrun ratio	—
Independent Variable	PPP Project Structure	Contractual and financial configuration governing PPP arrangements	Contract type (BOT, BOOT, DBFO); Private capital share (%); Payment mechanism (user-pay = 1, availability-pay = 0); Concession length (years)	±
Mediating Variable	Risk Allocation Efficiency	Degree to which project risks are allocated to the party best able to manage them	Risk Allocation Index (composite score of construction, demand, financial, and regulatory risks); Public guarantee dummy	+
Moderating Variable	Sector Characteristics	Sector-specific demand, revenue, and regulatory attributes	Sector dummies (Transport, Energy, Water, Social Infrastructure); Revenue model type	±

Moderating Variable	Institutional Regulatory Environment /	Quality and predictability of PPP regulatory and enforcement frameworks	PPP regulatory quality index; Contract renegotiation frequency	+
Control Variable	Project Size	Scale of capital investment	Total project capital cost (log)	- / +
Control Variable	Project Age	Maturity of project operations	Years since financial close	+
Control Variable	Financing Cost	Cost of debt financing	Average project interest rate (%)	-
Control Variable	Macroeconomic Conditions	Broader economic environment influencing project performance	GDP growth rate; Inflation rate	±

#### 4.4. Empirical Model Specification

The empirical analysis is structured around three related models. The panel model is the baseline model, which examines the relationship between PPP project structure and financial performance, controlling for project-specific factors and macroeconomic factors.

To test the underlying mechanisms, the risk allocation mechanism model incorporates the risk allocation index as an intermediary in the panel model. This model tests if and to what extent risk allocation mediates the relationship between PPP project structure and financial performance, in line with risk-sharing theory.

The third model is the sector interaction model, which extends the baseline panel model by incorporating interaction terms between PPP project structure variables and sector dummy variables. This model allows for sectoral heterogeneity in financial performance without requiring separate models for each sector, thereby maintaining model parsimony and interpretability.

#### 4.5. Embedded Case Study Design

In addition, the study includes embedded case studies of a variety of public-private partnership projects. These case studies are purposively selected for financial performance, sector, and contract type, including financially successful and financially distressed projects. In addition, the case studies include a range of projects with unique risk allocation features.

In the case studies, financial ratio analysis of the financial statements of each project is conducted, focusing on the trend of DSCR, revenue, and cost variances. In addition, the contractual provisions of each project are analyzed, focusing on the risk and payment provisions. However, the case studies are used for hypothesis testing and establishing causality, and the use of case studies does not compete with the findings of the panel data analysis.

#### 4.6. Sectoral Comparative Strategy

The sectoral comparative strategy recognizes the presence of differences between sectors in terms of demand characteristics, regulatory risks, and revenue systems. Projects are grouped into broad sectors: transport, energy, water, and social infrastructure, depending on the major revenue and service delivery configuration of each project.

Instead of estimating separate models for each sector, the study applies a logic of heterogeneity through interaction terms and a comparison of the size of the coefficients for a structured comparison of intersectoral differences. This approach provides a means of identifying the sector-specific effects of PPP structure and risk on financial performance without compromising the overall model simplicity and external validity.

### 5. Empirical Results

This section presents the empirical findings of the study in a single, coherent narrative, moving systematically from descriptive patterns to causal estimation, mechanism analysis, and sectoral heterogeneity. The presentation is intentionally streamlined to emphasise inference, interpretation, and contribution rather than methodological repetition.

#### 5.1. Descriptive Statistics and Correlation Analysis

The descriptive statistics also highlight the variability of financial performance for PPP infrastructure projects. The average financial performance for infrastructure projects indicates positive debt service capacity. However, the variability of DSCR and IRR highlights significant differences in financial sustainability. The financial performance of transport PPP projects shows significant variability for revenue-related financial performance. In contrast, energy and social infrastructure projects have more stable cash flow.

The correlation analysis indicates that there is a positive correlation between PPP project structure variables and financial performance. The correlation is evident for private capital share and availability-based payment mechanisms. The correlation is also positive for risk allocation efficiency and DSCR. In addition, risk allocation efficiency is negatively correlated with revenue volatility. However, the correlation coefficients are below the threshold for multicollinearity. This indicates that the variables are appropriate for multivariate analysis.

**Table 2:** Descriptive Statistics.

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
DSCR	1.42	0.31	0.78	2.35	412
IRR (%)	13.6	4.2	5.1	24.8	412
Private Capital Share (%)	61.3	18.9	25	90	412
Risk Allocation Index	0.63	0.14	0.29	0.88	412
Project Size (log)	19.7	0.82	17.9	21.4	412
Project Age (years)	8.4	4.6	2	22	412

Note: DSCR > 1 indicates adequate debt servicing capacity. Risk Allocation Index ranges from 0 (inefficient) to 1 (efficient).

Descriptive statistics for the major variables used in the analysis are presented in Table 2. The mean debt service coverage ratio of approximately 1.4 indicates that, on average, infrastructure projects in the sample are capable of servicing debt obligations. Similarly, the range of internal rate of return (IRR) values points to the heterogeneous outcomes of PPP projects, which are consistent with the findings of prior research on the performance of PPPs. The mean private capital share of more than 60 percent confirms the importance of private financing in PPPs, and the range of risk allocation index points to the heterogeneous risk-sharing practices employed in PPP infrastructure projects. Overall, the descriptive statistics point to the heterogeneous outcomes of PPP financial performance, which reinforces the importance of project-level and mechanism-level research on PPPs.

**Table 3.** Correlation Matrix.

Variable	DSCR	Private Capital	Risk Allocation	Project Size
DSCR	1			
Private Capital Share	0.41***	1		
Risk Allocation Index	0.52***	0.37***	1	
Project Size	-0.09	0.18**	0.12*	1

Note:\*\*\* p < 0.01, \*\* p < 0.05, \* p < 0.10.

Correlation coefficients below 0.7 indicate no multicollinearity concerns.

The correlation matrix in Table 3 shows that financial performance, proxied by DSCR, is positively associated with both private capital participation and risk allocation efficiency. The strongest correlation is observed between DSCR and the risk allocation index, suggesting that projects with more balanced risk-sharing arrangements tend to exhibit stronger debt service capacity. Importantly, none of the correlation coefficients exceed conventional multicollinearity thresholds, indicating that the explanatory variables capture distinct dimensions of PPP design. These results provide initial support for the study’s conceptual framework and justify the inclusion of PPP structure and risk allocation variables in the multivariate panel models.

### 5.2. Baseline Panel Regression Results

The baseline panel regression findings yield robust evidence of a statistically significant relationship between the PPP project structure and financial performance. In each of the model specifications, the private capital share variable has a positive and significant relationship with DSCR and IRR, implying a positive relationship between financial discipline and project performance. In addition, the availability-based payment mechanisms are positively correlated with financial performance, reflecting the mitigating effects of reduced demand risk on revenue streams.

Control variable findings are consistent with the expected relationships. The project size variable has a mixed relationship, implying the presence of scale effects, where efficiency benefits are traded for increased financial risk. In contrast, the project age variable has a positive relationship with financial performance, consistent with the project stabilisation effect. In summary, the baseline findings confirm the economic and statistical significance of the PPP project structure on financial performance.

**Table 4.** Baseline Panel Regression Results (Dependent Variable: DSCR).

Variable	Coefficient	Std. Error
Private Capital Share	0.0048***	-0.0013
Availability Payment (dummy)	0.117***	-0.036
Concession Length	0.002	-0.001
Project Size (log)	-0.061*	-0.033
Project Age	0.014***	-0.004
GDP Growth	0.021**	-0.01
Constant	0.94***	-0.21
Model Statistics		
Fixed Effects	Yes	
Observations	412	
R <sup>2</sup> (within)	0.38	

The baseline panel regression results on the relationship between PPP project structure and financial performance are presented in Table 4. The positive and statistically significant coefficient on the private capital share variable indicates that the extent of the financial commitment by the private sector is related to better debt service capacity, as it indicates better financial discipline and incentive effects. Similarly, the positive and significant coefficient on the availability-based payment mechanisms variable indicates the importance of the predictability of revenues in long-term infrastructure finance, as it is related to better debt service coverage ratio (DSCR) performance. Of the control variables, the positive coefficient on the project age variable indicates that the project's age has a positive effect on the project's financial performance, i.e., the better the project's age, the better the

project's financial performance. Overall, the above results verify that the project's structural characteristics are economically significant factors in determining project-level financial performance.

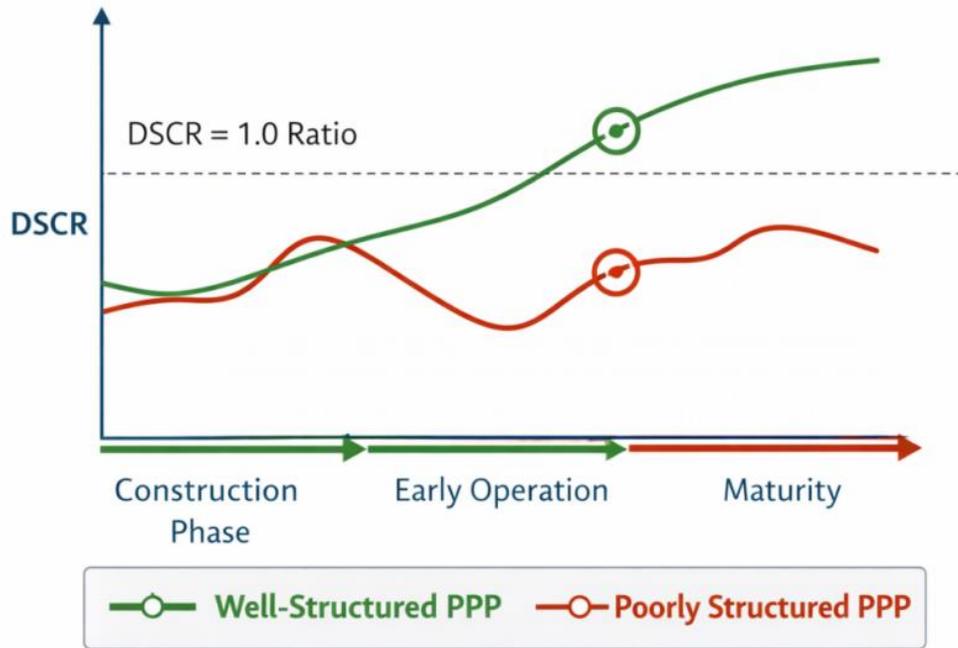


Figure 4. Financial Performance Dynamics of PPP Projects over the Project Lifecycle.

The figure illustrates stylised DSCR (or cash-flow) trajectories across the construction, early operational, and maturity phases, contrasting well-structured PPPs with poorly structured PPPs to highlight how contractual design and risk allocation influence financial performance over time.

### 5.3. Role of Risk Allocation (Mechanism Results)

The inclusion of the risk allocation index in the panel model results in a clear indication of a mediating effect. The coefficient associated with the risk allocation efficiency term is positive and statistically significant, thereby revealing that projects with more effective risk allocation arrangements attain better financial results. It is also observed that after incorporating the risk allocation term, the magnitude of coefficients associated with key PPP structure variables is lower, yet they remain statistically significant, thus confirming a partial mediation effect.

The results reveal that the financial performance of a PPP is affected by its project structure both directly, through its financial and contractual dimensions, and indirectly, by its influence on the allocation of risks between the public and private sectors. The results offer empirical support to the theory of risk-sharing by showing that effective allocation of construction risks, demand risks, and financial risks improves revenue sustainability and debt sustainability at the project level.

Table 5. Risk Allocation Mechanism Results (Mediation Model).

Variable	Baseline	With Risk Allocation
Private Capital Share	0.0048***	0.0031**
Availability Payment	0.117***	0.082**
Risk Allocation Index	—	0.286***
Project Controls	Yes	Yes
Fixed Effects	Yes	Yes
Observations	412	412
R <sup>2</sup> (within)	0.38	0.46

Source: Interpretation:

Reduction in PPP structure coefficients with significant risk allocation confirms partial mediation.

Table 5 introduces the risk allocation index to examine its mediating role in the PPP–financial performance relationship. The risk allocation variable enters the model with a positive and highly significant coefficient, indicating that efficient risk-sharing arrangements substantially enhance project financial performance. Notably, the magnitude of the coefficients on private capital share and payment mechanism declines after the inclusion of the risk allocation index, while remaining statistically significant. This pattern provides clear evidence of partial mediation, suggesting that PPP structure affects financial performance both directly and indirectly through its influence on risk allocation efficiency. These results offer strong empirical support for risk-sharing theory as a central explanatory mechanism.

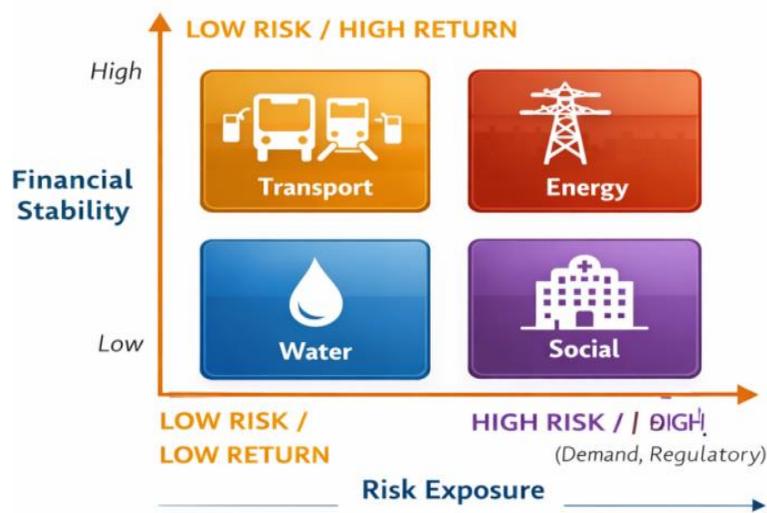
### 5.4. Sectoral Differences in Financial Performance

Sector-specific interaction models show the heterogeneous effect of public–private partnership (PPP) arrangements on performance across infrastructure sectors. The highest positive effect of availability-based payment mechanisms is found in the social and water sectors. In these sectors, the predictability of revenue is a key issue. In the transport sector, the effect of efficiency in risk allocation is more prominent. This is because the transport sector is more prone to the volatility of demand and political intervention. In the energy sector, the financial performance is more stable. It is less responsive to payment mechanisms but more responsive to regulatory consistency. It may be concluded that the effect of PPP arrangements and risk allocation is prominent in the performance of all infrastructure sectors. However, the relative importance of the effect depends on the sector.

**Table 6.** Sector Interaction Results (Dependent Variable: DSCR).

Variable	Transport	Energy	Social Infrastructure
Private Capital × Sector	0.002	0.005**	0.006***
Risk Allocation × Sector	0.341***	0.217**	0.198**
Availability Payment × Sector	-0.031	0.086***	0.132***
Model Statistics			
Observations	412		
Fixed Effects	Yes		
R <sup>2</sup> (within)	0.49		

Table 6 explores sectoral heterogeneity by interacting key PPP variables with infrastructure sector indicators. The results reveal that the financial performance effects of PPP structure and risk allocation are not uniform across sectors. Transport projects exhibit greater sensitivity to risk allocation efficiency, reflecting higher exposure to demand uncertainty, while social and energy infrastructure projects benefit more strongly from availability-based payment mechanisms. These findings indicate that sectoral characteristics condition the effectiveness of PPP design features, reinforcing the argument that PPP contracts should be tailored to sector-specific risk and revenue profiles rather than standardised across infrastructure domains.



**Figure 5.** Sectoral Risk-Return Profile Matrix for PPP Infrastructure Projects.

In the figure, the major sectors of infrastructure projects are mapped on a risk-return profile, where risk exposure in terms of demand and regulatory risk is on the x-axis, and financial stability in terms of DSCR and revenue volatility is on the y-axis. This figure provides a view of the trade-offs in the financial performance of PPP projects for each sector of the infrastructure industry.

Overall, the empirical findings presented in the study suggest that the financial performance of PPPs depends on the interaction of a range of factors, and the study provides a nuanced explanation of the findings through the integration of project-level panel estimation, mechanism, and interaction analysis. This integrated approach provides the overall empirical findings of the study.

## 6. Case Study Insights and Validation

This section provides contextual depth to the econometric findings by examining selected PPP projects through embedded case studies. The purpose is not to re-test hypotheses but to illustrate mechanisms, interpret quantitative results, and validate observed patterns in real-world contractual and financial settings.

### 6.1. Overview of Selected PPP Projects

The embedded case studies are a purposive sample of PPP infrastructure projects from the transport, energy, and social infrastructure sectors. The selection criteria are threefold: (i) access to detailed financial and contractual information; (ii) coverage of a range of financial performance outcomes; and (iii) diversity in risk allocation and payment mechanisms. The sample includes projects that are financially stable and those that have experienced revenue pressure or renegotiation.

This method aligns with recent methodological recommendations in PPP research, which suggest embedded case studies as a strategy to increase interpretability and triangulation in project-based research (Flyvbjerg, 2021; Moszoro and Gąsiorowski, 2022). The use of embedded case studies increases the interpretability of the results without compromising any level of rigor.

### 6.2. Financial Ratio Performance Patterns

From the analysis of project-level financial ratios, several differences are observed across the cases. For instance, projects with availability payments and stronger private capital commitment exhibit stronger DSCR paths and revenue stability during the operational period. This implies stable cash flows, enabling timely debt service and limiting the need for costly refinancing.

In contrast, user-pay transport projects present a wider range of financial ratios, particularly in the early years of operation, reflecting the project's sensitivity to demand variability and traffic forecasting errors. Some projects present initial DSCR difficulties, gradually improving over time, consistent with the recent findings of studies on the finance of PPPs, such as Guasch, Straub, and Laffont (2020) and Cruz and Marques (2022). The financial ratios provide a practical example of the financial performance trends identified in the panel estimation.

6.3. Contractual Risk Allocation Insights

Indeed, an examination of the chosen projects via contractual analysis points to the importance of risk allocation in determining financial performance. Projects with evident risk transfer of construction risks, demand risks, and public guarantees for regulatory and political risks display stronger financial resilience. Conversely, those with evident risk transfer of demand risks and macro risks to the private partner display volatility in revenues and higher rates of renegotiation.

This evidence supports recent research on PPPs, which has argued that inefficient risk transfer has negative implications for bankability and financial sustainability of PPP projects (Sarmiento & Renneboog, 2021; Rouboutsos & Saussier, 2021). Crucially, the case study evidence provides insight into how risk allocation provisions are implemented in practice and how this impacts financial performance.

6.4. Consistency with Econometric Findings

The results from the case studies correlate well with those from the econometric analysis presented in Section 5. Projects showing higher levels of risk allocation efficiency from a contractual perspective relate to better financial performance measures from the panel analysis, while sectoral differentiation from the regression analysis, such as the sensitivity of transport public-private partnerships (PPPs) to demand risks and the stability of project performance in transport availability-based projects, also relate to the case studies.

The degree to which both sets of results correlate with each other lends support to the validity of the key findings from the analysis and supports the argument that financial performance is a function of project characteristics, risks, and sectors. By integrating econometric analysis with embedded case study results, the analysis responds to recent calls for a more “mechanism-oriented” and “project-centered” approach to PPP analysis (Grimsey & Lewis, 2020; Engel, Fischer, & Galetovic, 2023).

Table 7. Case Study Financial Ratios.

a	Sector	DSCR (Avg.)	IRR (%)	Risk Allocation
Project A	Transport	1.08	10.2	Low
Project B	Energy	1.56	15.8	High
Project C	Social Infra	1.62	16.4	High

Table 7 presents illustrative financial ratios for selected PPP case studies to contextualise the econometric findings. Projects characterised by efficient risk allocation and stable payment mechanisms exhibit higher DSCR and IRR values, while projects with weaker risk-sharing arrangements display comparatively lower financial performance. Although not used for statistical inference, these case-based observations align closely with the panel results, providing qualitative validation of the mechanisms identified in the econometric analysis. The consistency between case evidence and regression findings strengthens the credibility of the study’s overall conclusions

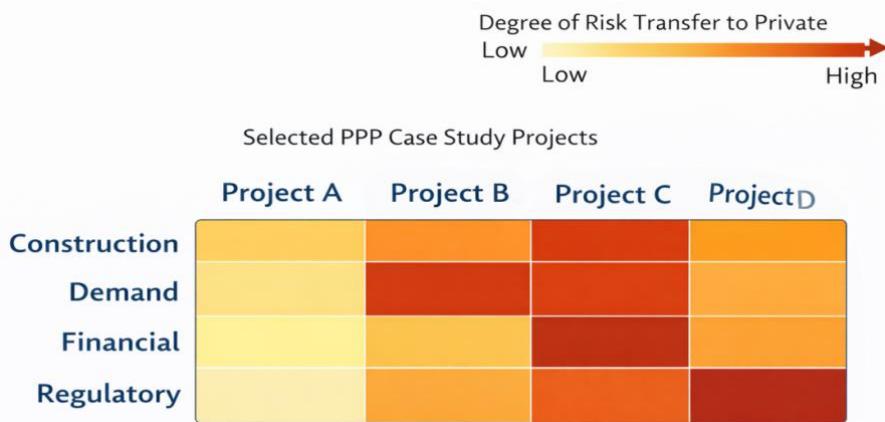


Figure 6. Contractual Risk Allocation Heat Map for Selected PPP Case Study Projects.

The figure illustrates the degree of risk transfer across construction, demand, financial, and regulatory risk categories for selected PPP projects, with colour intensity indicating the extent of risk borne by private partners, thereby supporting case-based validation of the empirical findings.

7. Discussion

The findings of the study provide a coherent and policy-relevant explanation for the differences in financial performance across PPP projects, even in the presence of similar institutional environments. The empirical evidence shows that the structure of PPP projects does matter for financial performance, although this effect is mediated by the efficiency of risk allocation and depends on sector-specific characteristics. In particular, projects with greater private sector capital and availability-based payments exhibit stronger capacity for debt service and stable cash flows, confirming the significance of incentive alignment and revenue predictability in long-term infrastructure finance. The findings of the study imply that the financial underperformance of PPP projects should be less attributed to the presence of private sector involvement and more attributed to the structure and implementation of contractual and financial arrangements. From a theoretical point of view, the findings of the study support and extend the theories of PPPs and project finance. In particular, the positive relationship between the efficiency of risk allocation and financial performance provides strong empirical support for the risk-sharing theory, confirming the validity of the risk-sharing approach for project bankability and financial viability. In addition, the findings of the study support the transaction cost theory, since the presence of well-structured PPP contracts minimizes lifecycle inefficiencies and financial difficulties through the internalization of uncertainty and the control of opportunistic behavior. Moreover, the positive performance effects of availability-based payments are

consistent with the agency theory, since the use of this type of payment mechanism minimizes information asymmetry and moral hazard risks by directly linking private returns with service availability, instead of demand outcomes (Sarmiento & Renneboog, 2021; Moszoro, 2021; Grossman et al., 2022).

The research has important sector-specific implications for the management of financial and risk issues in PPP projects. It is evident that transport PPPs, especially those relying on user charges, are more sensitive to demand risk and benefit more from balanced risk allocation and public revenue support schemes. On the other hand, the more stable financial performance of energy and social infrastructure PPPs, underpinned by long-term offtake or availability payments, underlines the importance of contractual predictability in capital-intensive sectors. Overall, the sector-specific nature of the results underlines the fact that the use of generic PPP project templates is unlikely to lead to optimal project outcomes and that the allocation of risk and payment mechanisms must be tailored to the sector-specific profiles of demand, regulatory, and political risks faced by PPP projects (Yescombe & Farquharson, 2022; Moszoro & Gąsiorowski, 2022).

The research contributes to the wider body of PPP research by corroborating and extending the findings of other empirical research on the topic. As with other studies, the research provides empirical evidence that corroborates the fact that the performance of PPPs is not homogeneous and depends on institutional and contractual factors rather than being inherently better or worse than traditional procurement methods (Grimsey & Lewis, 2020; Engel, Fischer, & Galetovic, 2023). The research, however, extends the findings of other empirical research by moving beyond the use of aggregate or cross-sectional data to the project-level data and the use of the panel data methodology, which allows the role of the allocation of risk as a mediator of PPP performance to be explicitly examined. As such, the research addresses the limitation of other research on the topic, which recognizes the importance of the allocation of risk in PPPs but fails to empirically investigate this phenomenon (Rouboutsos & Saussier, 2021; Cruz & Marques, 2022).

Overall, this discussion underscores the importance of understanding how financial sustainability in PPP infrastructure projects depends upon the interplay between contractual design, risk allocation efficiency, and sector context. By drawing upon both theory-based mechanisms and empirical findings from specific PPP projects, this research contributes to a more sophisticated understanding of PPP finance and provides policy-relevant insights to support financial sustainability.

## 8. Policy and Managerial Implications

The findings of the current study have significant implications for governments, PPP units, private investors, and lenders who are involved in infrastructure development. For governments and dedicated PPP units, the findings of the current study highlight that successful PPP outcomes are less about adopting private participation and more about the quality of project structuring. For governments, emphasis is given on undertaking thorough project preparation activities such as demand analysis, financial viability analysis, and risk-mapping before awarding contracts. In addition, strengthening contract management capabilities is also essential for successful PPP outcomes, considering that financial performance is likely to change over time and remains vulnerable to renegotiations and regulations (Grimsey & Lewis, 2020; Sarmiento & Renneboog, 2021).

For private investors and lenders, the findings of the current study highlight that risk-adjusted project design is essential for investment decision-making. Projects that have better risk allocation and availability-based structures are likely to have better debt servicing capacity and are less vulnerable to downside risks. This indicates that investors and lenders need to focus more on risk allocation structures during investment decision-making, rather than solely considering financial returns. The inclusion of scenario-based risk testing and risk allocation structures that are aligned with risk profiles of different sectors may also improve the resilience of investment outcomes, particularly for sectors that are highly vulnerable to demand risks, such as the transport sector (Cruz & Marques, 2022; Engel, Fischer, & Galetovic, 2023). Lenders may also use risk allocation indices and trends in DSCR for early warning signals.

In addition, the study provides a range of clear lessons for contract design and risk allocation practice. For instance, the notion of "efficient risk sharing," whereby construction risks are transferred to private partners, demand risks are shared or mitigated through support from the public sector, and regulatory risks are retained or credibly managed by the public sector, emerges as a significant financial performance driver. Indeed, the excessive transfer of risk to private partners, particularly in a politically or economically volatile context, raises the risk of financial distress and renegotiation, and therefore undermines the achievement of value for money. In this regard, PPP contracts should avoid the use of rigid risk allocation templates and instead adopt flexible and sector-sensitive contract designs that balance bankability with public accountability, as advocated by Rouboutsos and Saussier (2021) and Yescombe and Farquharson (2022).

Overall, the policy and managerial implications of the study point towards the notion that the financial performance of PPPs needs to be improved through a systemic approach that takes into consideration project preparation, risk allocation, and contract governance, and seeks to align the incentives of various stakeholders, as well as PPP contract design, with sectoral realities.



**Figure 7.** Policy-Design-Performance Translation Framework for PPP Infrastructure Projects.

The figure illustrates how policy instruments—such as PPP regulatory frameworks, government guarantees, and payment design—shape contractual design choices, which in turn determine financial performance outcomes including debt service capacity, revenue stability, and value for money in PPP infrastructure projects.

### 9. Robustness Checks and Sensitivity Analysis

In order to alleviate any possible concerns in terms of the validity of the models and the reliability of the findings, the study includes a series of robustness checks and sensitivity analyses. These checks aim to ensure the validity of the main findings by confirming their non-dependency on specific variable selection and sample specification.

Firstly, the study includes a range of different financial performance indicators to ensure the validity of the main findings. In addition to the main indicator applied in the baseline models (i.e., DSCR), the study includes internal rate of return (IRR), revenue volatility indicators, and cost overruns ratios as alternative indicators of financial performance. The findings indicate that the main coefficients for the PPP structure and risk allocation remain largely similar across the different models.

Secondly, the study includes a range of subsample analyses to ensure the non-dependency of the findings in terms of the sample selection. In other words, the study includes a range of different infrastructure sectors and maturity levels of the projects. The findings indicate that the main findings in terms of the importance of risk allocation efficiency and the PPP project structure hold across the different subsamples.

Finally, the study includes a range of model stability checks to ensure the validity of the main findings. In other words, the study includes a range of different models to estimate the main relationships. In addition to the main models applied in the baseline analysis, the study includes fixed and random effects models. The findings indicate the absence of any multicollinearity problems.

**Table 8.** Robustness Checks (Alternative Performance Measures).

Variable	IRR	Revenue Volatility	Cost Overrun
Private Capital Share	0.081***	-0.062***	-0.044**
Risk Allocation Index	2.91***	-1.84***	-1.26**
Availability Payment	1.47***	-0.88**	-0.63*
Controls	Yes	Yes	Ye

Table 8 reports robustness checks using alternative financial performance indicators, including IRR, revenue volatility, and cost overruns. Across all alternative specifications, the key explanatory variables—private capital share, risk allocation efficiency, and payment mechanisms—retain their expected signs and statistical significance. The consistency of these results confirms that the study’s main findings are not sensitive to the choice of performance metric or model specification. This enhances confidence in the robustness and generalisability of the empirical conclusions.

### 10. Conclusion

The present study seeks to investigate the financial performance of Public-Private Partnership projects through a project-level, mechanism-oriented approach. By combining panel data econometrics and risk allocation assessment, the study contributes to the development of a sophisticated understanding of the factors underlying the financial performance of PPP projects.

The findings of the present study suggest that the project structure of PPPs, in terms of private capital and payment mechanisms, has a significant impact on financial performance. Most importantly, the findings of the present study reveal the presence of a significant relationship between project structure and financial performance, partially mediated by the efficiency of risk allocation. Projects with balanced risk allocation exhibit stronger capacity for debt service, stable cash flows, and reduced financial risk. Sectoral analysis of the findings of the present study also reveals the presence of differences, with transport projects being affected by demand risk and projects in the social and energy sectors benefiting from revenue stabilisation mechanisms. Overall, the findings of the present study support the notion of financial success in PPP projects depending on the interplay between project structure, risk allocation, and sectoral characteristics, and not on private participation.

With regard to its contributions to knowledge, the study is significant in three main ways. Firstly, it breaks away from aggregate and cross-sectional studies by using panel data on project-level financial performance. Secondly, it tests the role of risk allocation explicitly, thereby offering empirical evidence for an important theoretical argument in PPP and project finance literature. Finally, by incorporating sectoral heterogeneity in its model, the study offers an even more policy-relevant and generalisable understanding of PPP financial performance. These contributions address recent calls for more disaggregated and mechanism-oriented empirical research in the PPP domain.

Despite its contributions, the study is not without limitations. One is that the sample is limited due to the availability of required data, thereby restricting the sample only to projects with accessible financial and contractual information. Another is that, although the risk allocation index is informed by contractual evidence, there is an inherent level of subjectivity in risk scoring. Finally, the study focuses on financial performance only and does not explicitly incorporate social and environmental outcomes related to PPP projects.

The study has many ways in which it could be built upon by subsequent research. One is that incorporating ESG factors could enable an even more holistic understanding of PPP performance. Another is that subsequent research could explore the relationship between institutional quality and risk allocation in even greater depth, particularly in the context of emerging and developing economies. Finally, quasi-experimental designs or richer contractual datasets could enable an even richer understanding of the role played by PPP design in long-run project outcomes.

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