Working paper

International Growth Centre

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Comparison of cost and quality of roads

Ram Singh

March 2018

When citing this paper, please use the title and the following reference number:
S-89209-INC-2

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Does choice of procurement contract matter for cost and quality of infrastructure?
Comparison of Cost and Quality of Roads

Ram Singh[*†]

Abstract

Does choice of procurement contract matter for cost and quality of infrastructure? This study addresses this and related issues by examining the relative performance of various types of procurement contracts used for highways projects in India. We model the incentive structures induced by Public Private Partnerships (PPPs or P3) contracts and the traditional procurement contracts used for infrastructure. The model is used to predict outcomes under PPP contracts versus the traditional contracts. Predictions emanating from the model are tested using a dataset of 313 national highways projects in India. The empirical analysis examines validity of a widely held belief that PPPs are better than the traditional contracts in terms of the cost and quality of infrastructure. We show that the construction costs are significantly higher for PPPs than the traditionally procured (non-PPP) highways. For a subset of projects, we compare the quality of PPPs with the non-PPP roads. Our analysis shows that the PPPs encourage life-cycle approach towards project costs. Moreover, the quality of PPP roads is better than the traditional highways.

[*]Department of Economics, Delhi School of Economics, University of Delhi, email: ramsingh@econdse.org.

[†]Acknowledgment: I am thankful to J V Meenakshi, and Neha Jain for valuable comments and suggestions. I have also benefitted from the several comments and suggestions provided by the research team of the International Growth Centre (IGC) on the project findings some which are used here. The funding support by the IGC and the institutional support by the Centre for Development Economics at the Delhi School of Economics are gratefully acknowledged. Kriti Jain and Nikita Gupta provided excellent research assistance. I am grateful to Mr Lars Forslöf, the developer of the Roadroid App, who kindly agreed to provide free access to the app for the purpose of data collection on the quality of roads and its analysis.

1 Introduction

During the last two decades, many governments from across the world have used private funding to develop infrastructure.[1] India is no exception. The successive governments at the centre have attempted to tap private funding to develop and extend networks of Roads, Ports, and Airports[2]. Private funding has also become a mainstay of plans of the state governments towards infrastructure development. The private funding is tapped through what are called the Public Private Partnerships (PPPs or P3).

In a typical PPP/P3 for an infrastructure project, the government provides land and is responsible for regulatory clearances for the project. The private partners take responsibility to build the project assets such as roads, railways, ports, airports, etc. Generally, the private partners are required to fund the project upfront, but the government retains the ownership of the assets developed through PPP. Moreover, the private partners are responsible for the upkeep of the assets during operation and maintenance phase of the project. In other words, the tasks of construction and maintenance are bundled together and assigned to one and the same contractor firm. This also means that the control and management rights over the project assets are assigned to the private partner during the terms of the contract. Many a times the private partners are also granted 'concessions' (rights) to charge user-fees. At the end of the contract period, the government reclaims all the rights granted to the contractor.

In contrast, under a traditional contract used for infrastructure projects, the contractor is required only to construct the project facilities; he is not responsible for maintaining it. That is, there is no bundling of the tasks of project construction and its maintenance. The government is responsible for the funding of the project. Maintenance of assets during maintenance is done either by the government or another contractor hired for this specific purpose. In other words, under a traditional contract the government retains all the control and ownership rights over the entire life cycle of the project.

Therefore, compared to the traditional approach, the PPP contracts are fundamentally different from the traditional (non-PPP) contracts, in terms of the responsibility and rights of the private sector towards financing, building, and maintaining of the assets needed for infrastructure services. In this paper, we present a model of project life-cycle. The model is used to make predictions about the outcomes under the different types of contracts.

As to the nomenclature, PPPs can be of several types, namely BOT (build, operate and transfer), DBOT (design, build, operate and transfer), BOOT (build, own, operate and transfer), etc. These forms differ mainly in terms of the decision and control rights delegated to the private investors during the contract period.

The official case for the use of PPPs depends on their perceived economic superiority over the traditional approach, that is, the belief that the PPPs can deliver public goods at relatively low life cycle costs. The policymakers seem to believe that private sector participation through the PPPs will ensure a speedier delivery of infrastructure as it will reduce the life cycle project costs. Moreover, it is believed that the PPPs have the potential to incentivize the private sector to deliver a superior quality infrastructure services. At least

[1]For more on types of PPPs, see Iossa and Martimort (2012), Yescombe (2011), and Grimsey and Lewis (2007).

[2]See Singh (2011)

officially, these beliefs seem to have been the driving force behind the advent and expansion of the PPP programme. For example, the draft of the National Public Private Partnership Policy (NPPPP) clearly states two of these objectives as: "Harness private sector efficiencies in asset creation, maintenance and service delivery; Provide focus on life cycle approach for development of a project, involving asset creation and maintenance over its life cycle;..."[3]

Following Hart et al. (1997) and Hart (2003), a large theoretical literature has come up on the subject PPPs. It shows that the partnership contracts have some merits vis-a-vis the traditional contracts. However, some features of PPPs can make the outcome under them worse than the outcome under the traditional contracts. In sum, depending on the context, either type of contract can be more desirable than the other.[4] Therefore, the following question arises: Is the belief in the superiority of the PPPs justified? There seems to be no empirical study to answer this question.

In this paper, we attempt to address this question and the related issues. In Section 2 we develop a model of project costs, quality and benefits. In Section 3, we compare the potential sources of efficiency of PPP contracts vis-a-vis the traditional contracts. The focus is on comparison of the incentive structure for the contractor under the PPPs vis-a-vis the traditional procurement contracts.

Our empirical analysis is based on a dataset of highways projects in India. The road sector accounts for the largest number of PPPs in the country. Within the road sector, largest number of PPPs are for national highways formed under the National Highway Development Programme. The PPPs for national highways projects have been implemented by a single agency, namely the National Highways Authority of India (NHAI). In fact, the NHAI accounts for the largest number of PPPs executed by any one agency in the country. So, in order to compare the comparables, PPP and the non-PPP road projects implemented by the NHAI is a plausible choice for empirical analysis. We use a dataset of 313 national highways projects to compare performance of the PPPs with the traditionally procured highway projects. The comparison is made in terms of the project costs and quality of roads.

Dataset and summary statistics are described in Section 5. It shows that the construction costs are significantly higher for PPPs than for non-PPPs. In Section 6 we empirically examine the outcomes under PPPs and the traditional contracts, in terms of the construction costs and quality of roads. Section 7 presents concluding remarks, on various possible reasons behind the relatively high construction costs for PPPs. It also discusses the existing empirical literature on the subject.

2 Model

Project Plan and Design. Provisioning of public goods, like road services, requires construction/building of roads. Therefore, procurement of road services starts with procurement of

[3]See National Public Private Partnership Policy, Ministry of Finance, GoI. Also see Page 8 (MCA (2011)).

[4]For the literature on PPPs see Blanden et al. (2016), Jerch et al. (2017), Trebilcock and Rosenstock (2015), Pritchett and Viarengo (2015), Amaral et al. (2018), Villalonga (2000), Iossa and Martimort (2012), Iossa and Martimort (2011), Dewatripont and Legros (2005), Tadelis (2012), Iossa (2015), Danau and Vinella (2015) among others.

road assets.[5] The process starts with what is called 'scoping' of the road project by the government department concerned. The scoping of a project requires specification of the 'output' and 'quality' features that the road assets should possess. For an expressway project, examples of the output features are: number of traffic lanes, number and location of cross-section, by passes, under-passes, over-passes, toll-plazas, major, medium and small bridges, etc. The examples of quality attributes are described in terms of smoothness, durability, load carrying capacity of the road surface along with the safety of designs. Besides, the government department provides estimates of the project costs, called expected costs.[6]

The next step is invitation for the bids and signing of the contract with the successful bidder. The next phase of the project is the construction phase. Once construction gets over, the project enters the operation and maintenance phase ($O\&M$). It is in this phase that the social benefits from the project are realised when road users start using the road project.

Specifically, assume that at $t = 0$, project scope is defined, the cost estimates are made and bids are invited. The bidding is a lengthy two-stage process. Suppose, the successful bidder is selected at $t = 1$ and the contract is signed. Construction phase starts at $t = 1$ itself and ends at $t = 2$. The $O\&M$ phase starts at $t = 2$ and ends at $t = 3$. **Please insert Timeline here.** For simplicity assume the project assets have no value after $t = 3$. Duration of a typical construction phase is 2-3 years. In contrast, $O\&M$ phase is much longer, generally 12-18 years.

The output features described above are 'observable', i.e., any deviation by the contractor from them can be seen by the government. Moreover, they are 'verifiable' in that deviations by the contractor can be proved before a third party, say a court. That is, using language of *contract theory*, the output features are contractible. Similarly, the main features of engineering design of the project are observable and verifiable. So, they can be fully described in contract and can be enforced subsequently. However, during construction the initial design may need changing or modifying if the ground or the underground conditions render the initial design inappropriate.

Under traditional contracts, the engineering design is prepared by the government engineers and provided to the contractor. During construction, if the initial design needs to be changed, the changes are also proposed by the government department; the contract allows government to make mid-way changes. In contrast, under PPPs, the task of designing is delegated to the contractor. The contractor firm can propose, use and even change a design mid-way, subject to the approval by the government department.

Our focus is on the post-contracting phases. Specifically, we examine the nature of interplay between the actions taken in the construction phase and their consequences for the operation-and-maintenance phase. Therefore, we assume away asymmetry of information between the government and the bidders/contractors.

Efforts and Innovations. As mentioned in the Introduction, one of the stated objectives

[5] A procurement contract is between the government and a contractor for construction of the assets needed for the purpose.

[6] It is the government (the buyer) who decides the output features of the assets. It also provides estimates of the work-items and their costs. However, depending on the procurement contract to be used, the detailed designing - that is detailed identification of the work-items and their quantities may be done by the contractor.

of the PPPs is to harness technical and economic efficiency of the private sector by allowing the contractor firms to adopt innovative engineering and construction techniques. We *use incomplete contract* framework to model activities of the contractor firm. Let, x denote the *non-contractible* innovative effort by the construction contractor.

This effort is put after signing of the contract, i.e., during the construction phase. Through this effort, the contractor learns about innovative designs and techniques for reducing the construction costs. Specifically, assume that the innovations emanating from effort x requires observable modifications in the output or the engineering features of the project. For instance, x can also be thought of as the effort in searching for changes in the design or output features that reduce construction costs.

However, the effort itself does not lead to cost savings. The reduction in construction costs materializes only if the cost reducing techniques learnt through the effort are actually implemented. For example, it is not enough to learn about a new and cheaper design. The construction process should actually adopt the new design only then the cost savings will be realized. Let, $c_1(x)$ be the cost saving if innovations learned through effort x are executed. Let, $c_1(0) = 0$, and $\frac{dc_1(x)}{dx} > 0$, & $\frac{d^2c_1(x)}{dx^2} < 0$.

Unlike the output and engineering features, the quality of construction are not contractible in that the deviations from the specified quality standards are not observable. Highways have several layers underneath the top surface layer. The durability and smoothness of the top layer in the long run depends on how carefully the underneath layers were laid and also the quality of material used in them. However, what is visible is the top layer. At date $t = 2$, looking at a newly built highway, it is not easy to tell what will its quality be after 5 or 10 years. The poor quality of road manifests itself in terms of potholes and bumpy and cracked surface during $O\&M$ phase, after several years of construction. Moreover, presence of corruption can render even the observable aspects of the quality as non-verifiable.

A contingent contract is also not helpful in addressing the issue. A contingent contract can make payment to the builder contractor contingent on whether the road remains good even after 5 or 10 years. However, enforcement of such a contract is far from easy. During the $O\&M$ phase, the road condition depends not only on quality of construction but also frequency and quality of the maintenance/repair works done after construction get overs. This means that builder contractor and those responsible for maintenance can blame each other for the bad condition of the road. Hence, it is very difficult to identify and penalize the party at fault.

We model the quality and cost reducing activity as another non-contractible effort y put by the contractor during construction phase. In contrast to effort x, the cost reducing ideas arising on account of y do not require observable changes in the output or engineering features of the road project. We can think of y as ways to dilute quality of construction that can go undetected. For example, the use of inferior inputs for the underground layers of the road, sub-optimum mix of concrete and cement, etc. These ideas can be implemented within the letter of contract. So, the contractor does not need permission of the government to implement these ideas. This also means that the benefits from effort y can be enjoyed by the contractor fully. Let, $c_2(y)$ denote the saving in construction cost from effort y; $c_2(0) = 0$, and $\frac{dc_2(y)}{dy} > 0$, & $\frac{d^2c_2(y)}{dy^2} < 0$.

To sum up, effort x captures those acts that reduce construction costs without diluting the quality of construction. Effort y is an index of activities that reduce costs at the expense of quality. A higher level of x [resp. y] means a larger number of cost-reducing-quality-neutral [resp. cost-and-quality-reducing] activities. Our modeling approach towards the efforts and innovations is similar to the one take by the relevant literature.[7]

Costs, Quality and Benefits. The total *actual construction* costs depend on the cost of inputs used (construction material, machine and labour, etc), along with the levels of the above efforts x and y put by the contractor. Let us write the actual construction costs, C^a, as

$$C^a(x, y) = c_0^a - c_1(x) - c_2(y),$$

where c_0^a is the actual construction cost of inputs such as material, labour, capital, etc., in the absence of efforts x and y.

Next we turn to the quality of construction. Let, q denote the quality of construction. Remember, effort x reduces construction costs without diluting the quality of construction. In contrast, y reduces costs as well as quality of the road. Formally,

$$\frac{dq(x)}{dx} = 0 \ \& \ \frac{dq(y)}{dy} < 0. \tag{1}$$

Therefore, we can simply write q as a function of y only; $q = q(y)$. In principle, one can think of quality improving counterparts of the efforts x and y. Such efforts will essentially be flip side of the efforts modeled by us. In any case, modeling of such efforts will not make qualitative changes to our claims about the incentives and outcomes under various contracts discussed in the next section.

As explained above, q is not contractible and becomes known only during the $O\&M$ phase. This means the quality shading effort y put in during the construction phase have bearing on quality of road which is observed in the next phase. That is y has across-the-phase externality for cost and benefits from the project. Let, M denote the operation and maintenance (repair) costs of the project, and B denote the Social Benefit from the road. M is incurred during the $O\&M$ phase, during dates $t = 2$ and $t = 3$. Similarly, B accrues in the $O\&M$ phase. It is plausible to assume that M is a decreasing function of the quality of construction, whereas B increases with the quality. In view of (1), M and B do not depend on x. While M increases with y, B decreases with y. Formally,

$$\frac{dB(y)}{dy} < 0 \ \& \ \frac{dM(y)}{dy} > 0.$$

Now, the net social benefit can be written as: $B(y) - M(y) - [c_0^a - c_1(x) - c_2(y)] - [x + y]$. Therefore, the social optimization problem is:

$$\max_{x,y} \{B(y) - M(y) - c_0^a + c_1(x) + c_2(y) - x - y\}. \tag{2}$$

[7] See, e.g., Hart et al. (1997), Bajari and Tadelis (2001), Hart (2003), Besley et al. (2001), Bajari et al. (2014), Besley and Malcomson (2018), Hart (2017), Bennett and Iossa (2006a), Müller and Schmitz (2016), Chen and Chiu (2010), Hoppe and Schmitz (2013), De Silva et al. (2017) among others.

We assume that all optimization problems are concave. For the above optimization problem, the necessary and sufficient first order conditions are:

$$\frac{dc_1(x)}{dx} \leq 1; \tag{3}$$

$$\frac{dB(y)}{dy} + \frac{dc_2(y)}{dy} - \frac{dM(y)}{dy} \leq 1. \tag{4}$$

Let x^*, y^* solve these equations, respectively and simultaneously. We assume $x^* > 0$. However, $y^* = 0$, i.e., the gains from quality reducing effort y are more than offset by the social costs in terms of increased maintenance costs and reduced benefits. Let, q^* denote the socially optimum level of quality, i.e., $q^* = q(y^*)$.

Finally, following the literature, we assume that $c_1(.)$, $c_2(.)$, $q(.)$, $M(.)$ and $B(.)$ all are part of common knowledge but are non-contractible.[8] There is no discounting.

3 Contract and Incentives

A source of efficiency behind PPP is the potential relative efficiency of the private sector. Unlike government departments, private firms have greater contractual options available to them. For example, a private firm can promise a contractor to award future works, if he delivers good quality of the existing works. However, a government department cannot make such promise as the future contracts will also be awarded through competitive bidding. As a result, compared to traditional government funded infrastructure projects, instances as well as magnitudes of project delivery time and total project costs can be reduced with suitable private sector participation.

The main source of efficiency is an appropriate bundling of responsibilities for the contractor firm. In contrast, under a PPP contract, the contractor firm is required not only to construct the project facilities but also to maintain it during the O&M phase. In other words, the tasks of construction and maintenance are bundled together and assigned to one and the same firm.

PPPs vs. Traditional Highways Contracts As mentioned earlier, our empirical analysis focuses on the national highways projects implemented by the NHAI, the government body responsible for building and expanding the network of (interstate) highways in the country. The NHAI has been using PPPs and traditional contracts to build the highway projects as a part of the National Highways Development Programme. As far as the PPP contracts used on the National Highways are concerned, there are three types of PPPs - BOT Toll, BOT-Annuity and Special Purpose Vehicles (SPVs). The PPP contracts differ in terms of the duration and the commercial risks borne by the contractor. As the names indicate, while a BOT Toll contract entitles the contractor to charge toll from road users, the BOT-Annuity and SPV contracts do not. Under BOT-Annuity contracts, the contractor receives contractually agreed biannual payment from the government. Under the SPVs, the ‘contractor’ also

[8]For the relevant literature making similar assumptions see Bennett and Iossa (2009), Hart (2017), Bergman et al. (2016), Albalate et al. (2017), Schmitz (2013), Iossa and Spagnoloõ (2010), Bester and Krähmer (2012), Bajari and Lewis (2011) among others.

happens to be the main user of the service. For example, a port trust can form SPV in partnership with the NHAI and the state government to improve its connectivity by building a road. In that case, the port trust will invest in building and maintenance of the project to get the right to use the road.

The non-PPP projects, on the other hand, are implemented by using what are called the 'traditional' non-PPP (NP) contracts'. These contracts are popularly known as 'cash contracts'. Under an NP, the contractor is responsible only for construction of project assets or facilities; maintenance of the facility is not his responsibility. Therefore, the contractual relation between the parties ends with the construction phase, i.e., at $t = 2$.

All types of partnerships possess the following common features: One, the tasks of construction of project facility and its maintenance are performed by the same contractor (or the same consortium of contractors); Two, most of the construction-related risks and all of the maintenance risks are borne by the contractor; Three, the project designing, building, financing, and its operation and maintenance are the responsibilities of the contractor. That is, PPP are based on the Design, Build, Finance, Operate and Maintain (DBFO&M) contracts.

Delegation of Decision Rights. As mentioned above, a PPP contract specifies only the output features. Most of the engineering and technological decisions related to 'how to build' the project assets are delegated to the contractor firm.[9] The idea is to harness the innovativeness and efficiency of the private sector. For instance, most of the technological decisions are taken by the contractor without much interference from the government. Moreover, he gets to choose engineering details and make the midway changes in them though under the oversight of the government.

In contrast, under a traditional contract, the output as well as most of the engineering and technological decisions are taken by the government. For example, the government engineers prepare the project designs which cannot be altered by the contractor.

To sum up, compared to traditional contract, a PPP contract delegates much more decision-making power to the contractor.

Let, α denotes the degree of decision rights delegated to the contractor; $0 \leq \alpha \leq 1$.[10]

The degree of delegation has bearing on the benefit enjoyed by the contractor from innovative ideas due to effort x. Since implementation of these ideas requires the observable changes in the output and engineering features, any unauthorized change will be detected and can be punished. In the absence of decision making power, implementation of an innovation would require the contractor to seek government's permission. In that case, he might have to share some of the benefits with the government. However, if the contract empowers the contractor to decide on engineering features, he can capture the full benefit from x by implementing the desired innovations without needing consent of the government. In general, the greater is the delegation of decision making powers, the larger will be the benefits enjoyed by the contractor from x.

Total cost saving benefits due to effort x is $c_1(x)$. The savings in the construction costs actually enjoyed by the contractor will be proportional to α. To keep things simple, let this

[9] For details see Williamson (2017), Bennett and Iossa (2006b), Iossa and Martimort (2009), Martimort and Pouyet (2008), Iossa and Martimort (2015), Benitez (2009) among others.

[10] $\alpha = 1$ means the contractor has authority to take all the decisions at will.

amount be $\alpha c_1(x)$. Of course, α will vary across contracts.

Let α^{NP}, α^{PP} denote the degree of delegation under traditional and PPP contract respectively. In view of the above, $\alpha^{NP} < \alpha^{PP} \leq 1$. Therefore, for given level of effort x, the gains enjoyed by the contractor are higher under PPP compared to the traditional contracts used for non-PPP project. For simplicity we have taken the degree of delegation to be the same under toll and non-toll PPPs.[11]

Recall, implementation of ideas arising from effort y can be done within the letter of contract, as it does not require any observable changes. This means that the contractor can realize full benefits from the effort regardless of the powers delegated to him.

3.1 Traditional Contracts

Duration of a traditional contract is just the construction phase, i.e., the period between dates $t = 1$ and $t = 2$. The contractor is paid for the construction works done by him at rates fixed by the contract signed at $t = 1$. Let,

P^{NP} denote the fixed payment received by the traditional non-PPP (NP) contractor.

For our purpose, a traditional contract is essentially a fixed-price contract; the payment received by the contractor is not contingent on the actual values of construction costs. Therefore, under a traditional non-PPP (NP) contract, the contractor solves:

$$\max_{x,y} \left\{ P^{NP} - [c_0^a - \alpha^{NP} c_1(x) - c_2(y) + x + y] \right\}.$$

That is, the NP contractor chooses effort levels to minimize the total construction cost, in total disregard for $O\&M$ costs and the social benefits. His effort choice, (x^{NP}, y^{NP}) solves the following first order conditions:

$$\alpha^{NP} \frac{dc_1(x)}{dx} \leq 1; \;\; \& \;\; \frac{dc_2(y)}{dy} \leq 1. \tag{5}$$

Recall $\alpha^{NP} \leq 1$. Therefore, $x^{NP} \leq x^*$. Also $y^{NP} \geq y^*$. Assume that at $y = 0$, $\frac{dc_2(y)}{dy} > 1$, therefore, $y^{NP} > 0$.

3.2 Annuity PPPs

Let P^{AP} denote the price/payment received by the annuity PPP contractor. Under an annuity PPP contract, the contractor receives contractually agreed biannual payment from the government. In particular, even though the contractor is required to bear construction and maintenance costs, but the payments received by him are not contingent on the actual values of these costs. Therefore, an annuity contract is a fixed-price contract. So, the contractor solves:

$$\max_{x,y} \{ P^{AP} - [M(y) + c_0^a - \alpha^{PP} c_1(x) - c_2(y) + x + y]$$

[11] In some respects, e.g., collection of user-fee, the degree of delegation is higher under toll-PPPs than annuity PPPs. However, the distinction won't change the nature of our results. So, to keep things simple we ignore this distinction.

where $0 \leq \alpha^{PP} \leq 1$ is as defined above. The contractor's choice of efforts solves the following first order conditions:

$$\alpha^{PP}\frac{dc_1(x)}{dx} \leq 1 \tag{6}$$

$$-\frac{dM(y)}{dy} + \frac{dc_2(y)}{dy} \leq 1. \tag{7}$$

Let the solution be (x^{AP}, y^{NP}). It is easy to see that $x^{AP} \leq x^*$ and $y^* \leq y^{AP} < y^{NP}$. It is plausible to assume that marginal effects of y give $y^* < y^{AP}$.

3.3 Toll PPPs

As the name indicates, under a toll PPP, the contract entitles the contractor to charge toll-fee from road users. Let P^{TP} denote the expected value of total fee to be received by the toll contractor. It is plausible to assume that a better road quality helps toll contractor by attracting more traffic to the project thereby raising the revenue. That is, P^{TP} is decreasing in the quality shading effort y. Moreover, a contractor can capture only a fraction of the total benefits from the road project. Therefore, let $P^{TP} = \gamma B(y)$, $0 < \gamma < 1$. A toll PPP contractor will solve:

$$\max_{x,y}\{\gamma B(y) - [M(y) + c_0^a - \alpha^{PP}c_1(x) - c_2(y) + x + y]\}.$$

The first order conditions are:

$$\alpha^{PP}\frac{dc_1(x)}{dx} \leq 1 \tag{8}$$

$$\gamma\frac{dB(y)}{dy} - \frac{dM(y)}{dy} + \frac{dc_2(y)}{dy} \leq 1. \tag{9}$$

Comparing (8) and (9) with first order conditions (3) and (4), respectively, it is easy to see that $x^{TP} \leq x^*$ and $y^* < y^{TP}$. Summing up, we get the following relationship among the effort choices under different contracts:

$$\begin{array}{ll} x^{NP} \leq x^{TP} = x^{AP} \leq x^* & ; \text{and} \\ 0 = y^* \leq y^{TP} < y^{AP} < y^{NP} & . \end{array} \tag{10}$$

3.4 Costs and Quality Comparisons

In view of (10) it is clear that none of the contracts achieves the first best in terms of effort choices made by the contractor. In the following we focus on predicting the quality and construction costs under the different types of contracts, since our empirical analysis will be based on comparisons of quality and construction cost across the three types of contracts.

Quality. Since effort choices vary across contracts, therefore the quality of construction also varies across the contracts. Let q^{NP}, q^{AP}, q^{TP} denote the quality level under contract non-PPP, annuity PPP and toll PPP, respectively. In view of $q_x \geq 0$, $q_y < 0$ and (10) the following claim is immediate.

Proposition 1 $q^{NP} < q^{AP} < q^{TP} < q^*$.

where $q^* = q(x^*, y^*)$ stands for quality level corresponding to the first best effort levels x^* and y^*. That is, none of the contract achieves the first best quality level. However, both types of PPP roads are better in quality than the non-PPP roads. The quality of road is highest under toll contracts and lowest under traditional contracts.

Construction Costs. Comparison of construction cost is not obvious. From (10) we can see that $y^{TP} < y^{AP} < y^{NP}$. That is, the level of the cost and quality reducing effort is highest under traditional contract and is lowest under toll-PPP. On this count the construction cost should be highest under a toll-PPP followed by annuity-PPP and traditional contract in that order. However, the level of the other cost reducing effort, x, is higher under PPP contracts than the non-PPP contract, since $x^{NP} \leq x^{TP} = x^{AP}$. On this count, the construction costs are lower for PPPs than the traditional non-PPP contract. Therefore, in principle, the construction costs can be higher for either type of contracts.

However, we can make precise prediction for the two types of PPPs. Since $\alpha^{AP} = \alpha^{PP}$, we have $x^{AP} = x^{TP}$. However, the cost reducing effort is higher for annuity than under toll contract. Therefore, we get the following result.

Proposition 2 *The construction costs are higher under a toll-PPP than under an annuity-PPP.*

In other words, for any given project the construction costs will be higher if the project is implemented through a toll-PPP contract rather than if the project is developed using an annuity-PPP contract.

In fact, we can make the following conditional claim about PPPs versus non-PPPs.

Proposition 3 *If $\alpha^{NP} = \alpha^{PP}$, construction costs are highest under the toll-PPP, medium under the annuity PPP contract and minimum under the traditional contract.*

The proposition says that if the delegation of decision making powers is the same for non-PPP and PPP, then the construction costs will be higher if a project is implemented as PPP (either toll-PPP or annuity PPP) than the level of costs if the project is developed using the traditional non-PPP contract. The proof follows from the fact that when $\alpha^{NP} = \alpha^{PP}$, we get $x^{NP} = x^{PP}$. However, $y^{TP} < y^{AP} < y^{NP}$.

3.5 Construction Cost Ratio

As discussed earlier, at date $t = 0$ there is uncertainty about the actual construction costs. However, the project planners put in efforts to get estimates of the construction costs from the estimated values of quantities of the engineering work-items for the project along with their per-unit costs. For several reasons, the actual cost typically turns out to be different from the estimated costs.[12] Formally put, at date $t = 0$, the construction costs c_0^a and C^a, as described above, are random variables. Let,

c_0^e denote the estimated value of c_0^a.

In view of the uncertainty about the quantities and costs of work items, relationship between c_0^e and c_0^a is stochastic. Assume that c_0^e is unbiased estimate of c_0^a. While c_0^e is

[12] See Singh (2010) and Singh (2011) for details.

assessed at date $t = 0$, the actual costs c_0^a become known at the end of construction on date $t = 2$. Specifically,

$$c_0^a = c_0^e + \epsilon^c \tag{11}$$

where $\epsilon^c \sim N(0, \sigma^c)$. Given our specification of C^a, we can write it as $C^a(x, y) = c_0^a - \kappa(x, y)$, where $\kappa(x, y) = c_1(x) + c_2(y)$. Now, one can easily derive C^e, the *estimated construction* costs from c_0^e. Suppose, x^e and y^e are levels of efforts assumed while estimating the cost at date $t = 0$, then $C^e(x^e, y^e) = c_0^e - \kappa(x^e, y^e)$, where $\kappa^e = \kappa(x^e, y^e)$. Moreover, $C^a(x^e, y^e)$, i.e., the actual costs conditional on effort levels (x^e, y^e), can be expressed as $C^a(x^e, y^e) = c_0^e - \kappa(x^e, y^e) + \epsilon^c$.

For a project, we define the construction cost ratio as:

$$CO = \frac{C^a}{C^e} = \frac{\textit{Actual construction costs}}{\textit{Expected construction costs}}.$$

For given $C^e = C^e(x^e, y^e)$, let,

$$\left(\frac{C^a}{C^e}\right)^{TP} = \frac{C^a\left(x^{TP}, y^{TP}\right)}{C^e(x^e, y^e)},$$

which is the actual construction costs realized at date $t = 2$ under a toll-PPP divided by the given estimated construction costs assessed at date $t = 0$. Similarly, we define

$$\left(\frac{C^a}{C^e}\right)^{AP} = \frac{C^a\left(x^{AP}, y^{AP}\right)}{C^e(x^e, y^e)} \;\&\; \left(\frac{C^a}{C^e}\right)^{NP} = \frac{C^a\left(x^{NP}, y^{NP}\right)}{C^e(x^e, y^e)}.$$

Keeping in mind our timeline where contract is awarded at date $t = 1$, i.e., after C^e is assessed, we can make the following claim.

Proposition 4 *For a project with any given cost estimates, C^e:*
(i) $E\left(\frac{C^a}{C^e}\right)^{TP} > E\left(\frac{C^a}{C^e}\right)^{AP}$
(ii) $\alpha^{NP} = \alpha^{PP} \Rightarrow [E\left(\frac{C^a}{C^e}\right)^{TP} > E\left(\frac{C^a}{C^e}\right)^{AP} > E\left(\frac{C^a}{C^e}\right)^{NP}]$.

Simply put, the proposition says that for any project with given expected costs derived at $t = 0$, the construction costs ratio will be higher if the project is implemented through a toll-PPP contract rather than if the project is developed using an annuity-PPP contract. Moreover, if the delegation of decision making powers is the same for non-PPP and PPP, construction costs ratio will be highest under the toll-PPP, medium under the annuity PPP contract and minimum under the traditional contract.

For a proof of (i) note that $C^a\left(x^{TP}, y^{TP}\right) > C^a\left(x^{AP}, y^{AP}\right)$. Moreover, for any given level of efforts, (x, y), we can express $C^a(x, y)$ in terms of the expected costs $C^e(x^e, y^e)$ and the error terms:

$$C^a(x, y) = C^e + \kappa(x^e, y^e) - \kappa(x, y) + \epsilon^c,$$

where ϵ^c is the error terms described in (11) above. Clearly, from the perspective of date $t = 0$, $E(C^a(x, y)) = C^e + \kappa(x^e, y^e) - \kappa(x, y)$. Now, it can be seen that $E(C^a\left(x^{TP}, y^{TP}\right)) > E(C^a\left(x^{AP}, y^{AP}\right))$ So, for any given cost estimates, C^e, $E\left(\frac{C^a}{C^e}\right)^{TP} > E\left(\frac{C^a}{C^e}\right)^{AP}$. Proof of (ii) follows from a similar reasoning in view of the fact that when $\alpha^{NP} = \alpha^{PP}$, the following holds: $C^a\left(x^{TP}, y^{TP}\right) > C^a\left(x^{AP}, y^{AP}\right) >> C^a\left(x^{NP}, y^{NP}\right)$.

Suppose, in an hypothetical empirical context, data shows that $\left(\frac{C^a}{C^e}\right)^{PP} > \left(\frac{C^a}{C^e}\right)^{NP}$. This would mean that the effect of the quality reducing effort y dominates over the effect of quality neutral effort x. Moreover, the actual difference in the construction cost ratio for the PPP and non-PPP on account of y is greater than what can be seen from the data - since the data shows the combined effect of x as well as y.

4 Bidding, Contracting and the PPP Policy

Once the government decides to develop a highway project, the NHAI decides on the main features of the project such as the number of traffic lanes, under and overpasses, etc. Thereafter the authority commissions a project feasibility report. It hires a private firm for the purpose through competitive bidding. The selected firm prepares the project feasibility report which provides estimate of engineering works needed to be performed for the project concerned, the estimates of construction time and costs. The report also provides estimates of traffic. As mentioned above, at date $t = 0$ the project planners put in efforts to get estimates of the construction costs. In addition, at date $t = 0$, the project sponsoring department also get estimates of M, R and hence π, where $\pi^a = R^a - C^a - M^a$ is the expected profit from the project. The actual value of M, R and the profit π become known only when the project completes its life-cycle. Let the relation between the expected and actual values be as follows:

$$M_0^a = M_0^e + \epsilon^m; \quad R_0^a = R_0^e + \epsilon^r; \ \& \ \pi^a = \pi^e + \epsilon^\pi$$

where $\epsilon^m \sim N(0, \sigma^m)$, $\epsilon^r \sim N(0, \sigma^r)$ and $\epsilon^\pi \sim N(0, \sigma^\pi)$. Note that the error terms ϵ^c (from expression (11)) and ϵ^π might be correlated.

The next step is to invite bids. With the estimates of C, M, R and the profit π, the NHAI takes the project to investors. If the project attracts private investment, it becomes PPP.

The 2005 Policy: Between 1997 and 2005 the government had offered to investors projects that seemed viable based the estimates of costs and traffic revenue. However, there was no clearly laid down legal and contractual framework in place to govern the PPP programme. In 2005, the government at the Centre decided to give a big thrust to PPPs. Accordingly, it was decided to give full thrust to the PPP programme by providing a comprehensive regulatory and contractual framework. The following excerpt from a decision by the Government of India amply illustrates the importance assigned to the PPPs and also the above mentioned official belief in superiority of PPPs:

"... it was agreed that for ensuring provision of better road services i.e. higher quality of construction and maintenance of roads and completion of projects without cost and time overrun, contracts based on BOT model are inherently superior to the traditional EPC contracts....Accordingly, it was decided that for NHDP Phase-III onwards, all contracts for provisions of road services would be awarded only on BOT basis..."[13]

[13]This is an excerpt of a decision taken in a meeting held in March 2005 and chaired by the then Prime Minister, regarding financing of the National Highways Development Project (NHDP). See GOI (2006).

Pursuant to this decision in 2005, the government launched several initiatives in order to attract private investment through PPPs. The steps included standardization of Bidding and Concession Documents and preparation of Model Concession Agreement (MCA), a standard contract document governing PPPs. To facilitate private investment, India Infrastructure Finance Company Limited (IIFCL) was set up. Beside, provision was made for the 'Viability Gap Funding' (VGF). Since not all projects are commercially viable, the government has made provisions for subsidizing commercially un-viable projects through the VGF, which is a capital grant for toll PPPs. The VGF is one-time up front grant decided at the time of signing of the contract.

The institutional structure to govern the scheme has been in place since August 2005. Since then most projects have been offered to investors, except those for which the estimated traffic was rather low. If there were no takers for a project on toll basis, it was offered on annuity basis. If a project did not succeed as PPP - neither as toll nor as annuity PPP - public funding was provided.

The bidding and contracting process takes about six months, and a project starts only after the contract has been signed. Therefore, we take that projects starting in and after January 2006 have been processed under the 2005 PPP policy. In the empirical analysis we will use Startyear Dummy which takes value 1 for projects that started in or after January 2006.

Contracting. The duration of non-PPP contracts is just the construction phase, i.e., 2-3 years. However, contract period for annuity PPPs is 12 years. For toll contracts, it is generally between 12-18 years. The contract period is decided before inviting the bid. It is also worth mentioning that the toll rates and the revision rules are based on a uniform and publicly known criterion. These rules are the same for the entire country, regardless of whether project is PPP or not - government also charges toll for many non-PPP projects.

For PPPs, the bidders are required to submit one-dimensional bid. For toll PPPs, the bid is the amount of money the contractor wants from the government to design, build and maintain road with pre-specified output features. This amount is in addition to the toll revenue expected by the bidder during the operational phase of the project at hand.

For lucrative (high traffic) projects, the bids can be negative. A negative bid means that in order to get the right to charge toll, the bidder is willing to pay money to the government in addition to taking responsibility for incurring cost of project design, construction and maintenance. For less attractive projects, bidders don't expect full recovery cost from toll. For such projects they submit positive bids. That is, in addition to the right to charge toll, the bidders demand money from the government. Lowest bidder wins the project. In policy documents, the positive bid for toll PPPs is known as Viability Gap Funding (VGF). That is, the VGF is the bid-amount or the *asking price* submitted by the bidders. The upper limit for VGF is either 40% of the expected project costs as defined above.[14]

Under annuity-PPP, the contractor is paid biannual annuity by the government - he cannot charge toll. Therefore, the bid is the annuity that the bidder is willing to accept to carryout project design, construction and maintenance tasks with pre-specified output features. Lowest bid wins the contract. There is no provision of VGF in these PPPs.

[14]Strictly speaking VGF can be utmost 40% of the expected project costs the cost in the financial agreement between the investors and their banks, whichever is less. The value of the latter is always higher.

Table 1: Category-wise Number of Projects

Project Category	Number of Projects
Toll-PPP	66
Non-toll-PPP	38
PPP (toll + non-toll)	104
Non-PPP	209
All projects (PPP + non-PPP)	313

When a project does not succeed as PPP and public funding is to be provided, the contract is signed with the bidder who submits lowest bid (asking price) for works mentioned in the design and scope of the project. The engineering design is prepared by the government.

5 Empirical Analysis

5.1 Data

Our dataset consists of all the highways projects started and completed during December 1997 and August 2015 under the supervision of the NHAI. During this period, a total of 313 national highway projects started and completed under the aegis of NHAI[15]. See Table 1.

The start date of these projects falls in the period December 1997- August 2012. Out of the 313 fully completed projects, the information needed for the empirical analysis was missing for 6 toll PPPs and 3 non-toll PPPs.

Figure 1 gives the year-wise number of PPP and non-PPP projects in our dataset which is sourced from NHAI. The first project was completed in February 2000 and the last one was in August 2015. Figure 2 gives the year-wise number of projects completed in this period for each category.

As is apparent from the graphs, the most of PPPs have come up after 2005 in response to the 2005-Policy, whereas the projects started and completed during late 1990s and early 2000s were mostly non-PPPs.

Below, we undertake two complementary analysis to show that quality of the PPP roads is better than the non-PPPs. First we examine the data on direct measure quality of highways. Later we examine the construction cost data to show that there is quality investment in the PPPs during the construction phase of the project.

5.2 Quality measured as road roughness

Proposition 1 lead us to the following hypothesis.

Hypothesis 1 *Quality of PPP roads is better than the non-PPPs.*

[15]During this period a total of 376 national highway projects were completed. The NHAI does not provide data for 60 odd projects most of which were implemented by the Ministry of Road Transport and Highways.

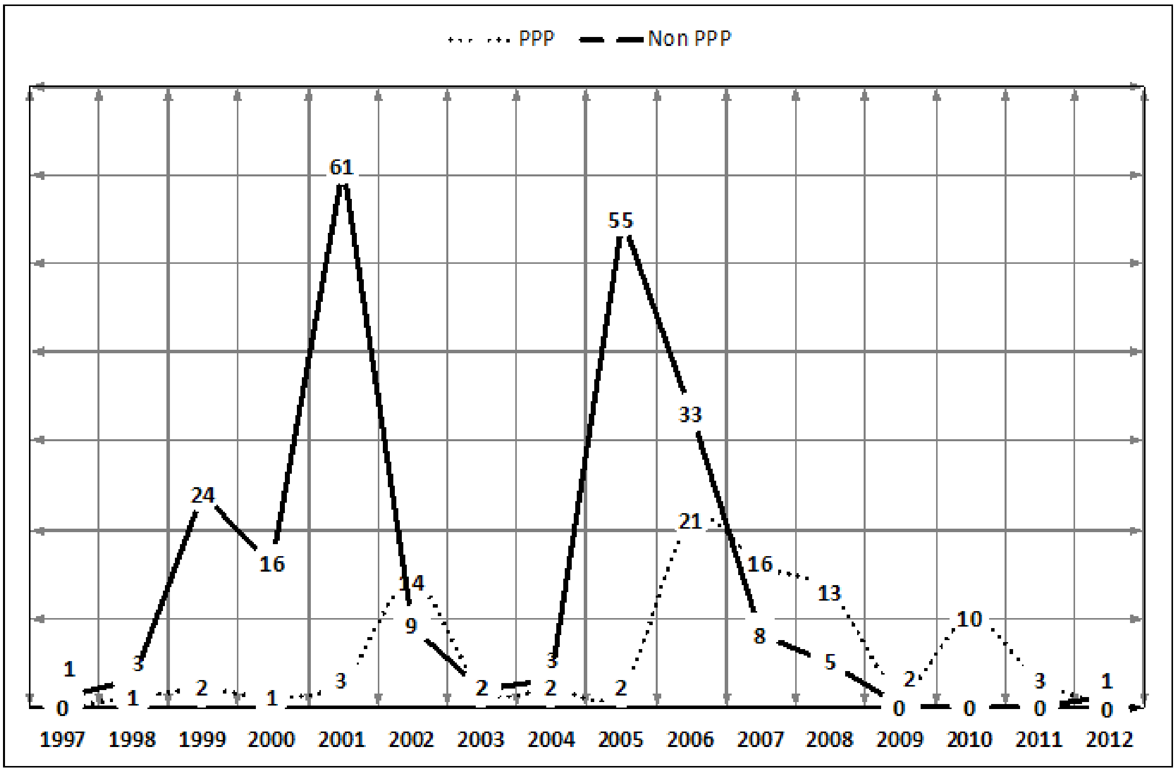


Figure 1: Year-wise number of PPPs and non-PPPs projects started during 1997 - 2012

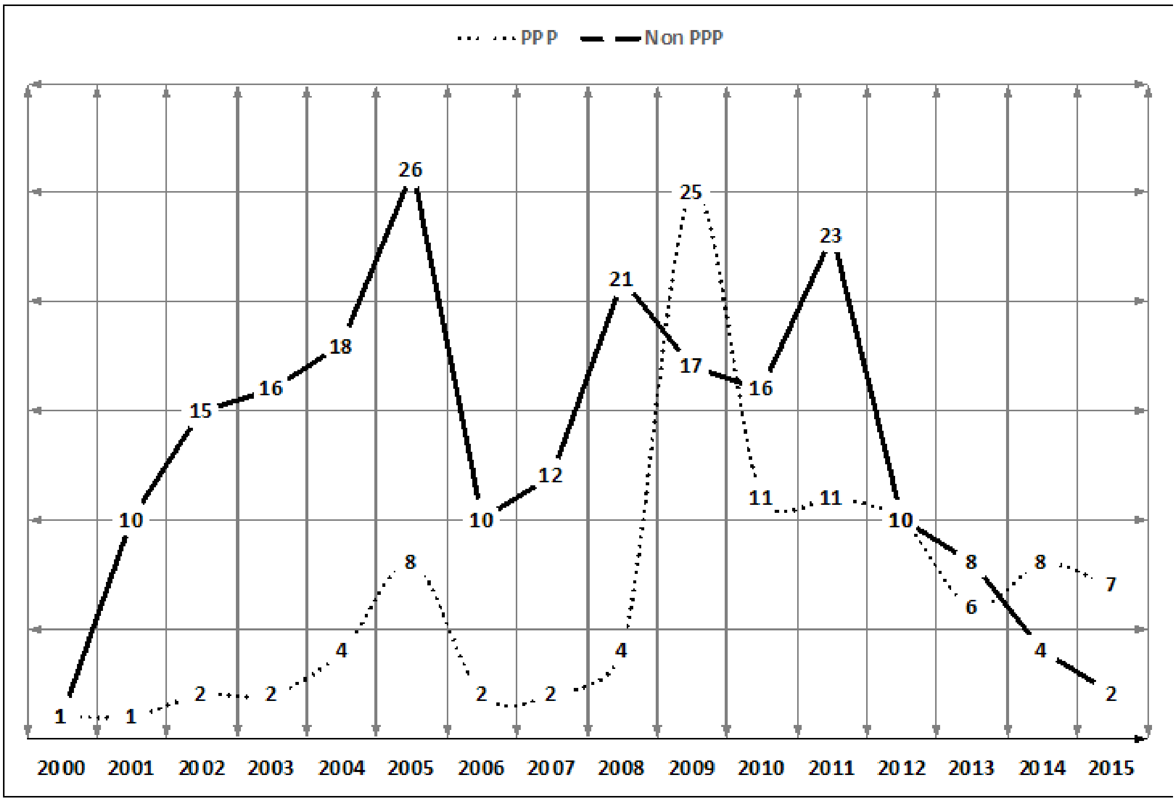


Figure 2: Year-wise number of PPPs and non-PPPs projects completed during 2000- 2015

Technique We test the hypothesis using an engineering measure of road quality. The measure used is called International Roughness Index (IRI). It is a widely used engineering measure of the roughness and quality of roads. The index takes the vibrations experienced by a vehicle as proxy for road roughness. The roughness depends on the extent of pot-holes, road-profile (bumps) and the unraveling of bitumen, which, in turn, depend on the quality of construction. The literature on road engineering establishes a direct link between quality on construction and the road roughness. The greater is the roughness, the poorer is the quality.[16] Roughness affects the level of wear and tear caused to the vehicles.

Data on road roughness has been collected using an *App* called **'Roadroid'**.[17] It is an android App developed by its developers in collaboration with the Automobile Association of Sweden. It uses the 'accelerometer' built-in Samsung smart-phone to measure road roughness.

For the purpose of data collection, the App-installed Samsung smart phones were mounted on the Car. The vibration received by the vehicle are collected as data by the App. The App portal is used to convert the data into the IRI. The IRI figures are reported as averages for every 20 meter of the surface covered.

The developers have compared the performance of the App with the *Laser Profiler* which is the most comprehensive engineering measure of the quality of road. They found that Roadroid data achieves satisfactory accuracy.[18] Besides, the app has been examined and found to be suitable for measuring road quality by several studies.[19]

Empirical Strategy. A National Highway (an inter-state road) is divided into many stretches. A stretch is a road segment connecting two major cities on the highway. Each stretch is taken up as an independent road project, i.e., construction cost estimates and bidding and contracting are done separately for each stretch. Some stretches have been developed as PPP; while others have been built as non-PPP roads.

Our empirical strategy essentially exploits the fact that on a given highway there are many instances where PPP stretches are interspersed with non-PPP roads. In other words, road projects built under different types of contracts are located adjacent to one another. Of course, in many cases the adjacent projects are of the same type; in some cases both are PPPs, in others they are both built using traditional contracts.

This suggests a plausible way to measure the impact of choice of contract type on road quality. Taking an approach similar to examination of 'matched differences', we focus on a comparison of roughness 'near the boundaries' of adjacent projects located on the same highway but built using different contract types.

Accordingly, our empirical strategy focuses on the comparison of the quality of roads close to the intersection of two adjacent road projects. For illustration, on a highway consider a point where two projects meet. Suppose one of these two neighbouring segments is PPP and the other is non-PPP. Specifically, consider three points on a highway; A, B and C. Suppose B is the boundary point of two projects. Let A and C be on either side of B. So, there is a

[16]For literature review see González et al. (2008) and Du et al. (2016).

[17]The World-bank has also developed a similar App. For the study Roadroid is used since its developers have generously provided free access to it.

[18]The app generated IRI has high coefficient of correlation (0.77 or more) with IRI generated by data using the laser profiler.

[19]For details see Du et al. (2016) and Myles Johnston. "Using cell-phones to monitor road roughness", University of Auckland, Auckland, New Zealand, 2013

switch in contract types across the two sides of the boundary; say $A-B$ is PPP, but $B-C$ is non-PPP. We compare roughness of segment $A-B$ with segment $B-C$, by choosing points A and C close to (say within 2 kms) from B.

The accompanying plots show roughness levels for the two sides of a boundary. One side is a PPP road while the other side is an adjacent non-PPP road. Both of these road projects are located on National Highway 10, and are of comparable age - each is more than six years old. Plot 'NH10 PPP Side 1' shows roughness on journey from point A to B; and Plot 'NH10 non-PPP Side 1' shows journey from point B to C, B is the boundary point for two of the projects. Each plot is for a 2 kms stretch.

Further, a road has two sides separated by the divider. In the plots, we compare one side of a PPP with the corresponding side of the adjacent non-PPP. The roughness measures for the other side are shown as Plot 'NH10 PPP Side 2' for journey from point B to A and Plot 'NH10 non-PPP Side 2' for journey from point C to B.

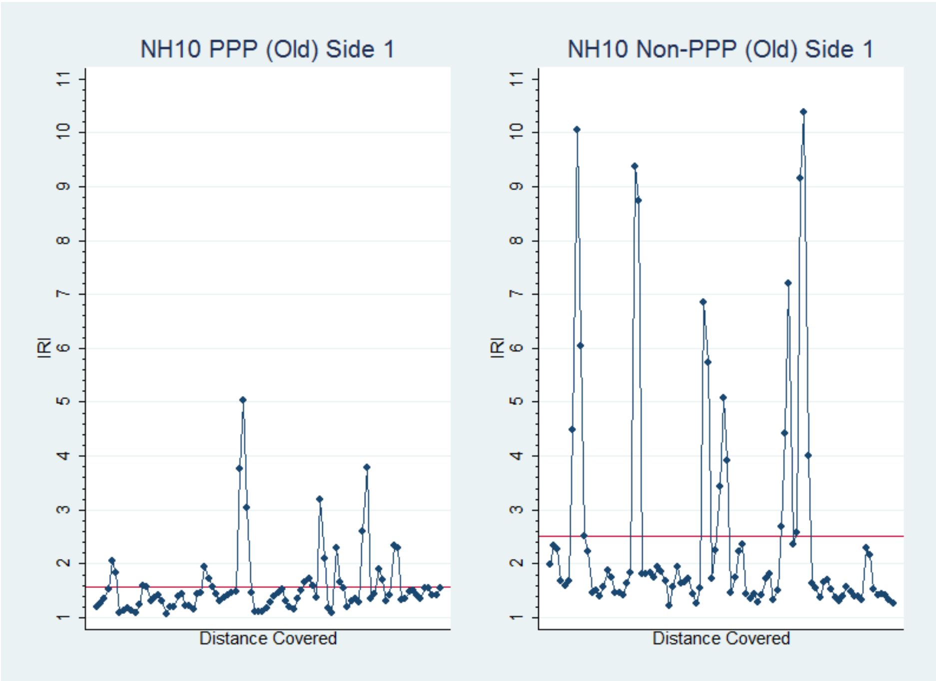
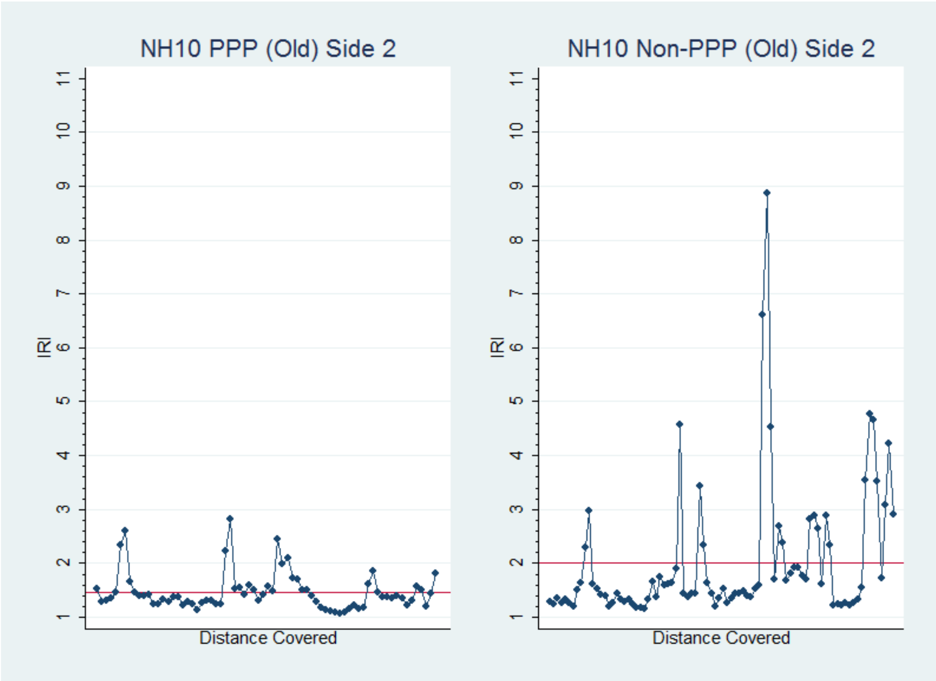


Table 2: Roughness Index-Summary Statistics

Project Type	Average	Min	Max	Standard Deviation
PPP	1.66	1.19	2.94	0.42
Non-PPP	2.41	1.42	3.64	0.61
All	1.96	1.19	3.64	0.62



These plots show that the compared to PPP, the non-PPP neighbour has a significantly higher level of average roughness as well as much larger variance.

Data. The dataset on roughness consists of 84 highways projects from five states of India - Haryana, Punjab, Rajasthan, UP and Tamil Nadu. Given the paucity of funds, the exercise could be carried out only for a limited number of project intersections. It has almost equal number of PPP and non-PPP projects. The distribution is as follows: Toll PPP 44; Non-Toll PPP 4; PPP (toll + non-toll) 48 ; Non-PPP 36; Total boundaries 54; Boundaries with different contract on the either side 30; Same contract on both sides of the boundary 24.

The roughness data was collected four times for each side of a project covered. The value of IRI for a side of a project is the average of values from these rounds. Summary is presented in Table 2.

Results. In general, the road roughness depends on several factors; such as, age of the road, its load carrying capacity, local traffic conditions, weather, geological conditions, etc. The vibration experienced by a vehicle depend on the road roughness but also on the make of the vehicle used. Let,

R_i denote the average value of IRI for road project i,

i.e., the roughness measured in terms of the vibrations experienced by the vehicle. A high value of R indicates poor road conditions. So, R_i can be expressed as:

$$\begin{aligned} R_i = \alpha_0 + \alpha_1 Age_i + \alpha_2 RepairFreq_i + \alpha_3 Design_i + \alpha_4 DPPP_i \\ + \alpha_5 Climate_i + \alpha_6 Traffic_i + \alpha_6 Vehicle_i + \epsilon_i. \end{aligned} \quad (12)$$

Recall, we have chosen points A and C close to each other (within 2 kms from the boundary point B). So, plausibly we take that the local traffic conditions, weather, geological conditions, and other non-observable factors having bearing of road roughness are similar on either side of the boundary. Therefore, conditional on the remaining covariates, a comparison of roughness of segments $A - B$ and $B - C$ provides an estimate of average causal impact on the contract type, i.e., PPP versus non-PPP. The covariates used are the design capacity and age of the roads.

For a National Highway, the NHAI sets the same engineering standards, regardless of the type of contracts used to build the road. The adjacent road projects for which we have collected roughness data lie on the same highway, so there are no changes in the design capacity of adjacent projects considered here. Moreover, we have used the same car for each side of any given boundary. This means, we can restrict out attention to covariates; Age, Maintenance Frequency and the contract type. Unfortunately, we have not been able to get information on the maintenance frequency. So, we estimate following specification.

$$\Delta R_{ij} = \alpha_1 \Delta Age_{ij} + \alpha_2 \Delta DPPP_{ij} + \epsilon_{ij} \quad (13)$$

where $\Delta R_{ij} = R_i - R_j$, observations on R_i and R_j, where i denotes roughness index for one of the projects at a boundary/intersection, j is another of the neighboring projects. A high value of R indicates poor road conditions. $\Delta Age_{ij} = Age_i - Age_j$. $DPPP_{ij} = 1$ if the two projects are built using different contracts, i.e., one of the project is PPP the other is not. $DPPP_{ij} = 0$ if both projects are built using traditional contracts or both are PPPs. The error terms ϵ_{ij} captures effect of differences on account of maintenance works and other local omitted factors.

In Table 3, the difference in Roughness is regressed on Difference in age of the road and the PPP-Non-PPP status. The difference in age of the road has the expected positive sign but not significant. The PPP dummy has negative sign and is highly significant. Moreover, the magnitude of the effect is non-trivial implying that road quality is significantly higher for PPPs. The age of the road has expected sign but is not significant, most likely on account of countervailing frequency of maintenance works, for which we could not get the data.

5.3 Construction Costs

Now, we use construction costs as proxy for quality of construction. As far as the project costs are concerned, the question is: How do we go about comparing the construction cost for PPPs vis-a-vis the non-PPP projects?

One approach to compare the construction costs of PPPs relative to non-PPP projects is to compare the per-kilometre per-lane costs of the two project types. However, the projects in our dataset are located across the length and breadth of the country. One consequence of this is that the per-kilometre costs vary across regions, due to variations in surface and underground conditions, and also due to the choice of the material used in road construction.

Table 3: Road Roughness: PPPs Vs non-PPPs

	(1) Difference in Roughness Index
Difference in age (in months)	0.00167
	(1.21)
Difference in PPP-Non-PPP status (adjacent)	-1.102***
	(-6.25)
Constant	-0.0221
	(-0.18)
N	54
R^2	0.500
adj. R^2	0.480

t statistics in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Moreover, road projects differ from each other in terms of the number and design of over and underpasses, service-lanes, and their proximity to urban centres, all of which have a significant bearing on the per-km construction costs. Besides, the time difference between some projects is large. So, the costs are bound to be different on account of inflation. Consequently, even within a region, the per-km construction costs can vary greatly from project to project. Therefore, a comparison in terms of per-kilometre per-lane costs does not seem to be plausible.

The alternative is to compare the following ratio for PPPs relative to non-PPP projects:

$$CO = \frac{C^a}{C^e}$$

where C^a is the actual construction cost and C^e is the expected construction cost of the project. As noted above, C^e is assessed at $t = 0$ by private firms hired by NHAI through competitive bidding. That is, C^e is assessed ex-ante to the choice of contract, i.e., before the PPP-non-PPP status of the project is determined. Therefore, it does not depend on the type of the contract used for the project. On the other hand, C^a , the actual construction costs become known at $t = 2$ when the construction gets completed, i.e., ex-post to the choice of contract.

However, both C^a and C^e are about one and the same project. Plausibly, C^e factors-in considerations like surface and underground conditions, the number over and underpasses, service-lanes, the material used in road construction, inflation, etc. This is indeed the case with C^a. Therefore, it seems plausible to compare the CO for PPPs with non-PPP projects.[20].

However, for the purpose of data analyses an explanation is in order. The official data on PPPs does not provide figures for the C^e as such. It provides figures on a head called the 'total project cost' (TPC), which includes the cost of interest during construction (IDC) along with the estimated construction costs. For PPPs, $TPC = C^e + 0.25C^e$. Therefore,

[20]Indeed, the literature on cost overruns uses the ratio CO to measure and analyse the cost overruns. A project is said to suffer from positive [negative] cost overruns if and only if the $CO > 1[CO < 1]$ See Singh (2011) for literature review.

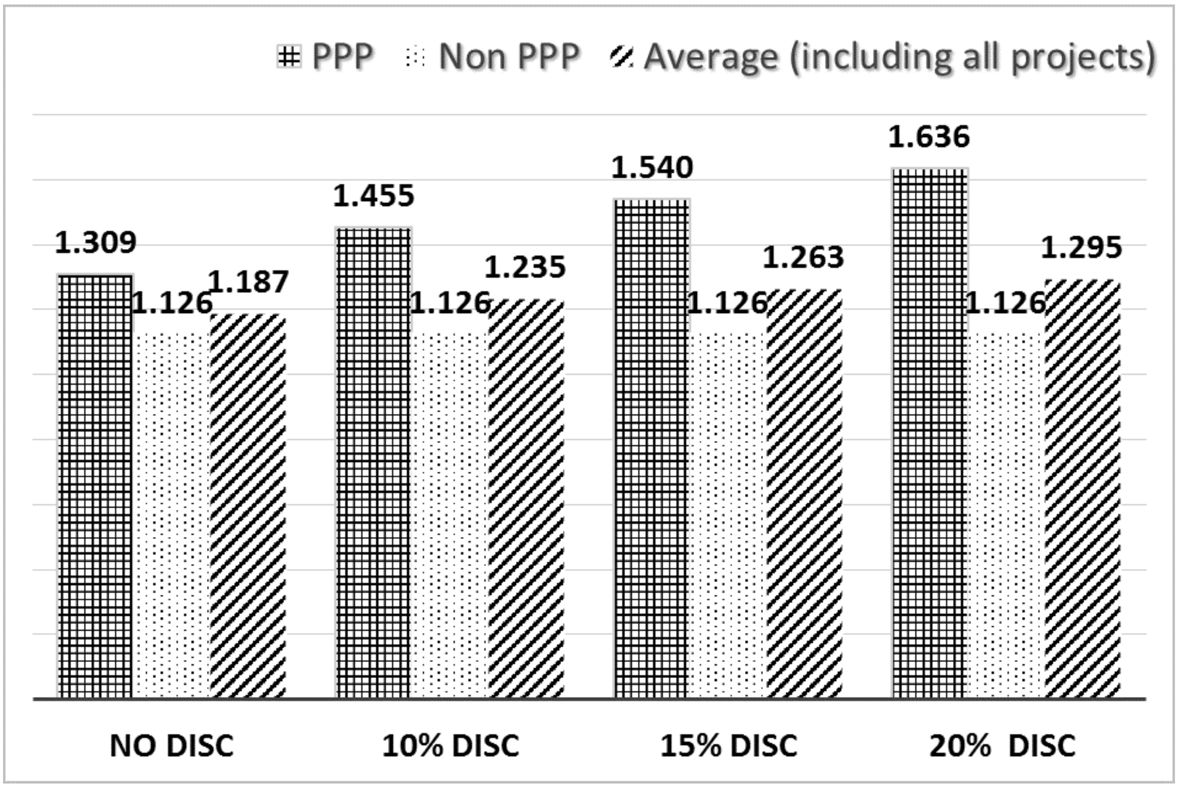


Figure 3: Construction Cost Ratio: PPPs versus non-PPPs

from the official data on TPC, we can retrieve C^e by discounting the official figures on TPC by 20%, i.e, $C^e = 0.80TPC$. That is, for PPPs, the cost ratio $CO = C^a/C^e = C^a/0.80TPC$. However, here we adopt a conservative approach and report results corresponding to 15% discounting for PPPs, i.e., for the ratio $CO1 = C^a/0.85TPC$. Note that the 15% discounting is less than the required level of discounting. Therefore, the results corresponding to it are conservative estimates, i.e., they under-estimate of the cost ratio for PPPs.[21] For non-PPPs the government provides full funding and the contractor does not fund the project at all, therefore the issue of IDC does not arise. So, for non-PPPs, $TPC = C^e$. So, for non-PPPs: $CO = CO1 = C^a/TPC$. As can be seen from Figure 3 the cost ratio for PPPs is much higher than for the non-PPP projects at all lavels of discouning.

5.3.1 Results

Tables A1 and A2 in the Appendix provide magnitude of the cost ratio for PPPs versus the non-PPP projects. About sixty percent of 209 non-PPP projects have cost ratio greater than one, i.e, have cost overruns. By comparison, most of the PPPs (91 out of 104) have cost ratio greater than one. Moreover, the average cost ratio for PPPs is very high at 1.54; whereas for non-PPP highways it is only 1.13. The differences are statistically significant.

The extensive literature on the subject shows that due to several reasons infrastructure projects experience cost overruns.[22] In terms of our terminology this means the cost ra-

[21] In fact, our results are robust to 10% and zero-discounting levels and are available on request.

[22] Such as the imperfect estimation techniques along with incompleteness of the project design. For details

tio is generally greater than one. However, the often cited reasons for cost overruns are equally applicable to traditional as well as PPP projects and therefore cannot account for the above observed differences in the cost ratios. Therefore, the question remains: Why are the construction cost ratios significantly higher for PPPs?

Analysis in Section 3 shows that a PPP contractor has incentive to maintain quality of construction to save on O&M costs; whereas a traditional contractor has incentive to cut cost at the expense of quality. On this count, ceteris paribus, we expect the cost ratio to be higher for PPPs than for non-PPPs. In fact, based on Proposition 4 we can make the following hypotheses:

Hypothesis 2 *Ceteris paribus, expected cost ratio, i.e.,* $E\left(CO = \frac{C^a}{C^e}\right)$
(i) is higher for PPPs than for non-PPP projects;
(ii) is higher for toll PPPs than for non-toll-PPP;
(iii) is highest for toll PPPs, medium for non-toll-PPP and least for non-PPPs.

As the discussion following Proposition 4 suggests, if it turns out that $\left(\frac{C^a}{C^e}\right)^{PP} > \left(\frac{C^a}{C^e}\right)^{NP}$, the actual difference in the construction cost ratio for the PPP and non-PPP is greater than what data can be seen from the data.

The details about the variables used in the empirical analysis and their data sources are in the Appendix. The information needed for the variables could not be available for 9 out of 313 projects.

We begin empirical analysis by identifying factors affecting the PPP verus non-PPP status of a project. The results are presented in Table A3 in the Appendix. The bigger/longer projects are more likely to become PPP. Specifically, the 2005-policy has had intended effect. The policy came into force in August 2005 and it takes about six months for a project to reach the bidding and contracting stage. So the policy has benfitted projects starting in or after January 2006. The Startyear dummy takes value 1 if the contract was signed in or after January 2006. The dummy has positive sign and is highly significant suggesting that the policy increased likelihood of a project becoming PPP.

For our empirical analysis of the relative construction costs, we need to factor in the time-cost trade-off. The revenue stream for the PPP contractors starts only when they charge user-fee or receive the annuity payments from the government. However, the user-fee can be levied only after construction is complete. Similar is the case with the annuity payments. In such a scenario, the PPP contractor may be willing to incur extra cost to complete construction sooner than they would do otherwise. This additional cost if incurred can increase the total construction cost, leading to higher cost ratio for the PPPs. As is shown in the figure 4, both types of projects have experienced timeoverrun, but delays are shorter for PPPs. To control for this effect we use of the following ratio: $TO = \frac{T^a}{T^e}$, where

see Singh (2010) and Singh (2011). Also see Arvan and Leite (1990), Flyvbjerg et al. (2003), Flyvbjerg et al. (2004), Morris (1990), Morris (2003) among others.

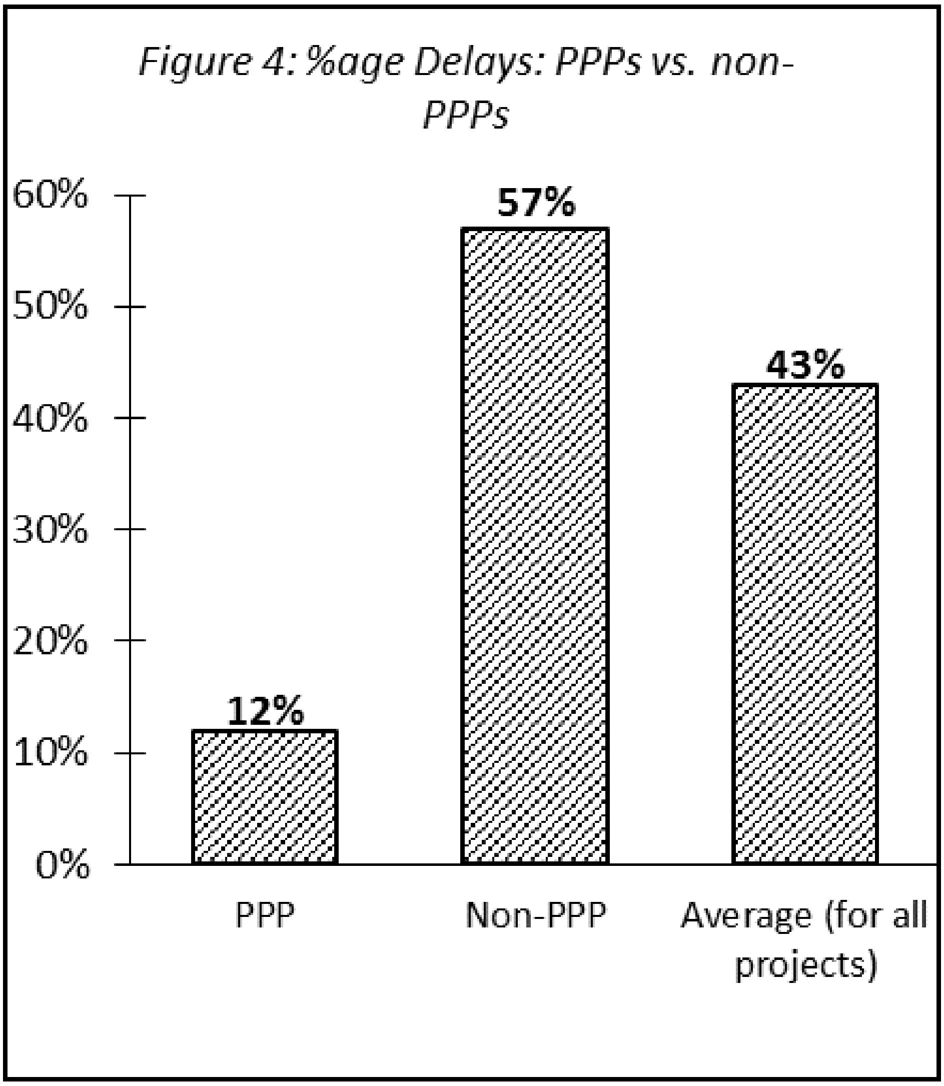


Figure 4: Time-overrun Ratio (TO): PPPs versus non-PPPs

T^a is the actual time (in months) taken by construction and T^e is the initially expected construction time.[23]

The OLS results presented in Table 4A provide empirical support to the hypothesis that cost ratio is relatively high for PPPs. Specifically, controlling for the effect of several relevant factors and project characteristics, the construction cost ratio for PPPs is higher than the non-PPPs by 0.44. Compared to the average cost ratio for non-PPPs (1.13), the difference is large and statistically significant. This inference is also corroborated by the effect of the Startyear Dummy on the cost ratio. The dummy has positive and highly significant coefficient implying that since January 2006 the cost ratio has gone up for the entire set of projects. Since most of the PPP projects have come up in and after 2006, so the increase in cost ratio overall is very likely due to PPPs. Moreover projects with delays also exhibit high cost ratio. Effect of local population on cost ratio is neither substantial nor consistent. See Table 5A.

However, it is important to address the potential problem of endogeneity, since the contract assignment to projects - PPP versus non-PPP - is not random. It is possible that there are project characteristics that make a project attractive to the investors may also be correlated with greater susceptibility to cost escalations. Formally, the error terms ϵ^C and ϵ^π described above might be correlated. This will make the PPP dummy an endogenous variable.

We address the issue of endogeneity by using Startyear Dummy as an Instrument. As is shown above, the Startyear Dummy is highly correlated with the PPP-non-PPP status of a project. However, it is plausible to argue that the start year in itself does not affect the cost ratio. The F statistic shows that the instrument is not weak at all, and the specification is exactly identified. Results presented in Table 6A confirm the causal effect of procurement contract on the construction costs. The costs are significantly higher for PPP contracts than the traditional non-PPP contracts.

Next we turn to Hypotheses 2(ii)-(iii) making distinction between the toll and non-toll-PPPs. As discussed above, the quality concerns and therefore the construction costs are expected to be higher for toll-PPPs than for non-toll-PPPs. Table A7 suggests that is the case. For toll-PPPs the cost ratio is consistently higher than the non-toll-PPPs as well as the non-PPPs. Whereas the difference between the cost ratio for toll-PPPs and the non-toll-PPPs is about 0.20; the difference between the toll-PPPs and the non-PPPs is more than 0.60. These results are corroborated by using Startyear Dummy as IV for toll-PPPs. Results are presented in Tables 8A and 9A. As can be seen from Table 8A, the dummy is highly correlated with toll-PPPs. Similar exercise is carried out by using the Startyear dummy as IV for non-toll-PPPs. See Tables 10A and 11A.

Moreover, out data allows a contractual inquiry confirming our conjecture about toll-PPPs versus non-toll-PPPs and the non-PPPs. In our dataset there are 35 toll projects with positive asking price, i.e., these projects have become toll PPP only because the government offered subsidy (VGF) to the investors; otherwise, they would have been non-PPPs. In other words, these 35 projects are innately non-PPPs but have been artificially converted

[23]In out dataset majority of PPP as well as non-PPPs have suffered from delays, though the average length of delays is storter for PPPs.

to toll-PPP. So, the above discussed issue of endogeniety is not a serious concern for these projects.

Recall, the VGF is one time final payment made by the government to the investor contractor. Nonetheless, we investigate the effect of VGF on the cost ratio. In principle there may be temptation to keep the actual costs higher than the expected costs, maybe to justify the VGF. Note, this problem can arise only for the toll projects with positive bids, i.e., the VGF. Since there is no VGF for annuity PPPs, so this problem does not arise. Still, we can examine whether the bid amount has a bearing for toll as well as all PPPs. To address this issue, we define the following variables for PPP projects:

$BP1 = \frac{Awarded-Cost}{TPC}$ (for all PPPs); $BP2 = \frac{Awarded-Cost}{TPC}$ (only for Toll PPPs), and $BP3 = BP2$ (only for Toll PPPs with positive bids i.e. $BP2 > 0$).

Table 12A presents results for these 35 projects vis-a-vis the non-toll-PPP and the non-PPPs. As can be seen from the table, the cost ratio for these toll-PPPs is significantly and consistently higher than the non-PPPs as well as the non-toll-PPPs. Table 13A shows, the bid prices have no significant bearing on the cost ratio for PPPs. In particularly, $BP3$, i.e., the VGF has no bearing on at all the cost ratio. Again, the contract matters for construction costs.

Together our results confirm that the contract has bearing on construction costs. The effect is most pronounced for toll-PPPs vis-a-vis non-PPPs but is significant for non-toll-PPPs vis-a-vis non-PPPs. Further, they suggest a higher quality investment in PPP projects during their construction phase.

Before concluding, we address the following factors that are not related to quality consideration but can potentially lead to a relatively high cost ratio for PPP highways.

Purposeful underestimation of C^e for PPP projects: In order to make the project seem attractive to investors, the NHAI might deliberately understate the expected cost of PPP projects. If so, the understated expected cost will show up as a higher cost ratio and cost overruns for the PPPs. However, this does not seem to be the case with projects under study. First of all, the project time and costs are not estimated by the NHAI. For all of the projects, PPPs or not, these estimates are made by private firms hired for the purpose through competitive bidding. Presumably, these firms have no incentive to systematically understate the costs for a subset of projects. Moreover, the detailed project report that has details of the factors used by a firm to arrive at estimates of construction time and cost are shared with the bidders. This enables the bidders to check if there is an attempt to mislead them by understating the expected project costs. Even otherwise, the estimates of time and costs are arrived at before the PPP-non-PPP status of a project gets known. Therefore, it is not obvious how the costs can be understated only for PPPs.

Ex-post changes in project works: If ex-post to the signing of the PPP contract the government demands more additions of works for PPP projects, it will lead to a higher construction cost than the actual and therefore higher cost ratio for PPPs. However, the MCA explicitly requires that the total cost of ex-post changes cannot exceed 15% of the initially estimated costs (C^e). In contrast, non-PPP contract does not have such an upper limit. In fact, the contract explicitly says that the contractor will have to perform all the work demanded by the government. Moreover, since the government has to compensate the contractor for such demands, therefore, it cannot gain by asking for additional works from PPP contractors. In other words, ex-post works are more of a concern for non-PPPs than PPPs.

Purposeful escalation of C^a by PPP Contractors: It is tempting to think that the PPP contractors may gain by inflating the construction costs. This will indeed be the case, if the contractor can use cost escalations to reduce tax liability or renegotiate the contract to extract more concessions from the government. The PPP contractors in India enjoy 'tax holiday' for as much as ten years of their choice. Besides, as per the MCA[24], construction costs cannot be a basis for any contract renegotiation. As a matter of fact also, no PPP contract has been renegotiated so far for any of the completed projects in our dataset. So, inflating construction cost doesn't seem to help the contractors, even though one cannot be sure given the complex nature of financial contracts.

6 Concluding remarks

Our study shows that PPPs deliver better quality roads than the ones procured using traditional (non-PPPs) contracts. The life-cycle approach induced by the PPPs is a leading factor behind the relatively high construction costs for PPPs. The PPP contractors want to maintain the quality of construction during the road building phase, so as to reduce their maintenance costs during the operational phase of the project. This enables them to minimize the life-cycle costs. In contrast, under the contracts used for government projects, the contractors are not responsible for the maintenance of roads built by them. So they have strong incentive to minimize the construction costs at the expense of the quality. The result is relatively low construction costs for government highways but poor quality roads with high maintenance and life-cycle costs. In other words, the PPP contracts induce quality of construction higher than the level induced under traditional contracts. Alternatively put, there is a desirable absence of quality-shading/cost-cutting incentives under the PPP contracts. Therefore, the relatively high construction costs for PPP highways seems to be due to the differences in quality of construction between PPPs and non-PPPs. The comparison based on the road roughness, an engineering measure of quality also supports this claim.

Our result about the higher construction costs for PPPs is similar to the findings in that Blanc-Brude et al. (2009). However, their study does not analyse the implications of higher costs for quality of project. Our inferences about the relatively high quality of PPP roads are further corroborated by the CAG reports on the National Highways Development Programme. In these reports most of the government projects (non-PPPs) were found to be deficient in quality. The quality of most of the PPP projects has been found satisfactory.[25]

[24] Model Concession Agreement is the standard contract document for PPPs.

[25] See, for example, CAG Report No. 7 of 2005 (PSUs), CAG Report No. PA 16 of 2008, and CAG report 36 of 2014. Also see Lok Sabha (2006). The CAG report 36 of 2014 does point out to poor road conditions in case of 6 PPPs. Unlike the PPPs in our data set for these PPPs the contractors were allowed to charge toll even prior to completing the project. This and the related terms of contracts diluted the key features of PPPs. Also see Singh (2010b)

Several surveys and field studies on quality of PPPs lend support our findings on the quality.[26]

Besides, we have searched for and examined the media reports on the issue of quality of national highway projects. Most of the standard problems namely, potholes, poor quality of road surface, deficient design, etc., are reported for the non-PPP projects.[27]

Our findings on relative project costs and quality seem robust on several counts. Nonetheless, it should be noted that our dataset on quality dimensions is small. So, a follow-up step study based on a larger set of projects will be desirable. Moreover, there are three unexamined factors that can contribute to high costs for PPPs. First, the pre-contracting delays for PPPs can be an issue. Awarding of PPP contracts is a protracted process. Even though the construction delays are shorter under PPPs, these projects seem to take much longer during the pre-construction phases. There is suggestive evidence that the PPPs are shifting the delays from the construction to the procurement phase. Such delays can contribute to the relative high cost ratio for PPPs.

Second, over-engineering for toll PPPs is possible. The toll contractors have incentive to capture as much traffic at the toll plazas as possible. In the process some of their investment might be just to extract more toll, e.g., they can over invest in railings near toll plazas to prevent the road users being able to exit without paying the toll. Finally, given the complexity of financial contracts between the investors and their bankers, one cannot completely rule out the possibility of cost manipulations by the investors. Effect of these three factors needs further examination.

To sum up, it is important to note that the project costs as defined above do not cover several aspects such as the social costs. Therefore, our findings do not make an unambiguous case for PPPs. The choice between the conventional approach and the PPPs involve several trade-offs. The overall superiority of PPPs over the conventional approach towards infrastructure depend on all of the costs as well as benefits for the road users and the society in general. Moreover, the above mentioned media reports reveal several problems with the way PPPs are being executed. Among the frequently reported problems are the defective designs and poor maintenance of the service lanes meant for the local traffic in urban areas. Similarly, at most of the toll plazas, the waiting time is unreasonably long. This is also a result of the cost cutting and profit maximising behaviour on the part of the private partners. The toll plazas are located strategically to capture maximum traffic but the number of booths is kept low. While such decisions are good for the contractor firm, it imposes huge cost in terms of time and fuel wasted by the waiting road users at these plazas. Another set of problems include inadequate capacity at entry and exit points, inadequate provisioning of pedestrian on bridges and under-passes, poor lighting facilities and other safety measures. This shows that the PPPs are putting excessive emphasis on cost cutting measures at the expense of the welfare of the road users.

APPENDIX

[26] These studies are based on feedback of road-users. See Ashwini (2015), Kurniawan et al. (2013) and Nagesha and Gayithri (2015) and **?**.

[27] For this exercise, we did google search using key words ?national highway, potholes, poor quality road, road users, toll plaza, commuters, road users, BOT, PPP?. We found 60 odd print media reports in English. The summary of these reports is available at http://econdse.org/ram-research/

Variables: Description and Data Sources

For each project in our data set, we have compiled to derive project specific value for the following variables and controls:

Startyear Dummy or Policy Dummy: It takes value 1 if the project started on January 01, 2006 or later; 0 otherwise. This variable aims captures effect of the 2005-Policy on the project outcomes in term of the likelihood of the project becoming PPP and also the construction cost ratio.

Expected Costs, C^e: It is the construction costs as assessed before inviting the bids. It is derived from the NHAI data on the total project cost (TPC), according to the official rules described in the Section 5.

Actual Construction Costs, C^a***:*** These are the total actual construction costs of the project when the construction gets over. In the NHAI files, the construction costs are recorded as 'cumulative expenditure'. For non-PPPs, it is the sum of the payment made by the government to the contractor. For PPPs, it the construction related expenses incurred by the PPP contractor. The PPP contractor is required to submit to the government the construction works related bills and expenses incurred him. Note for PPPs, cumulative expenditure does not include IDC. For PPPs, as a condition in the financial package, no re-payment of interest or principal can start until the second year after completion of the construction phase. Therefore, the contractors do not actually pay/incur IDC during the construction phase.

Construction Cost Ratio CO and CO1: These are defined as the ratio of the actual construction costs and the expected construction costs. That is, $CO = C^a/C^e$, where C^a and C^e are as defined above. The ratio CO1 represents conservative estimate of the cost ratio for PPPs. See Section 5.3.

Implementation Phase (Impphase) or the Expected construction time T^e: The duration (in months) in which a project is planned to be completed, i.e., T^e. Specifically, it is the time difference between the date of signing of the contract, and the expected construction completion date at the time of signing of contract.

Timeoverrun Ratio, TO: It is defined as T^a/T^e, where T^a is the actual time (in months) taken by construction, and T^e is as defined above.

Length (lenghtkm): It is the length of the project (in kms).

Local Population (LPopulation): It is the population of Class 1 towns (according to 2011 census classification) around the project. For each project, we have identified all class 1 town/cities located within 10 kms of the project. The idea is to see if extent of urbanization has any bearing of probability of a project becoming PPP and also on construction costs ratio.

Distance: It is the distance of the project from the nearest megacity (million plus city). For each project, we have identified the nearest megacity and calculated its distance from the project. Various studies show that megacities are hubs of economic and commercial activities, and therefore act as growth center for nearby areas. The idea is to see if proximity to a mega city has any bearing on probability of a project becoming PPP and also on the construction costs.

Bid Price: We have used the following three definitions of the bid price (BP): $BP1 = \frac{Awarded-Cost}{TPC}$ (for all PPPs); $BP2 = \frac{Awarded-Cost}{TPC}$ (only for Toll PPPs), and $BP3 = bp2$ (only for Toll PPPs with positive bids i.e. $bp2 > 0$).

Data source for variables 1, 2, 4, 6 and 10 is NHAI. These variables are used to compute values for variables 3, 5, 7 and 9. Variable 8 is computed using census 2011 data. Additional Data Sources: CAG: Various reports; MOSPI and NHAI: various quarterly reports and other publications; and MOF website for PPPs https://www.pppinindia.gov.in/

Table 1A: Summary Statistics: PPPs Vs non-PPPs

	PPP	Non-PPP	Average (for all projects)
Number	104	209	313
No. of projects with >1 CO	94	129	223
Average CO (for all projects)	1.64	1.13	1.29
No. of projects with >1 CO1	91	129	220
Average CO1 (for all projects)	1.54	1.13	1.26
Average Expected Cost	411.16	203.00	272.16
Average Actual Cost	555.57	225.71	335.31
Average Project Length	58.08	37.15	44.10

Table 2A: Toll PPPs Vs. Non-Toll PPPs

	BOT Toll-PPPs	Non-Toll PPPs
Number of projects	66	38
No. of projects with >1 CO	60	34
Average CO	1.79	1.37
No. of projects with >1 CO1	59	31
Average CO1	1.68	1.31

Regression Results

Table 4A: Correlates of Cost Ratio - PPP vs Non-PPP. OLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
PPP	0.543^{***}	0.448^{***}
	(9.36)	(7.99)
Length (in 100 km)	0.0812	0.0698
	(0.89)	(0.79)
Implementation Phase	0.00379	0.00378
	(1.89)	(1.95)
Time Overrun	0.123^{*}	0.122^{**}
	(2.55)	(2.62)
Local population (in millions)	0.0409^{**}	0.0389^{**}
	(2.64)	(2.60)
Distance (in 100 km)	0.00900	0.0103
	(0.24)	(0.28)
Constant	0.740^{***}	0.747^{***}
	(6.03)	(6.30)
N	304	304
R^2	0.307	0.250
adj. R^2	0.293	0.235

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5A: Correlates of Cost Ratio - Start Year Dummy (OLS estimates)

	(1)	(2)
Dependent Variable	CO	CO1
Start Year Dummy	0.520***	0.464***
	(9.01)	(8.48)
Length (in 100 km)	0.227*	0.183*
	(2.55)	(2.16)
Implementation Phase	-0.00348	-0.00270
	(-1.61)	(-1.31)
Time Overrun	0.0332	0.0516
	(0.72)	(1.18)
Local population (in millions)	0.0376*	0.0345*
	(2.40)	(2.32)
Distance (in 100 km)	-0.0152	-0.01000
	(-0.40)	(-0.28)
Constant	1.068***	1.022***
	(8.85)	(8.93)
N	304	304
R^2	0.295	0.266
adj. R^2	0.281	0.252

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 6A: Determinants of Cost Ratio - TSLS estimates (PPP Vs non-PPP)

	(1)	(2)
Dependent Variable	CO	CO1
PPP	1.08***	0.96***
	(8.11)	(7.50)
Time Overrun	0.27***	0.26***
	(4.27)	(4.32)
Implementation Phase	0.0040	0.0039
	(1.77)	(1.82)
Local population (in millions)	0.020	0.019
	(1.13)	(1.10)
Distance (in 100 km)	0.029	0.029
	(0.68)	(0.71)
Length (in 100 km)	-0.17	-0.17
	(-1.47)	(-1.54)
Constant	0.48**	0.50***
	(3.24)	(3.47)
N	304	304
Uncentered R sq	0.89	0.89
Centered R sq	0.11	0.040
Underidentification	73.0	73.0
Weak identification(Cragg-Donald Test)	93.8	93.8

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Instrument=Start Year Dummy

Table 7A: Correlates of Cost Ratio -Toll-PPP vs non-toll PPP vs non-PPP. OLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
Toll PPPs	0.739***	0.633***
	(11.00)	(9.73)
Non-Toll PPPs	0.294***	0.212**
	(4.00)	(2.99)
Length (in 100 km)	0.00653	-0.000837
	(0.07)	(-0.01)
Implementation Phase	0.00399*	0.00397*
	(2.08)	(2.14)
Time Overrun	0.149**	0.146**
	(3.21)	(3.26)
Local population (in millions)	0.0318*	0.0303*
	(2.13)	(2.09)
Distance (in 100 km)	0.0162	0.0171
	(0.45)	(0.49)
Constant	0.723***	0.731***
	(6.14)	(6.40)
N	304	304
R^2	0.365	0.310
adj. R^2	0.350	0.294

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table A7: Determinants of Toll-PPP participation (relative to non-PPP) - Logistic regression

	(1) Coeff	(2) (odds ratio)
Dependent Variable-Toll PPP		
Start Year Dummy (=1 after 2006)	3.577***	35.77***
	(7.44)	(7.44)
Length (in 100 km)	3.630***	37.70***
	(4.42)	(4.42)
Implementation Phase	-0.0259	0.974
	(-1.63)	(-1.63)
Distance from nearest mega city (in 100 km)	-0.481	0.618
	(-1.46)	(-1.46)
Local Population around project (in millions)	0.192	1.212
	(1.43)	(1.43)
Constant	-3.808***	0.0222***
	(-5.00)	(-5.00)
N	269	269
pseudo R^2	0.457	0.457
Log Likelihood	-77.47	-77.47

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table A8: Determinants of Cost Ratio - Toll-PPP Vs non-PPP. TSLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
Toll PPP	1.18***	1.06***
	(9.46)	(8.75)
Length (in 100 km)	-0.31**	-0.30**
	(-2.81)	(-2.85)
Implementation Phase	0.0067**	0.0066**
	(3.02)	(3.05)
Time Overrun	0.27***	0.27***
	(4.76)	(4.79)
Local population (in millions)	0.019	0.017
	(1.08)	(1.04)
Distance (in 100 km)	0.070	0.069
	(1.71)	(1.73)
Constant	0.46***	0.48***
	(3.40)	(3.62)
N	269	269
Uncentered R sq	0.91	0.91
Centered R sq	0.32	0.26
Underidentification	87.3	87.3
Weak identification (Cragg-Donald Test)	125.8	125.8

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Instrument =Start Year Dummy

Table A9: Determinants oF participation in Non-Toll PPP (relative to non-PPP) - Logistic regression

	(1)	(2)
Dependent Variable	Coeff	(odds ratio)
Non-Toll PPP		
Start Year Dummy (=1 after 2006)	1.796***	6.024***
	(4.21)	(4.21)
Length (in 100 km)	2.274**	9.715**
	(2.60)	(2.60)
Implementation Phase	-0.00825	0.992
	(-0.65)	(-0.65)
Distance from nearest mega city (in 100 km)	-0.0866	0.917
	(-0.28)	(-0.28)
Local Population around project (in millions)	0.0940	1.099
	(0.68)	(0.68)
Constant	-3.066***	0.0466***
	(-4.79)	(-4.79)
N	244	244
pseudo R^2	0.127	0.127
Log Likelihood	-87.60	-87.60

t ratios in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table A10: Determinants of Cost Ratio - Non-Toll PPP Vs non-PPP. TSLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
Toll PPP	0.84^{***}	0.75^{**}
	(3.51)	(3.19)
Length (in 100 km)	-0.18	-0.19
	(-1.46)	(-1.53)
Implementation Phase	0.0026	0.0027
	(1.35)	(1.41)
Time Overrun	0.18^{***}	0.18^{***}
	(3.37)	(3.39)
Local population (in millions)	0.00014	0.00017
	(0.01)	(0.01)
Distance (in 100 km)	0.018	0.019
	(0.47)	(0.50)
Constant	0.74^{***}	0.74^{***}
	(5.53)	(5.60)
N	244	244
Uncentered R sq	0.90	0.90
Centered R sq	-0.16	-0.21
Underidentification	22.2	22.2
Weak identification (Cragg-Donald Test)	23.7	23.7

t statistics in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Instrument =Start Year Dummy

Table A12: Determinants of Cost Ratio -Toll-PPP vs non-toll PPP vs non-PPP. OLS estimates

	(1)	(2)
Dependent Variable	CO	CO1
Non-toll PPPs Dummy	0.284***	0.205**
	(3.91)	(2.90)
Toll PPPs with VGF Dummy	0.753***	0.648***
	(9.63)	(8.55)
Length (in 100 km)	0.0186	0.00869
	(0.20)	(0.10)
Implementation Phase	0.00400*	0.00401*
	(2.08)	(2.15)
Time Overrun	0.137**	0.137**
	(2.97)	(3.05)
Local Population around project (in millions)	0.0229	0.0221
	(1.42)	(1.41)
Distance from nearest mega city (in 100 km)	-0.00493	-0.00267
	(-0.13)	(-0.07)
Constant	0.760***	0.762***
	(6.45)	(6.68)
N	285	285
R^2	0.325	0.273
adj. R^2	0.308	0.255

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table A13: Cost overruns vs. Bidding Price for PPPs. OLS estimates.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	CO	CO	CO	CO1	CO1	CO1
Length (in 100 km)	0.407*	0.0821	0.0591	0.432*	0.0872	0.0628
	(2.33)	(0.36)	(0.20)	(2.33)	(0.36)	(0.20)
Implementation Phase	0.00217	0.0156	0.0141	0.00230	0.0166	0.0150
	(0.46)	(1.48)	(0.95)	(0.46)	(1.48)	(0.95)
Time Overrun	0.177	0.229	0.207	0.188	0.244	0.220
	(1.29)	(0.96)	(0.66)	(1.29)	(0.96)	(0.66)
Local population (in millions)	0.0665*	0.0836*	0.0885	0.0706*	0.0888*	0.0940
	(2.36)	(2.33)	(1.66)	(2.36)	(2.33)	(1.66)
Distance (in 100 km)	-0.0730	0.0447	-0.125	-0.0776	0.0475	-0.133
	(-0.89)	(0.36)	(-0.81)	(-0.89)	(0.36)	(-0.81)
BP1	-0.337*			-0.358*		
	(-1.99)			(-1.99)		
BP2		0.00993			0.0105	
		(0.04)			(0.04)	
BP3			-0.574			-0.610
			(-0.88)			(-0.88)
Constant	1.079***	0.712	1.060	1.146***	0.757	1.127
	(3.59)	(1.46)	(1.46)	(3.59)	(1.46)	(1.46)
N	91	56	35	91	56	35
R^2	0.185	0.161	0.231	0.185	0.161	0.231
adj. R^2	0.126	0.058	0.066	0.126	0.058	0.066

t ratios in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

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