Unit Costs of Public and PPP Road Projects: Evidence from India

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Abstract: There has been an overall increase in the level of private-sector investment for the road sector in many developing countries during the past decade. However, there has been limited research on the effect of such increased private-sector participation on road costs. By using data from 521 public and private road projects in India, it was found that there are significant differences between public and private-sector projects. Public—private partnership (PPP) roads have a longer length, a higher project cost, and lower unit costs than public projects. Although regression analysis indicated that private-sector investment tended to increase unit costs, lower unit costs were achieved for PPP road projects because developers could take advantage of economies of scale. It was also found that the presence of foreign sponsors in the private consortium and prevalence of corruption increased unit costs. Results from a logistic regression analysis indicated that states that were more developed and had lower levels of corruption could be more successful in attracting private-sector investment for road projects.
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Introduction

The contribution of infrastructure, particularly roads, to economic development has been well recognized. During the last decade, substantial investments have been made in developing the road network in India. For the two five year periods 2001–2006 and 2006–2011, the total investment in roads was about 1.45 trillion Rupees (Rs. 1.45 trillion, approximately US$29.6 billion at a conversion rate of Rs. 49 per dollar) and Rs. 2.78 trillion (approximately $56.7 billion), respectively. For the ten year period 2011–2021, investment is expected to be in the range of Rs.10.5–11 trillion (US$214–222 billion). Given the constraints of public-sector financing, the private sector is expected to play a key role in meeting investment requirements. The share of private-sector investment in infrastructure accounted for approximately 20% of the total investment of Rs.10.7 trillion (US$218 billion) in infrastructure during 2001–2006. It is expected to increase to 30% of the total investment of Rs. 25.8 trillion (US$514 billion) in infrastructure during 2006–2011 (Planning Commission, Government of India, 2007). Not only the proportion but also the quantum of contribution from private sector for infrastructure has increased in the last 10 years.

According to the Ministry of Finance statistics (Indian Brand Equity Foundation 2011), road projects accounted for 60% of the 450 public—private partnership (PPP) infrastructure projects in India. PPP projects have been implemented both by the national (federal) and state governments. Of the total PPP projects in the road sector, 36% of the projects, involving a total project cost of Rs. 0.49 trillion (US$10 billion), were implemented by the national government, and the remaining 64% of the projects, having a project cost of Rs. 0.52 trillion (US$10.612 billion), were implemented by different state governments.

Although there have been several PPP projects in the road sector, academic research about the effectiveness of using a PPP approach for road development has been limited. In fact, there have been very few empirical studies about the effect of PPP in the road sector in developing countries in general. This study is an attempt to bridge that gap. With several developing countries embarking on large investment programs to develop their road networks, the authors believe that the findings of this study can substantially contribute to policy making in this area.

The remaining part of the paper is structured as follows. The next section provides a brief literature review. The following section presents the objectives of the paper. The next section describes the study data and methodology. The next section presents the results and analysis. The next section presents a discussion on the primary results. A summary of the paper is provided in the final section.

Literature Review

Studies that compare the cost of road development under the PPP format to the traditional public procurement model have been few. Frédéric et al. (2006) obtained interesting results in an empirical study about the European road sector. They formulated and analyzed a regression equation with unit cost as a dependent variable and project influencing variables viz., length, consumer price index, number of lanes, and country dummy, for comparing the differences between public—private partnerships and traditional public procurement. They estimated a 24% increase in unit costs for PPP projects over public procurement, which was expected because of the transfer of the construction risk and other demand-related risks to the private investor. Further justification of the

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increase was indicated by Jennifer et al. (2009), whose study stated that the procurement approach affected the division of risk between the parties, and such a risk, if not distributed accordingly, would lead to an increase of the project cost.

Further empirical analyses have been oriented toward understanding the risks involved with PPPs and risk mitigation techniques. Iyer and Mohammed (2010) stated that cost and schedule risks had the highest dependency on other risks and therefore are quite vulnerable and susceptible to change. Studies by Skamris and Flybjerg (1996, 1997) indicated that a cost overrun of 50–100% was common for larger transportation infrastructures and that costs were higher with the involvement of private players. Further, theories explained by Hart (2003) and Grout (2005) as applied to PPPs suggested that there were several reasons to expect that the cost of constructing an infrastructure asset should be higher in a PPP than in traditional public procurement.

Singh and Kalidindi (2006) in their study of various PPP contract structures stated that the cost of PPP projects was higher just as the cost of the capital arranged by the private investors was comparatively higher than the government's cost of borrowing because of the greater creditworthiness of public entities. Further, a CPCS Transcom Limited (2005) study revealed that in an annuity model, government guarantees may not be perceived adequate, and a substantial risk premium could be associated with it, which added to the project cost.

Contrary to these arguments, Jens (2003) suggested that involving the private sector in public-service production may lead to cost savings because of the difference in ownership and/or a difference in competitive pressures. PPP was further considered as an enabler for a win—win situation because Tang (2010) found that PPP blended public objectives with various private stakeholders' marketability and profitability.

Apart from the type of procurement, the physical, contractual, and state-specific characteristics also influence the cost of road projects. The costs of large road projects do not always vary linearly with respect to different facility sizes because of the existence of scale economies or diseconomies. Atsushi (2007) found evidence in China highway projects that depicted that economies of scale in road construction could lower the average cost of construction because of the observation that relatively long roads encouraged firms to bid aggressively, independently of the degree of competition.

Panagiotis et al. (2010) developed a framework based on a three-stage least-squares model to identify the expected cost of maintenance projects on the basis of project type, constituent work activities, physical size (length of the project), and contract type. The results showed that the estimated project cost for performance-based contracts (PBCs) was higher than the corresponding project cost of a traditional maintenance contract, but for longer-length PBCs, proved to be efficient by better use of economies of scale.

The other significant difference in contractual arrangements is the nationality of the various stakeholders in the projects. The involvement of foreign firms in road projects has become an increasing occurrence in the Indian road sector recently. However, there are not many empirical studies that have looked at the effect of foreign investors and sponsors on road costs. In a study on understanding the effects of foreign investment, Hironori et al. (2010) identified the institutional spillover effects stemming from a road construction project funded by foreign aid. They observed that the intervention of a foreign player into the local politics was often effective for the local stakeholders to overcome the locked-in system because it brought some momentum to shift the existing equilibrium and negotiate any changes in the system. They further affirmed that whenever the foreign player was a donor to the project, the influence of its intervention may be greater than the usual case, which often led to a well-structured transaction.

Governance levels play an important role in deciding project cost. Harris (2008) conducted a study to find the relevance of governance in project finance funding across Africa, and the study revealed that good governance was positively related to loan syndication in project finance structures, thereby optimizing unit project costs. The results revealed that the rule of law had a positive influence on structuring, providing the private player a security against political risks.

Stapenhurst (2000) defined corruption as "the abuse of public power for personal gain or for the benefit of a group to which one owes allegiance." The primary form of corruption in infrastructure projects involves bribes by private players to governments. Tanzi (1998) mentioned the fact that corruption was also likely to affect negatively the productivity of project finance investments, which, in turn, could lead to a reduction in the revenues generated. This may distort incentives by encouraging individuals to search for those to whom bribes must be paid and thereby incurring additional transaction costs.

Objective

In recent years, there has been a rapid growth in the number of road projects that are implemented in a PPP format, not just in India, but in many emerging countries. However, there has been limited research about the cost effectiveness of PPP projects vis-à-vis the traditional government procurement model. This paper is an attempt to address that gap. Specifically, this study has the following objectives. First, a comparative analysis of the PPP and public procurement road projects in terms of road lengths, project costs, and unit project costs will be discussed. Second, an analysis of the effect of the type of project procurement (PPP vis-à-vis public) on unit road costs, after controlling for other factors, will be presented. Third, the determinants that influence private-sector investment will be identified.

Data and Methodology

Data pertaining to road-sector projects in India were used for the analysis. Because there was no single source that provided the relevant information for both PPP and public projects, a data set was developed by compiling project information about various road projects undertaken in India during 1996–2010. To account for inflation during these years, the analysis was done after converting the financial data pertaining to all the projects to 2010 values.

The primary sources used for compiling the database were the PPP India database, the projects in public—private partnerships in India, the PPP cells in the project databases of various state governments, the World Bank PPP database, the project finance international database provided by Thomson Reuters, the NHAI database of ongoing/completed projects funded by World Bank, the Asian Development Bank and Japanese Bank for International Co-operation, and the implementation status report of road projects costing Rs.200 million (US$4.1 million) or more under the central government for the period April–June 2009.

Project classifications across different parameters are described by the following:

- Projects were classified as either a road or a bridge project, based on the type of structure. Bridge projects were included in this analysis because many of the PPP concessions have been awarded for bridge projects. All roads and expressways were classified as road projects, and other structures, such as bridges,

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elevated highways, and tunnels, were classified as bridge projects.
- Projects were classified either as a greenfield or brownfield project based on the work description. New roads were classified as greenfield projects, and widening and strengthening and strengthening and improvement projects were classified as brownfield projects.
- PPP projects were further classified as build—operate—transfer (BOT) annuity or BOT-toll, depending on the revenue arrangement. If the concessionaire received tolls from the users, they were classified as BOT-toll projects. If the projects received fixed regular payments for a specified time period from the government, they were classified as BOT-annuity projects.

Description of Data

The compilation yielded a data set of 521 PPP and public procurement projects with an approximate total cost of Rs. 2 trillion ($40.8 billion) over the 15 year period. The total number of public and PPP projects was 165 and 356, respectively. The number of road and bridge projects was 483 and 38, respectively.

Of the 483 road projects, the number of public-sector and PPP projects was 159 and 324, respectively. The total length of roads developed from these 483 projects was more than 29,900 km, of which 21% were from public-sector projects, and the remaining 79% were from PPP projects. Of the 38 bridge projects, 32 were in PPP format, and the remaining 6 were public-sector projects.

Of the 356 PPP projects, 264 were toll projects, and 92 were annuity projects. Fifty-three of the PPP projects had foreign investors in the sponsor consortium. Of the 165 public projects, 63 had investments from multilateral agencies.

Methods Used for Analysis

Broadly, the variables used in the analysis were classified as project-specific economic variables, technical variables, and state-specific variables. An explanation of the variables used in the study and their sources are given in Table 1. The comparison of public procurement and PPP projects was done by a Kruskal—Wallis test. An ordinary least squares (OLS) multivariate regression was used to analyze the effect of different factors on unit costs. Logistic regression was used to analyze the determinants that influence private-sector investment in road projects. A short description of these three methods is given in the appendix.

Results and Analysis

The results of the study are presented in five parts. First, the results from a comparison of both public and PPP projects are given. The next three parts showcase the results of unit cost analysis for PPP projects, for public-sector projects, and for the overall sample, respectively. The final part presents the analysis of the determinants that influence private-sector investment.

Comparison of Public-Sector and PPP Projects

The objective of this comparative analysis was to determine whether there were any differences between the PPP and public procurement projects, apart from the difference in the method of procurement. The two categories of projects were compared for road length, total cost of the project, and unit project cost. Because the data sets were nonnormal distributions, the nonparametric Kruskal—Wallis test was used to compare the medians. Results indicated that the difference was significant between the two types of projects for each of the three parameters. Results are given in Table 2. The comparison of length and unit cost was only done for the road projects because the bridge projects had substantially different characteristics.

The first row in Table 2 provides the comparative road lengths of the two types of projects. The results indicated that PPP projects were longer than public-sector projects, and the difference was

Table 1. Explanatory Notes for Different Variables

Variable	Description
UCOST	Unit cost of project in Rs. million per lane-km calculated from the cost of the project at the time of the award of the bid or the signing of the concession agreement, the length, and the width of the project
PROCUTYPE	Dummy variable that takes a value of 0 for public procurement and 1 for PPP projects
REVTYPE	Dummy variable used to analyze the effect of demand/revenue risk in PPP projects that takes a value of 1 in the case of annuity payments and 0 in the case of toll collection
CONPERIOD	Number of years of concession including the construction period of the project included to assess the effect of the recovery period of the investment
FSPONSOR	Dummy variable used to assess the influence of foreign sponsors in PPP projects that takes a value of 1 if a foreign company is in the sponsor consortium and 0 if the project is developed solely by domestic sponsors
MLAFUNDING	Dummy variable used to indicate whether the project has received funding from multilateral agencies that takes a value of 1 if there is support from multilateral agencies and 0 if there is no support
TIME	Year in which the project was awarded by the government that is assigned a value of 1 for projects awarded in 1996, 2 for projects awarded in 1997, and so on, included to account for the influence of time in project costs and procurement decisions
PROJTYPE	Dummy variable used to indicate the extent of development that takes a value of 1 for greenfield projects and 0 for brownfield projects
LENGTH	Length of the project used to understand the influence of economies of scale. This also signifies, to a certain extent, the level of construction risk in the project. Because there is substantial variation in road lengths, a log value of length was used in the regression
STRUCTYPE	Dummy variable that takes the value of 0 if it is a road and 1 if it is a bridge, elevated highway, or tunnel. This variable signifies the technology risk associated with road construction projects because bridge projects, in general, would require more expertise than road projects
PERCENTMLA	Percentage of funding from multilateral agencies to individual states to explain the effects of involvement of foreign lending agencies to local governments. These data were obtained from the World Bank
DENGROW	Used cumulative average growth rate (CAGR) of RND for individual states averaged over 2003–2009, which shows the variance among states in terms of road development during the period and also the extent of road network in a particular state
CORRUPTION	Composite ranking of states on petty corruption used to examine the effect of corruption on project cost, which signifies the risk of investment in unstable economies. The higher the value of the index, the higher the corruption in that state. The indexes were obatined from Transparency International's Indian corruption study (2005)

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Table 2. Comparison of Public-Sector and PPP Projects

Variable	PPP project			Public project			K statistic	K critical	P-value
	Median	σ[a]	N[b]	Median	σ[a]	N[b]			
Road length (km)	73.114	51.192	324	39.467	18.968	161	62.146	3.841	<0.0001
Total project costs (Rs., million[c])	5,837	5,898	356	3,219	1,555	195	15.263	3.841	<0.0001
Unit project costs (Rs., million[c] per lane-km)	40.28	45.18	324	45.07	23.61	161	13.539	3.841	<0.0001

[a]σ = Standard deviation.
[b]N = number of observations.
[c]Currency conversation rate, for reference, is US$ = Rs. 49.

statistically significant. One would have expected the length of public projects to be longer because public procurement is the traditional method of procurement, and the length of PPP projects to be shorter because a longer road would involve a higher risk for the private investor. But, the analysis showed that PPP roads were longer, indicating that PPP structures have reached a level of acceptance among both the government and private sector.

The second row compares the project cost of both categories of projects. The results indicated that the total cost of PPP projects was larger than public-sector projects, and the difference was statistically significant. From the results in the first row, the increase in cost was along expected lines because the length of PPP roads was longer than public projects. Although road development has traditionally been dominated by the public sector in India, these results indicate that the private sector has quickly developed the expertise and capability to implement large projects. Because PPP projects would also invariably involve debt funding, these findings also indicate that financial institutions and banks in India have developed the expertise to appraise and lend for private-sector road projects in India.

The third row compares unit costs (i.e., cost per lane-km) between the two types of projects. The results showed that the unit costs of PPP road projects were lower than public-sector projects, and the difference was statistically significant. The lower cost indicates that the private sector has been able to achieve higher levels of efficiency compared to the public sector.

In summary, significant differences were found between the two types of projects. In the next two sections, a discussion of the OLS multivariate regression used to analyze the variables that influence unit project costs in PPP and public roads is provided.

Unit Cost Analysis for PPP Projects

This section discusses the results of the regression analysis done on PPP projects. Eq. (1) gives the regression model used. Table 1 gives a description of the different variables.

$$\begin{aligned}\text{UCOST} = {} & \beta_0 + \beta_1(\text{LOG(LENGTH)}) + \beta_2(\text{STRUCTYPE}) \\ & + \beta_3(\text{REVTYPE}) + \beta_4(\text{CONPERIOD}) \\ & + \beta_5(\text{FSPONSOR}) + \beta_6(\text{TIME}) + \beta_7(\text{PROJTYPE}) \\ & + \beta_8(\text{PERCENTMLA}) + \beta_9(\text{DENGROW}) \\ & + \beta_{10}(\text{CORRUPTION}) + \varepsilon \end{aligned} \quad (1)$$

The independent variables used to regress the dependent variable unit cost, UCOST, are explained subsequently. The technical variables included in Eq. (1) are road length, LENGTH, and type of structure, STRUCTYPE. Construction activity offers substantial economies of scale of benefits that led the authors to include LENGTH in the regression model. Because cost would also depend on the type of structure, STRUCTYPE was included as one of the independent variables.

The project economic variables included in the model are the type of revenue collection mechanism, REVTYPE; concession period, CONPERIOD; whether the consortium included any foreign sponsors, FSPONSOR; year of award, TIME; and extent of development, PROJTYPE (i.e., greenfield or brownfield). REVTYPE was included because it indicates the risk private investors have to assume, which, in turn, could have an effect on the costs. PPP firms assume a higher demand risk when the revenue collection is by way of tolls compared to annuity payments from the public authority. CONPERIOD indicates the duration before which investors have to recover their capital and return on investment. A variable to include the effect of foreign sponsors, FSPONSOR, was included in the model because it was felt that foreign sponsors would perceive a higher level of risk of investing in a developing country than domestic sponsors. This, in turn, could effect project costs. The TIME variable was included to capture the effect of time on UCOST. The PROJTYPE variable was included to identify the effect of development risk on UCOST. The element of development risk was higher in greenfield projects than brownfield projects.

The state-specific variables included in the model were growth in road network density, DENGROW; multilateral agency funding channelized to the state as a percentage of total multilateral funding for the country, PERCENTMLA; and perception of corruption levels in the state, CORRUPTION. The DENGROW variable signifies the level and growth of road development in the state. The PERCENTMLA denotes the overall level of development activity in the state. The CORRUPTION variable was included to establish whether the corruption levels in the state had any effect on project costs.

The results of the regression are given in Table 3. A high R^2 value of 0.48 indicates the strength of the regression model. The independent variables that showed statistical significance are discussed subsequently. The coefficient of log[LENGTH] was negative, indicating that as road length increased, UCOST decreased. This relationship confirms that road projects have strong scale economies. STRUCTYPE was also significant, and had a positive coefficient. Because it is a dummy variable, which takes in a value of 0 for road projects and 1 for bridge projects, a positive coefficient was also on expected lines because UCOST of bridge projects was expected to be more than road projects, given the technical difficulties in executing bridge projects compared to normal road projects.

The coefficient for the CONPERIOD variable was positive and significant, indicating that the duration of the concession period was higher for a project with higher costs (i.e., private investors have a longer duration to recover their costs). Thus, a longer concession period was associated with projects that were complex and had high costs. Increasing the duration of the concession would help the concessionaire to recover its investment over a longer

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Table 3. Statistics of Regression Model for PPP Projects

Variable	Regression statistics	Coefficients	Standard error	*T*-statistic	*P*-value
Multiple *R*	0.707				
R square	0.5				
Adjusted *R* square	0.48				
Standard error	124.78				
Observations	356				
INTERCEPT		0	—	—	—
LOG (LENGTH)		−126.194	18.226	−6.923	<0.01[a]
STRUCTYPE		185.770	33.957	5.470	<0.01[a]
REVTYPE		12.547	16.551	0.758	0.448
CONPERIOD		6.26	1.256	4.981	<0.01[a]
FSPONSOR		46.18	19.163	2.409	0.016[a]
TIME		2.577	2.258	1.141	0.254
PROJTYPE		−28.58	21.407	−1.335	0.182
PERCENTMLA		0.029	0.325	0.090	0.928
DENGROW		−0.017	1.436	−0.012	0.990
CORRUPTION		0.216	0.057	3.774	<0.01[a]

[a]The coefficient was significant at the 1% level.

period and thereby would help to keep the toll levels/annuity payments at manageable levels.

The coefficient of FSPONSOR was positive, indicating that UCOST was higher when there was the presence of a foreign sponsor in the consortium. This was expected because foreign sponsors might perceive additional risk in investing in a developing country and would want a higher return commensurate with the additional risk. This higher return would, in turn, increase project costs. Whereas the presence of foreign investors would help in getting access to technology or management expertise to handle difficult situations, it also had the counter effect of increasing project costs. This relationship indicates that having a strong domestic industry to develop road projects over time would help reduce project costs.

The coefficient of CORRUPTION was significant and positive. This was expected because a high value of corruption indicates a higher prevalence of petty corruption in the state. Given the extensive interaction needed between a private firm and government agencies at each and every stage of project development, such as land acquisition, environmental clearances, and the resettlement of project-affected people, a high level of corruption could hinder the smooth progress of the project. The necessity of bribe payments to overcome such hurdles leads to an increase in project costs. Although the beneficiaries of bribe payments would be very few, the effect of higher project costs would affect the road users in terms of higher tolls or the taxpayer in terms of higher annuity payments. These results emphasize that reducing corruption levels would also reduce project costs.

Unit Cost Analysis for Public Projects

This section discusses the results of the regression analysis done on road projects that were implemented in the traditional public procurement model. Eq. (2) gives the regression model used. Table 1 gives a description of the different variables.

$$\begin{aligned}\text{UCOST} = {} & \beta_0 + \beta_1(\text{LOG(LENGTH)}) + \beta_2(\text{STRUCTYPE}) \\ & + \beta_3(\text{MLAFUNDING}) + \beta_4(\text{TIME}) \\ & + \beta_5(\text{PROJTYPE}) + \beta_6(\text{DENGROW}) \\ & + \beta_7(\text{CORRUPTION}) + \varepsilon \end{aligned} \quad (2)$$

The independent variables in Eq. (1) were changed to suit the context of public-sector projects. For example, in the project economic variables, REVTYPE, CONPERIOD, and FSPONSOR were dropped because they are not relevant for public-sector projects. There is no practice of annuity payment in a public-sector project, although some projects might have tolls. There is no concession agreement for a public-sector project because the project belongs to the public sector. The question of FSPONSOR does not arise because there are no private sponsors associated with the project, let alone a foreign sponsor.

A new dummy project economic variable, MLAFUNDING, was introduced to indicate the presence of multilateral funding for the project. Because the availability of multilateral funding provides a source of low-cost of capital, it would have an effect on project costs and, therefore, was included in the model.

Of the state-specific variables, PERCENTMLA was dropped because most of the projects were implemented by the central government, and this variable was no longer considered appropriate. The other state specific variables, DENGROW and CORRUPTION, were retained.

The results of the regression are given in Table 4. An R^2 value of 0.401 indicated a good fit for the regression. The independent variables that had a significant effect on UCOST in public-sector road projects were LENGTH, MLAFUNDING, TIME, and CORRUPTION. Similar to PPP projects, the coefficient of the LENGTH variable was negative, indicating the effects of economies of scale. The coefficient of MLAFUNDING was positive and significant, indicating that the presence of multilateral funding was associated with projects having high costs. There are two possible explanations for this trend. First, multilateral agency funding is normally seen in large projects that have substantial developmental benefits (which, in most circumstances, also tend to be costly) but may not have strong commercial viability to attract conventional sources of funding. Second, the involvement of multilateral agencies, such as the World Bank or the Asian Development Bank, impose more stringent conditions during project development, such as rigorous environmental impact assessment reports, extensive public interaction, and liberal resettlement and rehabilitation policies for project-affected people, which can lead to an increase in project costs.

The TIME variable had a positive coefficient, indicating that the unit cost of projects implemented in later years was more than the unit cost of projects implemented in earlier years, even after

Table 4. Statistics of Regression Model for Public-Sector Projects

Variable	Regression statistics	Coefficients	Standard error	*T*-statistic	*P*-value
Multiple *R*	0.633				
R square	0.401				
Adjusted *R* square	0.372				
Standard error	9.615				
Observations	165				
INTERCEPT		0	—	—	—
LOG (LENGTH)		−15.952	2.549	−6.257	<0.01[a]
STRUCTYPE		3.010	6.458	0.466	0.641
MLAFUNDING		6.816	2.046	3.331	<0.01[a]
TIME		0.882	0.293	3.011	<0.01[a]
PROJTYPE		−5.123	4.865	−1.052	0.293
DENGROW		−0.044	0.159	−0.280	0.779
CORRUPTION		0.034	0.007	4.516	<0.01[a]

[a]The coefficient was significant at the 1% level.

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accounting for inflation. This could be attributable to several reasons, such as the use of more advanced technologies in road development, which could be expensive. However, what is interesting is that the effect of UCOST increasing with time was not significant in the case of PPP projects. Additional studies could give more explanations for this result.

The coefficient for CORRUPTION was positive and significant, indicating that the presence of petty corruption tended to increase the costs of public projects as well because private contractors executing the project would be affected by the expectation of bribe payments. The lack of an adequate number of public-sector bridge projects would explain the nonsignificance of the STRUCTYPE variable in contrast to PPP projects.

Unit Cost Analysis for the Overall Sample

After separately analyzing the effects of different variables on UCOST for PPP and public projects, the effects of different variables on UCOST for the overall sample were analyzed. However, PROCUTYPE was included as one of the independent variables. The objective of this analysis was to check whether the type of procurement had any effect on UCOST for the project. The regression model developed is given in Eq. (3).

$$\text{UCOST} = \beta_0 + \beta_1(\text{LOG(LENGTH)}) + \beta_2(\text{STRUCTYPE}) + \beta_3(\text{MLAFUNDING}) + \beta_4(\text{PROCUTYPE}) + \beta_5(\text{TIME}) + \beta_6(\text{PROJTYPE}) + \beta_7(\text{DENGROW}) + \beta_8(\text{CORRUPTION}) + \varepsilon \quad (3)$$

The regression results are given in Table 5. An R^2 value of 0.431 indicated a good fit for the regression. The variables that had statistical significance were LENGTH, STRUCTYPE, PROCUTYPE, CORRUPTION, MLAFUNDING, and TIME. The coefficients of the variables LENGTH, STRUCTYPE, and MLAFUNDING were in line with the results obtained from the previous regressions. The coefficient of the TIME variable was in line with the results from previous regressions and was also significant for the public-sector projects.

The coefficient of the dummy variable PROCUTYPE was positive. The dummy variable had a value of 0 for public procurement projects and 1 for PPP projects. This indicated that the effect of the project implemented by PPP led to an increase in unit costs. This effect was as expected because a private investor would be faced with a higher risk than a public-sector investment because of the various uncertainties associated with implementing a road project. The private investor would expect a return commensurate with risk levels, which tended to increase the unit costs.

Table 5. Statistics of Regression Model for All Projects

Variable	Regression statistics	Coefficients	Standard error	*T*-statistic	*P*-value
Multiple *R*	0.657				
R square	0.431				
Adjusted *R* square	0.423				
Standard error	120.959				
Observations	521				
INTERCEPT		0	—	—	—
LOG (LENGTH)		−113.730	14.875	−7.646	<0.01[a]
STRUCTYPE		169.373	29.450	5.751	<0.01[a]
MLAFUNDING		58.214	20.419	2.851	<0.01[a]
PROCUTYPE		51.366	14.599	3.519	<0.01[a]
TIME		7.635	1.706	4.476	<0.01[a]
PROJTYPE		−11.082	18.909	−0.586	0.558
DENGROW		0.872	1.097	0.794	0.427
CORRUPTION		0.215	0.044	4.855	<0.01[a]

[a]The coefficient was significant at the 1% level.

Determinants of Private-Sector Investment

In this section, the influence of different variables on private-sector investment in roads is analyzed. The PROCUTYPE variable was considered a dependent variable in this case and regressed against the following independent variables: LENGTH, DENGROW, STRUCTYPE, CORRUPTION, and TIME. Because the dependent variable was a binary variable, logistic regression was used. Eq. (4) gives the regression model.

$$z = \beta_0 + \beta_1(\text{LOG(LENGTH)}) + \beta_2(\text{STRUCTYPE}) + \beta_3(\text{TIME}) + \beta_4(\text{DENGROW}) + \beta_5(\text{CORRUPTION}) + \varepsilon \quad (4)$$

The results of the regression are given in Table 6. The results indicated the significance of the following variables: LENGTH, DENGROW, STRUCTYPE, and CORRUPTION. The coefficient of LENGTH was positive, indicating that the chances of a project being implemented by PPP increased with length. The coefficient of DENGROW was negative, indicating that projects in those states that experience higher growth in road network density tended to be implemented by public procurement. Although additional research might be needed to explain this outcome, a possible explanation could be the following. States could have high growth rates because of the low density of existing road networks. A low density of road networks indicates a low level of overall development of the state. Private investors are keen to invest only in those states that have a high degree of overall development.

The coefficient of STRUCTYPE was positive. Because this is a dummy variable, which had a value of 1 for bridge projects, the result indicated that bridge projects had a higher probability of being implemented in a PPP format than road projects. The coefficient of CORRUPTION was negative, indicating that private investors would be reluctant to invest in states having a high level of corruption.

Discussion

In this section, some of the key results of the study are discussed. The results from comparative analysis indicated that there were

Table 6. Statistics of Logistic Regression Model

Variable	Regression statistics	Coefficients	Standard error	Wald—Chi-square	Pr > Chi^2
R^2 (McFadden)	0.118				
R^2 (Cox and Snell)	0.137				
R^2 (Nagelkerke)	0.193				
Observations	521				
INTERCEPT		0.558	0.890	0.393	0.531
LOG (LENGTH)		1.762	0.320	30.292	<0.01[a]
STRUCTYPE		3.812	0.760	25.141	<0.01[a]
TIME		0.038	0.031	1.422	0.233
DENGROW		−0.045	0.022	4.273	0.039[b]
CORRUPTION		−0.006	0.001	19.235	<0.01[a]

[a]The coefficient was significant at the 1% level.
[b]The coefficient was significant at the 5% level.

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significant differences between PPP and public-sector road projects. PPP road projects were longer and had higher total project costs. Because the cost of PPP projects was higher, in the Indian context, this indicates that PPP formats have been used to attract private capital in projects that were capital intensive in an attempt to conserve public-sector capital. It also indicates that the private sector has, over the years, acquired the management and operational expertise to successfully develop longer road projects.

Regression analysis on unit costs demonstrated the strong effect of economies of scale in the road sector. As road length increased, the unit cost decreased. It is, therefore, economical to structure fewer road projects of longer lengths rather than have many road projects with shorter stretches. The point at which the scale effect starts diminishing because of increasing costs associated with managing larger projects was not studied and should be an area of future research.

The prevalence of corruption increased unit costs. Projects costs are dependent not only on the project's technical and economic characteristics, but also on the external environment factors. The costs of projects were higher in states having a higher level of corruption. The presence of corruption, which normally results in bribe payments, benefits only a few in the political and administrative system. But the effect, which leads to higher project costs, affects road users in terms of higher toll charges or taxpayers in terms of the higher investment of public capital, or larger annuity payments, in the case of PPP projects. Any effort to reduce overall corruption and cleanse the administration would also have a positive effect on reducing the costs of infrastructure development activities.

The presence of foreign sponsors in the consortium was associated with higher unit costs for PPP projects. Because developed countries could have more experience in developing technologically complex projects, having foreign sponsors in the consortium would help developing countries, such as India, get access to that expertise. However, the negative aspect of having foreign sponsors was an increase in unit costs. Foreign investors could perceive additional risk in investing in developing countries, which would lead to an increase in cost. Therefore, the government should take suitable initiatives to develop the domestic infrastructure industry because it would have the effect of reducing project costs.

The regression analysis of the overall sample indicated that having a project in a PPP mode increased the unit costs of the project. This increase is in line with the expectation because the public sector would be in a better position to handle the risks and uncertainties associated with various externalities experienced in road projects. The private sector would expect a compensation for assuming these risks, leading to an increase in project costs. But the comparative analysis of PPP and public-sector projects indicated that PPP projects had lower unit costs—not higher. The regression coefficients indicated that this reduction could be attributed to the way projects have been structured and an economies of scale effect. Private-sector road projects are longer than public-sector road projects and derive substantial benefits from economies of scale. The benefits achieved from economies of scale would be higher than the increase in costs resulting from the private sector bearing the risks of the project, thereby leading to an overall reduction in unit costs.

This, in a way, also indicated the positive features of the PPP policy that has been followed. If PPP projects were implemented in the same way as public-sector projects, costs would have been higher. Therefore, to keep the costs lower, PPP projects have been structured as longer projects to keep unit costs lower. By implementing longer projects, governments have been able to leverage the superior management capabilities and operational efficiencies of the private sector.

Logistical regression indicated that bridge projects had a higher probability of being implemented in a PPP format than road projects. Bridge projects were short stretches compared to road projects but were technically more complex. This characteristic would suit the private sector because it has superior expertise in design, management, and operational aspects of project development than the public sector, whereas the public sector is better equipped to handle the externalities associated with the project. Because bridge projects are well defined and have short stretches, the uncertainties associated with externalities would be lower than road projects.

The overall development and corruption levels also had an effect on the probability of a project being implemented in a PPP format. Private investors are more comfortable investing in well-developed states than in states that are lesser developed. In lesser-developed states like Assam, Arunachal Pradesh, and in remote areas of the states of Uttar Pradesh and Jharkhand, the development of roads has only been done by the public sector because of the prevailing local conditions. However, in highly developed states, such as Andhra Pradesh and Gujarat, many road projects have been completed in the PPP format. The private sector is also reluctant to make investments in states in which corruption is high. Administrative reforms aimed at reducing corruption levels would not only attract private-sector investment in the state, but would also lower the cost of projects.

Conclusions

The results of this study indicate that there are significant differences between PPP and public-sector road projects in India. PPP road projects are longer and have higher total project costs than public-sector projects. Although implementing a project in a PPP format has the effect of increasing unit costs, it was determined that unit costs are lower for PPP projects than public-sector projects. Because PPP road projects are longer, they have been able to take advantage of the benefits of economies of scale, leading to lower unit project costs (i.e., the cost increase as a result of private-sector investment has been more than offset by the economies of scale). The ability to capture the scale economies also indicates that the private sector has been able to bring much higher levels of performance efficiencies to the sector.

Additional analyses on unit costs indicate that state-specific variables also have an effect on costs in addition to project technical and economic variables. Reforms and tighter monitoring that can lead to a reduction in corruption levels also lead to a reduction in costs. States that are already well developed and have lower levels of corruption are more successful in attracting private-sector investment. Although the initial infrastructure development has to be done by the public sector, it becomes easier to attract private-sector investment after attaining a certain level of development. For policy makers, this clearly indicates that if they are keen on attracting private-sector investment, they have to implement reforms that reduce overall corruption.

PPP's have made a significant contribution to the development of roads in India. In addition to creating new capacity, they have brought in capital and much needed efficiency in the sector. However, to offset the inherent costs associated with private-sector investment, PPP road projects have to be longer to capture the benefits of economies of scale. Policy makers and the government need to realize this difference when structuring PPP projects to ensure that the development of roads is done cost effectively.

This study was based on data from road projects in India. The results are believed to be relevant for developing and emerging

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countries in general. A study that includes data from more emerging and developing countries could be done in the future to make the results more representative and also to analyze country-specific effects seen in PPP projects.

Appendix: Short Description of the Data Analysis Techniques Used

Kruskal—Wallis Test

The Kruskal—Wallis test is a nonparametric method for testing the equality of population medians among groups (Iman et al. 1975). It is identical to a one-way analysis of variance with the data replaced by their ranks. Because it is a nonparametric method, the Kruskal—Wallis test does not assume a normal population, unlike the analogous one-way analysis of variance. However, the test does assume an identically shaped and scaled distribution for each group, except for any difference in medians. The test statistic is given by

$$K = \frac{12}{N(N+1)} \sum_{i=1}^{g} n_i \bar{r}_i^2 - 3(N+1)$$

where n_i = number of observations in group i; $\bar{r}_i^2$ = average rank of all the observations in group i; and N = total number of observations across all groups.

One of the limitations of the Kruskal—Wallis test is that if the difference in the data is not significant, it cannot be concluded that the samples are same. Further, while comparing more than two samples, if there are strong differences, the nonparametric comparison tests available include a lot of manual work.

Multivariate Ordinary Least Squares Regression

OLS regression attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data (Ravishankar and Dey 2002). Every value of the independent variable X is associated with a value of the dependent variable Y. The model determines the regression equation by minimizing the sum of squares of the residuals, and the accuracy of future outcomes on model is predicted by a coefficient of determination, R^2. In a regression, R^2 is a statistical measure of how well the regression line approximates the real data points with 1.0 being the best ideal fit.

The deterministic model written for observation i is as follows:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_p X_{ip} + \varepsilon_i$$

where $i = 1, \ldots, n$; Y = dependent variable; β_0 = intercept; $\beta_1, \beta_2, \ldots$ = coefficients of independent variables; $X_1, X_2, \ldots$ = independent variables; and ε = error term.

Logistic Regression

Logistic regression is a type of predictive model that can be used when the target variable is a categorical variable with two categories. Logistic regression can be used only with two types of target variables: binary variables and a continuous target variable that has values in the range 0.0–1.0, representing probability values or proportions (Peng et al. 2002). The logistic model formula computes the probability of the selected response, P, as a function of the values of the predictor variables, as indicated by

$$P = \frac{1}{1 + e^{-(\alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_3 X_3)}}$$

were β_0 = constant; and $\beta_{1,2,3,\ldots,i}$ = coefficients of the predictor variables $X_{1,2,3,4,\ldots,i}$.

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