RAM SINGH*
Department of Economics, Delhi School of Economics,
University of Delhi

Determinants of Cost Overruns in Public Procurement of Infrastructure: Roads and Railways

Introduction

Public spending on infrastructure constitutes a major part of the total expenditure of the Central Government of India.[1] During the last decade, an increasing amount of funds has been allocated for the provisions of infrastructure. The successive central governments have declared infrastructure to be a high priority area. However, instances of delays and cost overruns in infrastructure projects continue to be really large. At the same time, due to inadequate research on the subject, there seems to be a general lack of understanding regarding the causes behind cost and time overruns. This paper aims to contribute to the public policy by providing a better understanding of the factors responsible for delays and cost overruns in India. Though the combined set of projects from 17 infrastructure sectors is analyzed, the focus is going to be on the road and railways projects.

The existing literature on delays and cost overruns in India is a collection of very insightful case studies. There are some empirical works too.

* I am indebted to the editor, Arvind Panagariya, and referees, Shashanka Bhide and Kenneth Kletzer, for very enriching suggestions and a detailed set of comments on the first version of the paper. The paper has greatly benefited from very helpful comments by T. C. A Anant, Abhijit Banerjee, Suman Bery, Neha Jain, Rakesh Mohan, Rohini Pandey, T. N. Srinivasan, and conference participants at the India Policy Forum. Atika Gupta and Nitya Mittal provided excellent research support. Finally, I am thankful to the Centre for Development Economics, at the Delhi School of Economics, for institutional support.

1. Calculations based on figures provided in Economic Survey for 2006–07 (pp. 55, 281–83) show that total public expenditure on infrastructure is 4.23 percent of GDP, and 14.4 percent of the total outlay of central, state government, and union territories during that fiscal. Public spending on infrastructure has increased since and currently is about 6 percent of the GDP. Under the XIth plan it is projected to increase to 6.8 percent of GDP in 2011–12.

The literature cites several reasons for the cost and time overruns. Such as, delays in land acquisition, shifting of utilities, environmental and inter-ministerial clearances, shortage of funds, litigations over land acquisition, and contractual disputes. See, e.g., Dalvi (1997), Thomas (2000), Sriraman (2003), Thomsen (2006), Jonston and Santillo (2007), Raghuram et al. (2009), and McKinsey and Company (2009), among others. Morris (1990, 2003) and Singh (2010a) are empirical works. Singh (2010a) based on a very large dataset of completed projects from 17 infrastructure projects shows the existence of strong and interesting correlations between the delays and cost overruns, on one hand, and several project related characteristics, on the other hand. However, the study does not offer insights on the sector-specific causes behind cost overruns. Indeed, infrastructure sectors are quite different from each other. Presumably, each sector has idiosyncratic factors that can cause delays and cost overruns. A combined analysis of all sector projects is very likely to miss out on at least some of the sector-specific causes behind cost overruns.

There is a large body of international literature on the subject, though it is of limited help in understanding the nature of cost overruns in India. It suggests that delays and cost overruns are generic to infrastructure projects and is a global phenomenon. This seems to be especially true of large transport projects, such as large projects in road and railways sectors. For instance, empirical studies by Flyvbjerg et al. (2002, 2003, and 2004), covering 20 countries across the five continents, show that transport projects often suffer from cost overruns. Merewitz (1973), Kain (1990), Pickrell (1990), Skamris and Flyvbjerg (1997), among others, have also come out with similar findings. In addition, there are numerous case studies depicting the extent and gravity of delays and cost overruns in infrastructure projects. However, these empirical works do not explain the causes behind delays and cost overruns, though several studies have demonstrated the correlation between cost overruns and other project attributes.[2]

The inadequacy of research on the subject notwithstanding, the government has been actively encouraging private sector to participate in the delivery of public goods and services, especially infrastructure. The private sector participation is enabled through what are called the public–private partnerships (PPPs). Generally, PPPs in infrastructure are formed with the help of the build-operate-transfer (BOT) contracts between the government and the private sector. For the last several years the railways, the

2. See Odeck (2004) and Flyvbjerg et al. (2002, 2003, and 2004).

roads and surface transport, and the finance ministers have been announcing measures to encourage PPPs in infrastructure. Here is an excerpt from the Railway Budget Speech, 2008–09:

> Railways would have to make heavy investments for the expansion of the network, modernization and up gradation of the technology and for providing world class facilities to the customers in the coming years. … we have started many PPP schemes for attracting an investment of ₹1,00,000 crore over the next 5 years… (Government of India, 2008)

The incumbent roads and surface transport minister has even more ambitious target of attracting ₹100,000 each fiscal through PPPs. The policymakers have come to believe that private sector participation can reduce delays and cost overruns in infrastructure projects. The following quote amply illustrates this:[3]

> … 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…(Government of India, 2006a)

However, there is no empirical work to support or repudiate the official belief in the above claimed superiority of the private sector. This paper is a first attempt to address the issue, though only to a limited extent. A proper understanding of the causes behind delays and cost overruns, calls for across-sectors as well as sector-specific empirical analyses. The empirical analysis in this paper addresses these issues, among others, by focusing on road and railways sectors. Sector-specific approach taken here enables testing of several hypotheses which may not be possible in a general study, either for conceptual reasons or for the lack of suitable data. For instance, the following questions are addressed and answered: Between the roads and the railways, which sector has better infrastructure delivery mechanism? Can PPPs mitigate the problems of delays and cost overruns?

Coming back to the literature, the theoretical literature on the subject offers several explanations for cost overruns. For example, Ganuza (2007) attributes cost overruns to an underinvestment in designing efforts by the

3. This is an excerpt of a decision made on March 15, 2005 in a meeting (chaired by the Prime Minister) regarding financing of the National Highways Development Project (NHDP). See Government of India (2006a).

project sponsor; the sponsor underinvests in design and keeps the estimates less accurate so as to reduce the rent appropriated by the bidders. In Lewis (1986), contractor underinvests in cost reducing efforts towards the completion of the project. Indeed, many works, including by Laffont and Tirole (1993), attribute cost overruns to strategic reasons. Morris and Hough (1987), Gaspar and Leite (1989), Bajari and Tadelis (2001), and Arvan and Leite (1990), attribute cost overruns to imperfect information and technical constraints. According to these works, due to imperfect estimation techniques and the lack of data, the estimated and the actual project costs turn out to be different. That is, delays and cost overruns are claimed to be a manifestation of "honest" mistakes on the part of government officials.[4]

However, testable predictions implied by the theoretical literature are not in sync with the reality. For instance, if time and cost overruns are only due to the imperfect estimation techniques, then one would expect the estimation errors to be "small" compared to project cost, and unbiased with zero mean. Since, due to technological constraints or imperfect project design, underestimation of cost should be as likely as overestimation. On the contrary, many studies show that cost overruns tend to be positive in most cases and have positive bias. Moreover, these works cannot explain the varying degree of delays and cost overruns across sectors and across projects within a sector.

This paper is an attempt to explain the above discussed features of cost overruns. The proposed explanation in the paper offers several testable predictions. These predictions are tested with two large and unique datasets. Among other things, we show that: compared to other projects, civil construction projects have experienced higher cost overruns and longer delays; compared to the Indian Railways, the National Highways Authority of India (NHAI) has significantly superior project delivery system; compared to other road projects, PPP projects in India are experiencing shorter delays but higher cost overruns!

As far as policy implications are concerned, the analysis shows that the choice of the procurement contract has significant bearing on the project outcome. Ceteris paribus, contracts that club the responsibility of project maintenance with that of construction complete project sooner, as compared

4. Another strand of the literature attributes cost escalations to political factors, i.e., to "lying" by politicians. See, e.g., Wachs, 1989; Kain, 1990; Pickrell, 1990; Morris, 1990; and Flyvbjerg, Holm, and Buhl, 2002; Flyvbjerg et al., 2004, among others. According to these works, politicians understate costs and exaggerate benefits in order to make projects saleable.

to the contracts that do not do such bundling. Moreover, delays and cost overruns can be reduced by improving the incentive and resource allocation structures within the government departments. The analysis also suggests that incompleteness of project designs and contracts may be one of the leading causes behind delays and cost overruns. Therefore, a better initial designing may help reduce delays and cost overruns. The other findings and their implications are discussed in the last two sections.

The section "Infrastructure Projects" provides discussion on the life cycle of infrastructure projects, including project costs, design, contracts, and renegotiation processes. The section "Cost Overruns" provides a detailed discussion on the potential causes behind cost overruns. The section "Data, Empirical Frameworks, and Results" provides data description and presents an overview of the delays and cost overruns in infrastructure projects in India. It also introduces the regression model as well as empirical results. The section "Concluding Remarks" concludes with policy implications of the study.

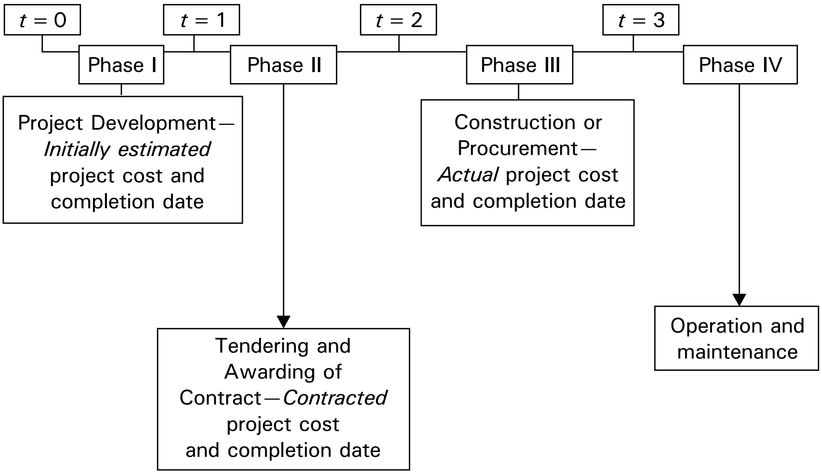
Infrastructure Projects

Life Cycle

A typical infrastructure project has to undergo several stages: from planning of the project, to its approval, to awarding of contract(s), to actual construction/procurement, and so on. More specifically, the life cycle of an infrastructure project can be divided into following four phases: development phase, tender and contract award phase, construction or procurement phase, and the operation and maintenance (O&M) phase. See Figure 1.

Planning and designing of a project is done in its development phase. In the beginning of this phase, a project sponsoring department prepares estimates of time and costs (funds) needed to complete the project. Based on the time estimates, a project schedule is prepared. For projects involving construction of assets/facilities, such as, roads, railways, airports, etc., project specifications and, in many cases, designs are prepared in this phase. The project design and specifications involve the following activities: *One*, the description of the scope of the project. *Scope* of a project is the description of the "output" features the project assets or facilities must possess. It also specifies the list of work-items or the tasks that need to be performed to build the assets. For example, for a road project the scope may specify the length of the project highway, number of traffic lanes, number and locations of

FIGURE 1. Four Phases of a Project



Source: Prepared by the author for this paper.

overpasses, underpasses, toll-plazas to be built-in, etc. *Two*, identification of tasks/work-items that need to be performed to build the assets, and estimation of quantities of the work-items. *Three*, a detailed engineering design and drawings, etc., specifying how the construction should be carried out.[5]

Once the estimates of time and cost along with the design have been approved by the appropriate authority in the department, the project is ready for tendering and award of contract(s), i.e., it enters the next phase.[6] At $t = 1$, the department invites bids for project works. The bid documents provide information on various aspects of project at hand. The provided information depends on the contract to be used. However, regardless of the contract to be used, bid documents provide information about the scope of the project and the cost estimates for project works. Bidders are required to submit the (asking) price-bids. The exact form of bids depend on the nature of contract to be used and, as is shown below, differs across contracts.

5. As a matter of fact, for infrastructure procurement, government engineers carry out all of the designing tasks. However, depending on the procurement contract to be used, the last two activities—finding out of the work-items and estimation of project cost—may be performed by the bidders, i.e., potential contractors. But, the scope of the project, i.e., the specifications of the good to be produced is always decided by the relevant government department.

6. In addition, a project generally requires approval from several other departments. For example, a typical civil aviation project needs clearances from the ministries of civil aviation, finance, environment and forest, and the Airports Authority of India.

A contract is signed between the sponsoring department and the successful bidder. Generally, the contractor is selected through competitive bidding; the lowest price-bidder wins the contract. Depending on the context and the activity, a contract can be for construction or for procurement of equipments, machinery, etc. At times, the cost and the time estimates get revised at the time of signing of the contract. The project enters the construction/procurement phase when the contractor(s) start construction at the project site or arrange to deliver the procurement items, as the case may be. During the construction phase, the project requires active cooperation from the sponsoring authority, the contractor(s), and several other ministries/departments. Whether a project can be delivered in time depends on how well the activities and efforts of the departments involved and the individuals concerned are coordinated. Due to several reasons, the actual date of completion of project works is invariably different from the expected, i.e., initially planned date of completion. The actual time and therefore duration of completion get known only at the end of the construction phase. The project facilities deliver intended services during the O&M phase.

Project Costs

Two definitions of project costs are important for the purpose of analysis in the paper, namely *expected costs* and *actual costs*. Besides, we will also discuss what are known as *contracted costs.* As mentioned above, during the project development phase, the sponsoring department provides cost estimates of project works, called the expected project costs. These cost estimates are based on the estimates of quantities of the work-items and their estimated costs. However, the actual values of quantities get known to the contractor and government engineers only at the end of the construction phase. As a result, the value of the actual project costs are realized only when the project gets completed at the end of Phase III. Due to the reasons discussed below, the actual quantities of work-items and consequently the actual costs invariably turn out to be different from their estimated values.

For the ease of concreteness and detailed exposition of the above issues, let us use some formal notations. Suppose, for a given project n tasks (work-items) need to be performed. Let q_i denote the quantity of the ith task/work-item. So, $q = (q_1, q_2 \ldots q_n)$ denotes the vector of quantities of work-items. Let $c_i(\omega)$ be the unit cost function of the ith work-item, where ω is a vector of input prices. For simplicity assume constant returns to scale. This implies that if the quantities in the vector $(q_1, q_2 \ldots q_n)$ are actually delivered, the project cost will be $C(q, \omega) = c(\omega).q = (c_1(\omega), c_2(\omega) \ldots c_n(\omega)).(q_1, q_2 \ldots q_n)$, where $q = (q_1, q_2 \ldots q_n)$ is a column vector of the quantities of the deliverables. During the development phase, the sponsoring department arrives at the estimates of q, say, $q^0 = (q_1^0, q_2^0, \ldots, q_n^0)$, and of c, say $c^0 = (c_1^0, c_2^0, \ldots, c_n^0)$. As a result, the cost as estimated by the department is $C^0 = c^0.q^0$. Table 1 demonstrates actual description of project works by the NHAI.

TABLE 1. Example of a Project Design by NHAI

Description of work-item	*Unit*	*Quantity* q_i^e	*Per-unit cost* c_i^e	*Per-item amount* $q_i^e.q_i^e$
Dismantling of existing structures like culverts, bridges, retaining walls, and other structure comprising of masonry, cement concrete, wood work ...	cum	25.75		
Providing and applying tack coat with bitumen emulsion....on the prepared bituminous/granular surface cleaned with mechanical broom.	sqm	38,824		
Providing and laying semi dense bituminous concrete....using crushed aggregates of specified grading, premixed with bituminous binder @ 4.5 to 5 percent of mix....to achieve the desired compaction as per MoRTH specification clause No. 508 complete in all respects.	cum	1,067.6		

Source: www.nhai.org.

Let $q^a = (q_1^a, q_2^a, \ldots, q_n^a)$ denote the vector of quantities of work-items actually performed.

Denote the actual project costs by C^a. While the estimated project costs depend on the costs of estimated quantities, i.e., $(q_1^0, q_2^0, \ldots, q_n^0)$, the actual costs depend on the number of actual quantities delivered, i.e., $(q_1^a, q_2^a, \ldots, q_n^a)$. So, the actual construction costs are given by $(c_1^a(\omega), c_2^a(\omega), \ldots, c_n^a(\omega)).(q_1^a, q_2^a, \ldots, q_n^a)$. The definition of actual project costs is different for different parties, and is discussed below.

The actual quantities invariably turn out to be different from their initial estimates, i.e., $(q_1^a, q_2^a, \ldots, q_n^a) \neq (q_1^0, q_2^0, \ldots, q_n^0)$ holds on many occasions. This can happen because the actual work conditions (the state of nature) that arise during the construction phase can necessitate some changes in the project design, resulting, in turn, in $(q_1^a, q_2^a, \ldots, q_n^a) \neq (q_1^0, q_2^0, \ldots, q_n^0)$. To illustrate, the optimum mix of the concrete and bitumen, the type of foundations needed for flyovers, etc., depends on the quality of soil at the project site. If the work conditions at the project site turn out to be different from those for which project was designed, there will be a change in the design and the quantities of work-items. Such changes in project design and quantities are result of imperfect estimation and design techniques. Simply put, $(q_1^a, q_2^a, \dots, q_n^a) \neq (q_1^0, q_2^0, \dots, q_n^0)$ can hold simply on account of measurement and design errors.

Moreover, at times the conditions at project site may even necessitate what is known as a *change in scope* of the project; i.e., a significant change in the number of project works. For instance, a road project originally could be designed to simply resurface the existing stretch without any changes in the undersurface. However, the actual site conditions may necessitate strengthening of the undersurface and shoulders. This clearly would mean that the initial scope has to be changed to accommodate new work-items and to revise the quantities of the existing work-items. On top of it, during the construction phase the government may discover that some relevant works are missing from the original scope. For example, for a highway project, the government engineers may discover the need for more of flyovers or underpasses. Similarly, for a railways project, the government may find that they have missed out on some safety measures in the initial design. Such realizations will also lead to renegotiations between the employer and the contractor to change the scope. At times, demand from local public can add to the list of work-items, thereby necessitating a change in scope. An inevitable consequence of a change in scope is that actual quantities and, therefore, the ex-post project costs are different from the estimated ones.[7]

The cost and risk-sharing arrangements differ across contracts. So, the interpretations of the contracted and actual cost differ across contract types. We discuss these issues in the following subsections.

Infrastructure Contracts in India

A procurement contract specifies the project works to be performed by the contractor along with the associated compensation schemes. The contract also specifies costs of the works, known as the *contracted cost*. The meaning and interpretation of the contracted amount vary across the types of contracts and are discussed below. As far as the project types are concerned, three types of contracts dominate the infrastructure procurement processes in India. These contracts are the *Fixed-Price* contracts, the *Item-rate/Unit-rate* contracts, and the *PPP* contracts.

7. Empirical studies suggest that a change in scope, generally, leads to increases in the quantities of the existing work-items as well as brings in new tasks under the scope of the project, leading to additional costs. See, e.g., Bajari et al. (2009).

As the name indicates, under a Fixed-Price (FP) contract, the procuring department promises a fixed payment to the contractor for the works specified in the contracts. Generally, FP contracts are employed in situations where there is little uncertainty about the feature of the good to be procured.[8] So, FP contracts are used for procurement of equipments and machinery such as locomotive engines, signalling equipments, etc. In some cases, these contracts have been used for construction works as well. Under an FP contract, a bidder submits bids of asking price at which s/he is willing to deliver the equipment or the works described in bid documents. The contract is signed with the bidder with lowest asking price-bid. When an FP contract is used for construction works, generally, the task of project designing is delegated to the contractor.[9] That is why such contracts are generally called design-and-build (D&B) contracts.[10] For these contracts, the price quoted by the contractor in his bid, say P^{FP}, is called the contracted cost/amount.

Item-Rate (IR) contracts are used for construction projects in our dataset. Most of the road projects and construction projects in railways, urban-development, civil aviation, and other sectors have used IR contracts. These contracts are used in situations wherein there is little uncertainty with respect to the tasks to be performed but lot of uncertainty regarding the quantities of the tasks. Under an IR contract, a bidder submits *per-unit* price (popularly known as IR) for each task/work-item at which s/he is willing to complete project tasks. The contractor is paid for the actual quantities of work-items at the contractually agreed IRs. Formally, when an IR contract is to be used, the bid documents provide information about the vectors $(c_1^a, c_2^a, \ldots, c_n^a)$ and $(q_1^0, q_2^0, \ldots, q_n^0)$ to the bidder along with other project details, specifically the project design. Each bidder submits the per unit price/IR for each of the tasks specified in the scope and design of project. That is, a bidder submits a vector of IRs. Let there be K number of bidders and $P^j = (p_1^j, p_2^j, \ldots, p_n^j)$ be the bid of jth bidder. The contract is awarded to the bidder whose bid requires lowest payment for the estimated work-items, i.e., jth bidder wins the bid if the bid $(p_1^j, p_2^j, \ldots, p_n^j)$ leads to lowest value of $(p_1^k, p_2^k, \ldots, p_n^k).(q_1^0, q_2^0, \ldots, q_n^0)$ for all $k = 1, \ldots, K$. So, if the jth bidder gets the contract and is expected to deliver $q^0 = (q_1^0, q_2^0, \ldots, q_n^0)$ vector of works, as a first approximation, he will

8. See Bajari and Tadelis (2001).

9. Even when the bid documents provide the design, the departments still allow the contractor to improve upon it.

10. In India, only the Delhi Metro Rail Corporation (DMRC) has used FP (D&B) contracts for construction projects.

be paid $P^{IR} = P^j.q^0 = (p_1^j, p_2^j, \dots, p_n^j).(q_1^0, q_2^0, \dots, q_n^0) = \sum_{i=1}^{n} p_i^j q_i^0$ In case of IR contracts, the amount $\sum_{i=1}^{n} p_i q_i^0$ is called the contracted cost.

Under FP and IR contracts, 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 at $t = 3$. However, there is one important difference between these two contract types. Under the FP contract, the contractor bears most of the construction costs–related risks. In contrast, under an IR contract the contractor shares construction costs–related risks with the government, especially those arising due to variations in quantities of work-items. We will discuss these issues in greater detail under the subsections on contract renegotiations and cost overruns.

Under a PPP contract, in contrast, the contractor is required not only to construct the project facilities possessing contractually agreed features but also to maintain it during the O&M phase. So, the contractual relation between the parties lasts till the end of the O&M phase at $t = 4$. The contractor bears most of the construction costs related risks and all of the maintenance cost related risks. In our datasets the use of PP contracts is restricted to the national highways (NH) projects.

The PPP contracts used in India have three essential and 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 construction related risks and all of the maintenance risks are borne by the contractor; three, the project designing, building, financing, and its O&M are the responsibilities of the contractor. That is, PPP projects are Design, Build, Finance, Operate, and Maintain (DBFO&M) contracts. This is especially true of PPPs in roads. The PPP contracts differ largely in terms of the degrees to which the usage or the commercial risks are borne by the contractor. Under BOT Annuity contracts, the contractor receives contractually agreed biannual payment from the government. Under BOT toll contracts, the contractor is granted concession to charge toll fee from road users.[11]

The contract price/amount in case of BOT annuity projects is the annuity payments agreed by the two parties. However, in case of BOT toll, it is the price paid by the government. For less attractive projects, where expected toll revenue is not very high, the contract price is positive. In contrast, for

11. For details see Anant and Singh (2009).

highly lucrative projects the contract price can even be negative, i.e., the contractor offers to pay the government for the right to charge toll, over and above promising to bear the construction costs. This attribute of PPP contracts brings out yet another major difference between the PPPs, on one hand, and the FP and IR contracts, on the other hand. The following remark summarizes this difference:

Remark 1: *While under the FP and IR contracts the contracted cost/amount is a reflection of the construction cost, under PPP it is a function of the expected revenue along with the construction cost. While the expected and contracted costs are likely to be highly comparable for IR and FP contracts, the latter costs can be negligible compared to the former in case of PPP contracts. In any case, one should be extremely cautious while comparing the contracted amount across contract types.*

For road projects in our (NHAI) dataset, the correlation coefficient between the expected costs and contracted costs is 0.93 for IR contracts. In contrast, for PPP contracts it is merely 0.32.

Since our focus is on cost overruns during construction phase, we consider a simple form of PPP (PP) contracts that capture the above-mentioned three attributes. Specifically, under a PP contract, the contractor/concessionaire is responsible for construction of the infrastructure facility with output features specified in the initial contract as well as for its maintenance during $t = 3$ and $t = 4$. And, the contractor is paid a mutually agreed fixed price, say P^{PP}.[12]

Contract Renegotiation

At times parties need to renegotiate the contract at the beginning of or during the construction phase. If the actual conditions at the project site turn out to be significantly different from those specified in the initial contract, renegotiation of the original contract may become necessary. For instance, the actual number and/or the quantities of work-items that need to be performed can turn out to be different from their initial estimates. As noted above, the actual quantities invariably turn out to be different from their initial estimates, i.e., $(q_1^a, q_2^a, \ldots, q_n^a) \neq (q_1^0, q_2^0, \ldots, q_n^0)$ holds on many occasions. In such cases, the parties may renegotiate the terms of the initial contract. Besides, contract renegotiation becomes inevitable if need arises for works in addition to those specified in the contract. In that case, parties renegotiate the terms of the original contract, including the number and quantities of

12. P^{PP} can be interpreted as the expected value of future revenue stream in case the usage or the commercial risk is borne or shared by the contractor.

additional work-items, and the compensation.[13] The events and implications of renegotiations differ from contract to contract.

Under an IR contract, the contractor is paid for the *actual* quantities delivered by him, as per the bid/price rates submitted by him. The rates remain unaltered as long as the actual quantities are in the range of ± 25 percent, regardless of whether the actual quantities are different on account of measurement errors or *change in scope*. Specifically, for the *i*th work-item the contractor will paid at the rate of P_i[14] as long q_i^a is in the range of $0.75q_i^0$ to $1.25q_i^0$. The compensation rate is renegotiated if q_i^a lies outside of this range. To sum up, under IR contracts, the cost risk on account of variations in quantities of work-items due to measurement errors is borne by the government department, as long as variations are small. If the variations are large, i.e., if q_i^a turns out be out of the range $[0.75q_i^0, 1.25]$, p_i gets renegotiated to say p'_i and the contractor is paid $p'_i \cdot q_i^a$. So, in such a scenario, the risk is shared by the two parties though most of it is still rests with the department. However, the situation is somewhat different when a change in scope of the project is required. Since, it not only makes actual quantities differ from the estimated one, it generally adds to the list of task/work-items as well. In such an event, the contractor and the government engineer will negotiate the item-rate (IR) of the new work-items. The costs (benefits) of the additional (reduced) work-items due to the change in scope are borne [enjoyed] by the government department.

Under the FP contract, in contrast, regardless of whether the actual quantities differ from the estimated one or not, the contractor is paid the contractual agreed amount P^{FP}. Therefore, under FP contract, the cost risk on account of variations in quantities of work-items due to measurement errors is entirely borne by the contractor. The contract is renegotiated only if the government department demands a change in scope of the project. In that case, the contractor and government engineer negotiate the compensation for the changes in work-items necessitated by the change in scope. As under IR, the costs (benefits) of the additional (reduced) work-items due to the change in scope are borne [enjoyed] by the government department.

The PP contracts are very similar to FP contracts, as far as the compensation for construction costs are concerned. Under these contracts, again, the

13. In most cases, the contract renegotiation is triggered by the change in project scope demanded by the department. However, the contractor can also demand renegotiation under certain circumstances, such as, *force-mesure*.

14. Recall that $P = (p_1, p_2, \dots, p_n)$, is the vector of per unit asking price submitted by the lowest bidder. It is also the vector of contracted IRs.

cost risk on account of variations in quantities of work-items due to measurement errors is entirely borne by the contractor. There is no provision for compensatory payments on account of variations in quantities alone. The contractor is compensated only for the works demanded by the change in the scope of the project. Before proceeding further another remark is in order.

Remark 2: *The IR and PPP contracts lie on the opposite extremes, as far as the delegation of decision rights and construction cost related risk to the contracts are concerned. Under IR (resp., PPP) contracts most decision rights regarding project design, financing, and maintenance, etc., rest with the government (resp., contractor), who also bear most of the construction cost related risks. The FP contracts lie in between these two extremes.*

Cost Overruns

One can think of cost overrun as the difference between the actual (final) project costs and the *contracted* project costs. However, for the purpose of comparing cost overruns across sectors and contract types, the first definition, i.e., difference between the actual (final) project costs and the *estimated* project costs is more suitable. Since, in our dataset only road sectors has completed PPP projects. More importantly, as we noted earlier, the contracted amount/costs figures for PPP contracts can be very small and even negative as they are more of a reflection of the expected revenue than of the construction costs. Therefore, contracted costs and as a result the cost overruns based on them are not comparable across sectors and contract types. We define the "cost overrun" as the difference between the actual (final) project costs and the initially expected project costs. This also happens to be the official definition of cost overruns and is also widely used in literature—both theoretical and empirical.

In official terminology, the expected cost at project approval stage is called the initial project cost. The actual costs become known only at the time of completion at the end of the construction/procurement phase, i.e., at $t = 3$. The percentage cost overrun for a project can be defined as the ratio of the cost overrun and the initially anticipated cost of the project (multiplied by hundred). Clearly, percentage cost overrun can be positive, zero, or negative.

Recall, under PPPs the actual project costs are borne by the concessionaire—except the cost of implementing the midway changes in scope demanded by the government department. It is important to emphasize that the final project costs do not refer to the actual construction costs incurred by the construction contractor. It is the actual project cost borne by the procuring department in case of non-PPPs and by the concessionaire for PPP projects. We have already defined the initially expected cost as $C^0 = c^0.q^0$, where $q^0 = (q_1^0, q_2^0, \ldots, q_n^0)$ and $c^0 = (c_1^0, c_2^0, \ldots, c_n^0)$. These cost estimates are provided by the procuring department. The actual costs depend, among other things, on the type of contract used and whether the contract is renegotiated or not.

Under the IR contract the final cost to the department will be $p.q^a = (p_1, p_2, \ldots, p_n).(q_1^a, q_2^a, \ldots, q_n^a)$ plus adjustments on account of contract renegotiations if any. In contrast, under FP contract (resp. PP contract) the final cost to the department will be P^{FP} (resp. P^{pp}) plus adjustments payments on account of change in scope, if any.

Due to several reasons, the ex-post actual costs generally differ from their initial estimates. In the following subsections, I discuss the potential causes as well as their plausibility/applicability for our datasets.

Uncertainty

The uncertainty regarding the quantities and costs is surely one reason why the actual costs turn out to be different from the estimated ones. Due to imperfect estimation techniques and the lack of data, the estimated and the actual project costs turn out to be different.[15] In some cases this results in cost overruns. The same logic applies to the time estimates. Therefore, delays and cost overruns can be a manifestation of "honest" mistakes on the part of government engineers.

However, as we argued in the Introduction, if cost overruns are only due to the imperfect estimation techniques, then one would expect the estimation errors to be unbiased with zero mean. Since, due to technological constraints, underestimation of cost should be as likely as overestimation. As a result, in each sector negative cost overruns should be as frequent as positive cost overruns. Moreover, as more and more projects get implemented, the officials should be able to learn from the past mistakes and avoid them in future. Therefore, cost overruns should be "small" compared to project cost.

Purposeful Underestimation

Another strand of the literature attributes cost escalations to political factors, i.e., to "lying" by politicians. According to these works, politicians

15. A strand of literature indeed attributes cost overruns to imperfect information and technical constraints and the resulting measurement errors. See Morris and Hough (1987), Gaspar and Leite (1989), Bajari and Tadelis (2001), and Arvan and Leite (1990).

understate costs and exaggerate benefits in order to make projects saleable.[16] Competition for given funds among government departments may also lead to purposeful underestimation of the initial cost. If ministries have to compete for funds from say finance ministry or the planning commission, then in order to get the funding approved they may have incentive to understate projects' cost.

In our datasets, the national highways (road) projects do not seem to suffer from this phenomenon. The implementing agency NHAI does not compete with other ministries or departments within the ministry for funds. The internal revenue and market borrowings are the main sources of funding. Though some projects have been funded by international donors such as WB, ADB, and JICA, but cost estimates are scrutinized by the funding agency. However, the railways projects seem to be vulnerable to "lying" by politicians.

Trade-off between Construction Costs and Benefits during O&M Phase

If the construction contractor has also the concession rights to collect fees from users, he will have incentives to start fee collection sooner rather than later. However, the user-fee can be levied only during the O&M phase, i.e., after construction is complete. In such a scenario, the contractor may find it profitable to complete the project ahead of schedule even if it means incurring extra cost. This additional cost if incurred will increase the total construction cost, leading to cost overruns. However, this trade-off can arise only if the contract couples the construction and O&M tasks. This indeed is the case with the PPPs contracts for NHs in India. However, such a trade-off does not arise under IR and FP contracts.

Trade-off between Construction Costs and O&M Costs

If the same construction contractor is responsible for construction and subsequently the maintenance of a project, s/he will try to minimize the life-cycle costs rather than just the construction costs. In particular, the contractor may find it incentive compatible to make quality enhancing investment during the construction phase so as to reduce the O&M costs. Quality enhancing investment will increase the construction cost, resulting in cost overruns. However, only the PPPs provide incentives to the contractor to undertake quality enhancing investment. The IR and FP contracts, in contrast, do not create such incentives.

16. See, e.g., Wachs, 1989; Kain, 1990; Pickrell, 1990; Morris, 1990; Flyvbjerg, Holm, and Buhl, 2002; Flyvbjerg et al., 2004, among others.

Incomplete Design, Contract Renegotiation, and the Hold-up

Incompleteness of project design can also cause the actual project cost to be different from the initially estimated cost. Designing of infrastructure projects is a complicated task. It involves basic work and many supplementary works. The nature and quantities of the latter works varies depending on the actual conditions at the project site. The project design can be incomplete in the following two different senses. First, the initial design may provide engineering and quantity details only of the basic works but not of the supplementary works. For example, for a highway project government engineers may not include the engineering details of flyovers or underpasses that should have been part of the project. Similarly, for a railways project the government may find that they have missed out on some safety measures in the initial design. As a matter of fact, the need of supplementary works generally arises and their details are provided only during the construction phase of the project. Supplementary works cause an addition to the list as well as quantities of work-items. Additional works inevitably lead to an increase in the project costs, even if there is no increase in the price-rate of work-items. Formally speaking, if the initial design misses out on project works then $(q_1^a, q_2^a, \ldots, q_n^a) \geq (q_1^0, q_2^0, \ldots, q_n^0)$ will hold. In such a scenario the parties will need to renegotiate the contract. The renegotiated contract will specify the additional works to be performed by the contractor and the corresponding additional payment that the government will have to make to the contractor. This clearly would mean that $C^a > C^0$ will hold.

Second, the initial design may turn out to be inadequate for the actual project site conditions. To repeat an earlier example, the optimum mix of concrete and bitumen, the type of foundations needed for flyovers, etc., depend on the quality of soil at the project site. If the work conditions turn out to be different from those for which the project was designed, there will be a change in the quantities of work-items. As a result, the actual quantities and costs are bound to be different from the estimated ones.

It is important to emphasize that the contract renegotiation in itself puts an upward pressure on the project costs to the department, even if there is no significant increase in quantities of work-items. This is so because at the time of award of the initial contract, the contractor has to compete with other bidders. However, at the time of renegotiation, there are no competitors around. As a result of this fundamental transformation in the bargaining process, the contractor is in a position to hold-up the project and, therefore, is likely to get a better deal. Specifically, the payments by the department for changed works and quantities are likely to be higher compared to the scenario in which they are incorporated in the initial design and contract themselves.

Delays

As discussed in the Introduction, infrastructure projects in India suffer from long delays, i.e., time overrun. Several factors, such as, dispute over land acquisition, slow process for regulatory clearances, inter and intra-organization failures, contractual disputes, shortage of skilled manpower, etc., are the leading causes behind delays. Several reports, including the official ones, corroborate this claim.[17] A delay in project implementation affects the actual costs. This can happen simply on account of inflation itself. If there are delays, inputs will become more expensive and, in turn, will cause an increase in the project cost. Moreover, certain overhead costs have to be met as long as the project remains incomplete. Delays will increase these costs also. Also, a long delay may cause depreciation of project assets, necessitating expenses on repairs or replacements. Therefore, delay in implementation is very likely to cause cost overrun for the project.

Regional (State-level) Factors

Local infrastructure and capacity of local contractors may have bearing on actual project costs and therefore cost overruns. If a state/region has better transport, power, and telecommunication infrastructure in place, it is expected to be easier to execute projects in that state, perhaps leading to lower cost overruns. Similarly, availability of sufficient number of experienced and capable contractors has potential to execute projects at lower cost overruns.

Here it should be noted that if the data analysis shows regional/state level differences in cost or time overruns, the same cannot be attributed to the state level differences in terms of activities, such as, cost estimation, project designing, contracting and its monitoring. For all the projects in our dataset, these activities are performed by the central government department concerned.

Other Factors

In principle some other factors, e.g., corruption, if exists, etc., can also cause the actual costs to exceed the estimated costs. Besides, one may argue, in order to reduce tax payments the contractors may be inflating the actual costs. However, for our dataset such factors do not seem to be plausible

17. See Lok Sabha (2006), LEA International Ltd. (2008), and quarterly reports of MOSPI. Also see Singh (2010).

or significant. For instance, for IR contracts in our data, projects costs are costs for the department and not for the contractor. Since costs to the department are also income to the contactor; therefore, an increase in projects costs means increase in contractor's income. This should increase contractor's tax liability and not reduce it. As regards to the PPP contactors, in fact, they enjoy income and other tax holiday of as much as 10 years (see, Anant and Singh, 2009). So, inflating cost will not help them save tax payments. The government officials also don't seem to have any incentive to inflate actual project cost figures.

***Remark 3*: *Due to the factors listed in the sub-sections "Uncertainty" to "Delays" the actual project costs will be different from the estimated costs. However, on account of the factors discussed under the Subsections "Purposeful Underestimation" to "Delays," the actual costs are more likely to exceed than be exceeded by the initial cost estimates, i.e., the estimated costs. Moreover, the other factors, such as, initial design and estimated costs, etc., held constant, on account of factors discussed in the sub-section "Trade-off between Construction Costs and Benefits during O&M Phase" and "Trade-off between Construction Costs and O&M Costs," construction costs of a project are likely to be higher, if the project is implemented using a PPP contract, as opposed to an IR or an FP contract. Therefore, ceteris paribus, the cost overruns are likely to be higher for the PPPs than for IR and FP contracts.*

Now, we are in a position to predict whether cost overruns are likely to vary across projects, for any given contract type. Here, it will help to explore the implications of project complexity for the cost overruns. It will also help to be mindful of the project cost estimation techniques actually used by project planners. Discussions with several engineers involved in project designing for road and railways sectors suggest that estimates of construction costs at the project planning stage are arrived at in the following manner: first, the cost estimates of the essential work-items are made; second, additional allowance is made for the changes in the project works due to "commonly experienced" contingencies.[18] In terms of the terminology in the sub-section "Incomplete Design, Contract Renegotiation, and the Hold-up," the estimated construction costs are arrived at by adding the estimated costs of the basic works with the estimated costs of frequently encountered supplementary works. In such a scenario, incompleteness of the initial designs and of the initial contracts is likely to increase with the "complexity" of

18. The contingency allowance is about 10–20 percent of the cost of the basic good.

projects. Since, costs of supplementary works, relative to the basic works, is very likely to increase with project complexity. However, a basic-work focused initial design is unlikely to make enough provision for them. This means that more complex projects will have higher vulnerability to renegotiations. Therefore, in view of the arguments in the sub-section "Incomplete Design, Contract Renegotiation, and the Hold-up," more complex projects are likely to exhibit higher cost overruns. Two more implications follow from this conjecture. For instance, construction projects are inherently more complex than those involving simple purchase of machinery. So, the construction projects are expected to show relatively high cost overruns. Within the class of construction projects, the cost overruns are expected to increase with the complexity.

Next, we can discuss how cost overruns will vary over time, other factors such as contract type and project complexity held fixed. Intuitively, cost overruns should decline over time. Since the initial designs should improve as engineers become more and more experienced with project planning and implementation. After all, with experience project designers will become better educated about the possible states of nature and their requirements. As a result, they will be able to include increasing number of the states of nature in the initial design itself, reducing the incompleteness of the initial design as well as of the contract. This means that, ceteris paribus, the cost overruns should decline over time. The following proposition summarizes the hypotheses following from the above discussion.

Proposition 1: *Ceteris paribus, average cost overruns will:*

1. *decrease as the project designers become more experienced;*
2. *increase with the complexity of the project;*
3. *increase with the delay, i.e., time overrun;*
4. *be higher for PPP contracts than for IR and FP contracts; and*
5. *be higher for construction projects than for simple procurement projects.*

Data, Empirical Frameworks, and Results

Data Description

Two datasets of completed infrastructure projects are used. The first dataset includes 934 projects from 17 infrastructure sectors, completed during April, 1992–June, 2009. All projects in this set, with the exception of a few road projects, have been funded and executed by the relevant department of Government of India. Each project is worth ₹200 million or more. This dataset has been compiled from quarterly reports of the program implementation division of the Ministry of Statistics and Programme Implementation (MOSPI). Projects are quite diverse in terms of the nature of activities covered. Given that projects are from 17 different sectors, ranging from Finance to Atomic Energy to Urban Development, the heterogeneity across projects is not surprising. In fact, in several cases projects within a sector are also quite diverse; e.g., some of the power sector projects are construction project while others have involved simple purchase of machines such as turbine. As is discussed in the section "Data, Empirical Frameworks, and Results," this heterogeneity means that different projects employ different contracts to complete project works. Yet, road, railways, and urban-development sectors make for a somewhat homogeneous group; most projects in these sectors are construction projects. Similarly, sectors telecom and atomic energy also make a homogeneous group in that a large number of projects in these sectors are for purchase and/or installation of equipments. In contrast, in civil aviation, ports, and power sector project activity varies from purchase of equipments to extensive construction; though many projects are predominantly construction based.

The second dataset has 195 road projects in India. These NH projects have been implemented by the National Highways Authority of India (NHAI). Source for this dataset is the NHAI. As regards road projects, there is an overlap between the two datasets. The second set includes most of the 169 road projects contained in the first dataset.[19] However, this is a larger set. Moreover, for highways projects the NHAI dataset is richer in terms of information on various project characteristics. For instance, for each project in this set we know whether it is a publically funded or a privately funded project; i.e., whether a project is a PPP or not. We also have information regarding date of award of contract for the implementation of the project, which obviously comes after the date of approval. The MOSPI provides information about the latter but not about the date of award of contract. So, this dataset enables us to explore the issues of delays and cost overruns

19. However, there are some road projects in the first dataset which are absent from the NHAI dataset, and vice versa. The difference arises because MOSPI gives information only on projects worth more than 200 million rupees and irrespective of their implementing agency. The NHAI dataset, on the other hand, includes all projects executed by NHAI but excludes national highways projects implemented by the Ministry of Roads and Surface Transport. There seem to be some reporting errors too.

during the project implementation phase by excluding the delays during the project planning stage, i.e., the delays in the award of contract.

For every project in either dataset, we have compiled information on the aspects mentioned in Table A-1. For tables and figures please see the Appendices.

Summary Statistics

Tables A-2 and A-4 provides summary statistics for the larger dataset. As is evident from the statistics, there are wide-ranging variations across sectors in terms of the number of projects, average percentage delays, and cost overruns, and their standard deviations. For analytical convenience, we have divided the MOSPI dataset into several sectoral and regional categories. The sectoral categories are: road, railways, and urban-development; civil aviation, shipping and ports and power projects; telecom and atomic energy; and, all other projects. The regional categories are: states of Punjab, Haryana, Delhi, Gujarat, and Maharashtra; states of Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala; the states of Northeast and Jammu and Kashmir; and, the rest of the Indian states. Table A-3 provides the number of projects belonging to each category. The rationale behind these groupings is explained in detail later on.

As discussed in the Introduction, among other things, this paper aims to examine the road and railways sectors with respect to delays and cost overruns, as well as to compare the performance of these two sectors. Therefore, a closer look at the data on road and railways projects is called for. I must point out that while analyzing the road sector individually we will use NHAI dataset, given its more detailed information. For the study of railways projects we are restricted to use MOSPI dataset, since this is the only source of information for these projects. Moreover, when we compare the two sectors, in the interest of consistency, we will be working with the MOSPI dataset for both the sectors.

Tables A-5–A-7 provide summary statistics for the road and railways projects. Figures A-1–A-4 show the (non-linear) time-trends for percentage time overrun, percentage cost overrun, project size in terms of the initial project cost, and the implementation phase for road sector. Similarly, Figures A-5–A-8 show how these variables have behaved over time for railways projects. As is clear from Figures A-1–A-4, project size in term of the initial project cost has increased for road projects over time. The implementation phase has also increased over the years. While cost overruns have increased over time, there has been decline in delays in percentage terms.

As far as railways projects are concerned, the initial project cost has first increased but declined during more recent years. The trend for the implementation phase is just reverse of the trend for project cost. As far as the time (cost) overruns are concerned, initial years have witnessed a decline (an increase) in delays (cost overruns). However, in recent years cost overruns have come down but delays seem to have gone up.

Regression Models

The model presented in the previous section offers several testable predictions regarding cost overruns across contracts and projects; such as for PPP versus non-PPP contracts, construction versus simple procurement projects, etc. However, to test the predictions related to project complexity and experience of the planners, we need measures of these aspects.

As far as the experience with project designing is concerned, its proxy is easier to get. We can measure it in terms of number of months that have elapsed since the start of the first project in the sector or dataset under consideration. We call the duration as TIMELAPSE. We will denote its square by TIMELAPSESQ or $TIMELAPSE^2$. Ceteris paribus, the contractual incompleteness is expected to decrease with TIMELAPSE. As a result, the cost overruns are also expected to come down. But, what can measure complexity of a project? The project size seems to be a reasonable measure of complexity. Presumably the complexity increases with project size. Since, compared to smaller ones, bigger projects involve larger number of works that are also likely to be more complicated. The designing and coordination problems naturally increase with the number and magnitude of works, in turn, increasing the complexity. If so, the issue boils down to determining the measures of project size. The data provides two measures of project size. The first is the initially estimated project cost. Following the terminology in Singh (2010a), we will call the estimated project cost to be simply the INITIALCOST.[20] The second measure is the implementation phase; the duration in which a project is initially planned to be completed. We will term this measure as the IMPLEMENTATIONPHASE, or the IMPLPHASE for short. Plausibly, as the number of works or their intricacy increases, it will take longer to complete the project. Presumably, the project planners

20. The initially expected project cost, rather than the actual cost, is a better indicator of the size and incompleteness of the contract. Due to cost overrun, the final cost can be large even for small projects. The same argument applies to the implementation phase.

will increase the implementation phase in proportion to its complexity. In other words, the IMPLPHASE should be proportional to the complexity of the project. Indeed, implementation phase seems to be a better measure of project size, its complexity, and hence of the contractual incompleteness.

As argued above, arguably any delay in implementation will also cause cost overrun for the project. At the same time, it is pertinent to keep in mind that contract renegotiation is a time consuming and generally contested process. This means the contractual incompleteness is expected to cause not only cost overruns but also delay. Moreover, organization or interdepartmental failure during the construction phase can trigger delays as well as cost overruns. These arguments suggest simultaneity between cost and time overruns. However, as is shown in Singh (2010a), while there is simultaneity between the two, the causation runs from delays to cost overruns and not the other way around. To sum up, we have the following testable predictions:

Proposition 2. *Ceteris paribus, average cost overruns will*

1. *increase with INITIALCOST;*
2. *increase with IMPLPHASE;*
3. *increase with TIME OVERRUN;*
4. *decrease with TIMELAPSE;*
5. *be relatively high for PPP contracts; and*
6. *be relatively high for construction projects.*

The analysis presented above, in the Section "Infrastructure Projects" and in this section, suggests the following regression model for percentage COSTOVERRUNS or $PCTO_t$ for short:

$$PCTO_t = \alpha_0 + \alpha_1 TIMELAPSE_t + \alpha_2 TIMELAPSE^2{}_t + \alpha_3 INITIALCOST_t + \alpha_4 IMPLPHASE_t + \alpha_5 PCTO_t + \varepsilon_{1t} \quad (1)$$

For time overrun PCTIMEOVERRUN, or PCTO for short, we will estimate the following model:

$$PCTO_t = \beta_0 + \beta_1 TIMELAPSE_t + \beta_2 TIMELAPSE^2{}_t + \beta_3 INITIALCOST_t + \beta_4 IMPLPHASE_t + \varepsilon_{2t} \quad (2)$$

We will add several dummies while estimating the above equations. Dummies DRRU, DCSPP, DTA are used to test the last conjecture in Proposition 2. DRRU is dummy for road, railways and urban-development projects, and DCSPP for projects in civil aviation, shipping and ports, and power sectors. As was discussed in the section "Infrastructure Projects," most projects in road, railways, and urban-development sectors are construction projects. Construction projects are typically more complex and therefore more difficult to plan and execute, than is the case with non-construction projects. Majority of projects in civil aviation, shipping and ports, and power sectors too involve construction and are complex even otherwise. The degree of incompleteness of the initial contract is higher for construction and complex projects. So, compared to other sectors, projects in road, railways, urban-development, civil aviation, shipping and ports, and power sectors should exhibit higher cost overruns. Separate dummies are used for two reasons: one, projects in the latter category are generally unique in terms of its requirements, so learning from across projects is limited; two, projects in road, railways, and urban-development sectors are more homogeneous, in that most projects involve construction. Dummy DTA is for telecom and atomic energy sectors. Most projects in these sectors are for procurement of equipments and machinery. Designing of such projects is expected to be fairly complete and therefore not vulnerable to cost overruns.

Apart from sectoral dummies, regional dummies have been included as well. The motivation is to capture the effects of local factors, such as, infrastructure and capacity of local contractors, on delays and cost overruns. Generally, richer states are assumed to be in possession of superior infrastructure and more capable contractors. In contrast, due to the law and order related problems as well as due to difficult terrain project implementation is likely to be difficult in the Northeastern states and Jammu and Kashmir. To check statistical validity of these conjectures, states have been clubbed in four categories. Five richest states, in terms of per-capita income, are grouped together. These are Haryana, Punjab, Delhi, Gujarat, and Maharashtra. Dummy DMRICH is used for these states.

In the next category, we have four southern states: Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu. These states have well above average per-capita GSDP and are considered to be better governed; that is why a separate dummy is needed. For these states the dummy used is DRICH. In the third category are the Northeastern states and Jammu and Kashmir with dummy DNE. Dummy DSTATE has been used for interstate projects.

The above Equations (1) and (2) form the base model. Several close versions of this model have been estimated. The estimation has been undertaken for all of the 17 sectors taken together; for road and railways sectors combined; and for road and railways sectors individually.

Results

For each variant of the base model, the relevant dataset has been treated for outliers and influential observations.[21] For each version and every application of the model the two error terms are uncorrelated with each other. However, a significant number of observations get dropped as outliers. For instance, for all the sectors together we have 928 observations, out of which 131 have turned to be outliers.[22]

ALL SECTORS. The regression results for all of the 17 sector projects are presented in Table A-8. Model 1 is the same as the base model and is estimated using the OLS technique. For this model, most of the hypotheses have turned out to be correct. For both cost as well as time overrun equations, TIMELAPSE has a negative coefficient and is extremely significant at 1 percent for time, as well as, cost overrun equation. Besides, in both the equations, the coefficient of TIMELAPSESQ is positive and significant at 1 percent. That is, the downward trend for percentage cost and time overruns is statistically significant. However, the effect is U-shaped, which is not surprising. After all, as project planners move up the learning curve, additional learning is expected to come down. The coefficient of INTIALCOST in Equation (1) is positive and extremely significant at 1 percent. The coefficient of IMPLPHASE in Equation (1) is not significant! However, at a close look this outcome should not be entirely surprising, since both INTIALCOST and IMPLPHASE are picking up the same effect, namely, the project size. Result of Model 2 confirms this conjecture. If we drop INTIALCOST, variable IMPLPHASE becomes significant. Time overrun is one of the most important factors behind cost overruns. The coefficient of percentage time overruns, PCTO, is positive and extremely significant at 1 percent. Indeed, regardless of the underlying cause, delays in implementation are a major factor behind cost overruns. As predicted, variables DRRU and DCSPP have turned out to be positive and extremely significant for delays as well as cost overruns. That is, the other factors held constant, the road, railways,

21. In order to identify outliers, studentized residuals were predicted and observations having absolute value greater than two were dropped. To identify influential points STATA's in built command for calculating leverage of each observation, DFITS, DFBETA, WELSCH DISTANCE, and COVRATIO were used (see Belsley et al., 1980).

22. A close look at the dropped outliers shows that for many projects in the dataset the time and the cost overruns figures appear to be rather incredible. Several projects have experienced very long positive time overruns and simultaneously huge but negative cost overrun. There are many projects with time overrun of 20 percent or more and negative cost overruns of at least 70 percent! Most probably these are instances of reporting errors. For more on this issue see Singh (2010a).

and urban-development projects have experienced relatively long delays and high cost overruns. The same is the case with civil aviation, shipping and ports, and power sector projects. However, dummies DTA and DSTATE have not shown any consistency. Projects in Telecom and Atomic energy sectors have shown longer delays but lower cost overruns; the technological breakthroughs in these sectors could be one possible reason.

A robustness check has been done by estimating the model using Quantile regression on the entire dataset of 928 projects (see Table A-9). In view of a large number of outliers this check is helpful; compared to OLS, the Quantile regression is less vulnerable to the effects of outliers. Results are very similar to those reported in Table A-8.

ROADS. In this subsection, we take a close look at the performance of the projects delivery system for NHs, in terms of delays and cost overruns. Tables A-10 and A-11 present the relevant results. Of course the sectoral dummies are not relevant here. For projects we estimate the following equations:

$$PCTO_t = \alpha_0 + \alpha_1 TIMELAPSE_t + \alpha_2 TIMELAPSE^2{}_t + \alpha_3 INITIALCOST_t + \alpha_4 IMPLPHASE_t + \alpha_5 PCTO_t + \alpha_6 DPPP_t + \alpha_7 DMRICH_t + \alpha_8 DRICH_t + \alpha_9 DNE_t + \varepsilon_{1t}$$

$$PCTO_t = \beta_0 + \beta_1 TIMELAPSE_t + \beta_2 TIMELAPSE^2{}_t + \beta_3 INITIALCOST_t + \beta_4 IMPLPHASE_t + \beta_5 DPPP_t + \beta_6 DMRICH_t + \beta_7 DRICH_t + \beta_8 DNE_t + \varepsilon_{2t}$$

for cost overruns and time overruns, respectively.

First important observation relates to the effect of time overrun on cost overrun. Here effect is quadratic in nature. Informally and somewhat loosely speaking, this implies that short delays in implementation do not matter much for cost overruns. However, long delays do seem to contribute to cost overruns.[23] As far as variables TIMELAPSE, and TIMELAPSESQ are concerned, both are highly significant and the results are similar to those for all the sectors combined. That is, other things held fixed, the effect of TIMELAPSE is quadratic in nature for both delays as well as cost overruns, as before. However, results are different regarding variables INITIALCOST and IMPLPHASE. In contrast, now the variable IMPLPHASE in Equation (1) is positive and extremely significant at 1 percent. That is, when the effect of

23. If we estimate the base model without PCTIMEOVERRUN square, the PC-TIMEOVERRUN does not come out to be very significant. Value of R-square also suggests that it is a better model for road sector.

other factors is held fixed, cost overruns swell as IMPLPHASE increases. The result is as expected. However, the coefficient of INITIALCOST in Equation (1) is negative though not very significant. As predicted earlier, implementation phase seems to be a better proxy of contractual incompleteness. In Equation (1), the coefficient of INITIALCOST is positive and significant implying that delays increase with the project size. On the other hand, IMPLPHASE has negative and extremely significant (at 1 percent) effect. That is, ceteris paribus, time overrun decreases with implementation phase! However, on a closer look, the result makes sense. For illustration, consider two same-sectors (which indeed is the case here) with same-works and therefore same-cost projects. Between these projects, the one with the longer IMPLPHASE should show shorter percentage time overrun; since it has already got more time to complete the same number of works. While absolute time overrun may and is likely to increase with project size/IMPLPHASE, ceteris paribus, there is no reason to expect delays to increase in percentage terms with the IMPLPHASE.

What is the combined effect of the IMPLPHASE and INITIALCOST variables? It seems the implementation phase is driving the results. Since the implementation phase has gone up in recent years, as a consequence while there has been decline in the percentage time overruns, but cost overruns have increased. Figures A-1–A-4 depict these conclusions clearly; note that the implementation phase and the cost overruns have moved in the same direction.

As is clear from the results in Table A-11, the above discussed other variables continue to have the same signs and the levels of significance. However, the rich states do not show significantly and consistently superior performance. The results are robust to the choice of the datasets (with and without outliers) and regression technique used. However, the number of outliers identified by the STATA continues to be significant; it dropped 57 observations as outliers.[24] To confirm veracity of the above results, I have run Quantile regressions.

As far as PPP projects are concerned, as one would expect, PPP projects have experienced shorter time overruns. However, the results are very striking with respect to cost overruns. Controlling for the effect of several relevant project characteristics, compared to non-PPP projects PPP projects have exhibited significantly higher cost overruns. The coefficient of PPP

24. This disquieting feature is common to all of OLS regressions, regardless of the model used and the sector studied.

dummy is positive and extremely significant at 1 percent. These findings imply important policy lessons and are discussed in the last section.

While in view of the arguments presented in the sub-sections "Trade-off between Construction Costs and Benefits during O&M Phase" and "Trade-off between Construction Costs and O&M Costs" the result regarding relatively high cost overruns in PPPs is not surprising, nonetheless we need to discuss several other possibilities. May be the relatively high cost overruns in PPPs are a result of deliberate underestimation of the initial cost or of some strategic behavior on the part of PPP contractors. Besides, we need to be mindful of one potential source of endogeneity; there could be some factors which affect cost overruns as well as the PPP outcome, i.e., whether a project will attract PPP or not.

As regards to the first issue, the estimates of project cost (INITIALCOST) and time (IMPLEPHASE) are arrived at by the NHAI[25] for both PPP as well as non-PPP projects. Moreover, these estimates are arrived at before the outcome whether a project will attract private investment, i.e., become PPP, is known.[26] A priori there seems to be no reasons for deliberate underestimation of project costs for PPPs. As far as strategic exaggeration of actual cost by the contractor is concerned, as per the MCA—the contract document for PPPs—and other official documents, the contractor does not stand to gain by inflating the actual cost figures; VGF[27] is determined on the basis of the INITIALCOST and not on the actual cost. Moreover, the contractors are provided tax exemption for 10 years. So, it is difficult to attribute the above difference in cost overruns to strategic reasons, even if they are there. To guard against the endogeneity with respect to choice of projects for PPPs, in Equation (1) on percentage cost overruns, we have included most of the variables that significantly affect the likelihood of a project being taken up as PPP.[28] These variables are not correlated with the error term, so the OLS estimates are likely to be consistent.

Furthermore, it is relevant to point out that the relative high cost overruns in PPPs cannot be attributed to the "Trade-off between construction costs and income from the O&M phase" as discussed in the Subsection "Trade-off between Construction Costs and Benefits during O&M phase."

25. More specifically, the consultants hired by NHAI provide these estimates.

26. Most of PPPs in the data have been formed after 2005. Since 2005 NHAI has offered all projects on PPP basis. A project is implemented with IR contracts, only if it does not attract PPP.

27. Viability gap funding (VGF) is the official grant provided to contractor for unviable projects. For such projects, the bidders submit (asking) bids for this amount.

28. See Anant and Singh (2009).

To see why, note that the IMPLPHASE along with TIMEOVERRUN together are nothing but the total construction time. Therefore, we have already controlled for the total construction time, though indirectly.

However, there is one factor that can potentially increase cost of PPPs more than that of the non-PPPs. It is possible that the PPP contractors during the construction phase find it in their interest to increase the scope of projects. Since with additional/ supplementary projects works they may be able to provide better road services; which, in turn, will secure them higher revenue income. If so, PPP contractors are likely to put in greater effort to convince the department of the desirability of additional works. The IR contracts, in contrast, do not induce contractors to put in such efforts. Due to the reasons discussed in the sub-section "Incomplete Design, Contract Renegotiation, and the Hold-up" additional works lead to cost overruns. The nature of data available at present does not permit an across the board control of this effect.

To sum up, it does not seem to be implausible to attribute the relatively high cost overruns in PPPs to the factors cited in the sub-section "Incomplete Design, Contract Renegotiation, and the Hold-up" and, to an extent, to the quality investment as discussed in the sub-section "Trade-off between Construction Costs and O&M Costs."

RAILWAYS. The regression model used for railways projects is the same as our base model and the one used to study road projects. Again, the sectoral dummies are not relevant here. Now, instead of PPP dummy we have DCIVILENG dummy among the list of explanatory variables; railways sector has no completed PPP project. Railways projects have been clubbed in two categories, namely, civil construction projects and others. DCIVILENG is a dummy for the former category of projects; other projects are largely for procurement and installation of equipments, etc. Specifically, for railways projects we estimate the following equations:

$$\begin{aligned} PCTO_t = {} & \alpha_0 + \alpha_1 TIMELAPSE_t + \alpha_2 TIMELAPSE^2{}_t \\ & + \alpha_3 INITIALCOST_t + \alpha_4 IMPLPHASE_t + \alpha_5 PCTO_t \\ & + \alpha_6 DCIVILENG_t + \alpha_7 DMRICH_t + \alpha_8 DRICH_t + \alpha_9 DNE_t + \varepsilon_{1t} \end{aligned}$$

$$\begin{aligned} PCIO_t = {} & \beta_0 + \beta_1 TIMELAPSE_t + \beta_2 TIMELAPSE^2{}_t \\ & + \beta_3 INITIALCOST_t + \beta_4 IMPLPHASE_t + \beta_5 DCIVILENG_t \\ & + \beta_6 DMRICH_t + \beta_7 DRICH_t + \beta_8 DNE_t + \varepsilon_{2t} \end{aligned}$$

for cost overruns and time overruns, respectively. Tables A-10 and A-12 show the regression results for railways projects. As far as results are concerned, variables TIMELAPSE and TIMELAPSESQ have shown results that are similar to those for all the sectors combined and for the NH projects. That is, the U-shape effect continues for delays as well as cost overruns. The coefficient of IMPLPHASE in cost overrun equation is positive and extremely significant at 1 percent. Moreover, the coefficient of INITIALCOST in the equation is also positive and significant. That is, when effect of other factors is held fixed, percentage cost overruns increase with IMPLPHASE as well as with INITIALCOST. As was the case with road projects, in Equation (2), IMPLPHASE has negative and extremely significant at 1 percent effect; i.e., other factors held fixed, percentage time overruns decrease with the implementation phase, perhaps due to the similar reasons. INITIALCOST has no significant effect on time overruns. As before, project implementation is not significantly better in rich states. As regards to the combined effect of variables INTIALCOST and IMPLPHASE, again, the implementation phase seems to be driving the results. Earlier years experienced a decline in delays and cost overruns due to declining implementation phase. In recent years cost overruns have gone up along with the implementation phase. Figures A-5–A-8 show these trends clearly; the movements of cost overruns and the implementation phase are in the same direction.

However, the result related to the dummy DCIVILWORKS is of special interest. Note that both in Equation (1) as well as in Equation (2), the dummy has positive and extremely significant coefficient. This means that, compared to non-construction projects, railways construction projects have experienced significantly longer delays and much higher cost overruns; clearly an outcome predicted in the section "Cost Overruns." So, this result is yet another confirmation of validity of our theoretical model.

Railways versus Roads. If we estimate the base regression model for roads and railways project combined (MOSPI data), results are similar to the above reported findings. The results are presented in Table A-13. Yet again results related to variables TIMELAPSE and TIMELAPSESQ are exactly similar to those for all the sectors combined. The results are somewhat different regarding variables INITIALCOST and IMPLPHASE. The coefficient of IMPLPHASE in Equation (1) is positive and extremely significant at 1 percent. However, the coefficient of INITIALCOST in Equation (1) is negative though not highly significant. That is, when effect of other factors is held fixed, cost overruns swell as IMPLPHASE increases. The result is as expected. On the other hand, ceteris paribus, increase in INITIALCOST has dampening impact on percentage cost overruns! In Equation (2), IMPLPHASE has negative and extremely significant (at 1 percent) effect; INITIALCOST has no significant effect on time overruns.

That is, ceteris paribus, percentage time overrun decreases with implementation phase. Again, in view of the arguments presented above, the results are not entirely surprising.

What can we say about the relative performance of these two sectors? The signs and significance levels of the dummy DRAILWAYS in Table A-13 provide a clear answer to this question. The dummy is used for railways projects. First of all note that the coefficient of DRAILWAYS in Equation (1) is not significant at all. More specifically, controlling the effect of delays, there is no significant difference in the cost overruns exhibited by the road and railways projects. But, in Equation (2) the coefficient of DRAILWAYS is large and statistically extremely significant. That is, the other things held fixed, compared to highways projects, railways projects have suffered from significantly longer delays. Since, delays in turn are an important factor behind cost overruns; therefore, railways projects are vulnerable to relatively high cost overruns as well. This effect becomes even more pronounced if we compare just the construction projects in the two sectors; recall within railways projects, the construction (civil engineering) projects show relatively long delays and high cost overruns. Moreover, if we drop the PPP projects from the set of road projects, the dummy DRAILWAYS also becomes significant with a positive sign in the cost overrun equation. Therefore, the railways project delivery system is clearly inefficient and inferior to the one for NHs. This result is yet another demonstration of preventability of delays and the resulting cost overruns to a significant extent.

Concluding Remarks

We have analyzed projects from 17 infrastructure sectors together. Besides, we have studied the data on the road and the railways projects in detail. The following findings have emerged from the econometric analysis of all projects taken together: since 1980s the delays and the cost overruns have declined. Cost overruns have systematically declined not only in absolute terms but also as a percentage of project cost. Similar is the case with delays. However, the effect is U-shaped; delays regardless of their source are one of the crucial causes behind the cost overruns; relatively big projects have experienced much higher cost overruns compared to smaller ones. Specifically, absolute as well as percentage cost overruns soar with the project size, measured in terms of the project cost; percentage cost overruns also escalate with length of the implementation phase—the longer is the implementation phase, the higher are cost overruns in absolute as well as percentage terms;

compared to other sectors, projects from road, railways, urban-development, civil aviation sectors, as well as those from shipping and ports, and power sectors have experienced much longer delays and significantly higher cost overruns; there are no consistent regional difference, though southern states seem to have done marginally better in terms of avoiding delays in project implementation.

The analysis suggests that incompleteness of project designs and contracts may be one of the leading causes behind delays and cost overruns observed in public procurement of infrastructure in India. The incompleteness of designs and contracts results in an addition to the list of project works in the middle of the construction phase. Additional works naturally add to the project cost and the execution time leading to delays and cost overruns. The cost overruns on account of additional works are not necessarily bad. However, the incompleteness of initial design and contract necessitates midway changes. Consequences of the changes in work-items are qualitatively different in nature. Changes in the ongoing works cause wastage of resources, apart from delays in implementation; which, in turn, lead to avoidable cost and time overruns. The wastage becomes increasingly pronounced with an increase in the project size or its complexity. For similar reasons and as is demonstrated by the empirical findings, compared to non-construction projects, those involving construction are more susceptible to cost overruns; and, compared to the other sector projects, road, railways, and urban-development projects are more vulnerable to cost overruns. Our findings suggest that a better initial designing may help reduce delays and cost overruns.

I must point out that the available data does not permit quantitative measuring of the changes in design and the consequent changes in work-items. Therefore, we cannot be completely sure of how the incompleteness of design and contracts adds to delays and cost overruns. Indeed, further empirical research is needed on this issue. Nonetheless, case studies cited in the Introduction suggest that our arguments are not quite unfounded. The MOSPI reports too cite the change in project scope as one of most important and frequent reasons behind delays and cost overruns. Moreover, empirical results with respect to our proxies for project complexity—the implementation phase and the project cost—also corroborate this belief. Cost overruns increase with project size, especially when measured as the implementation phase. Presumably, project complex increases with its size and so does the incompleteness of design, which, in view of the above discussed reasons, leads to higher cost overruns.

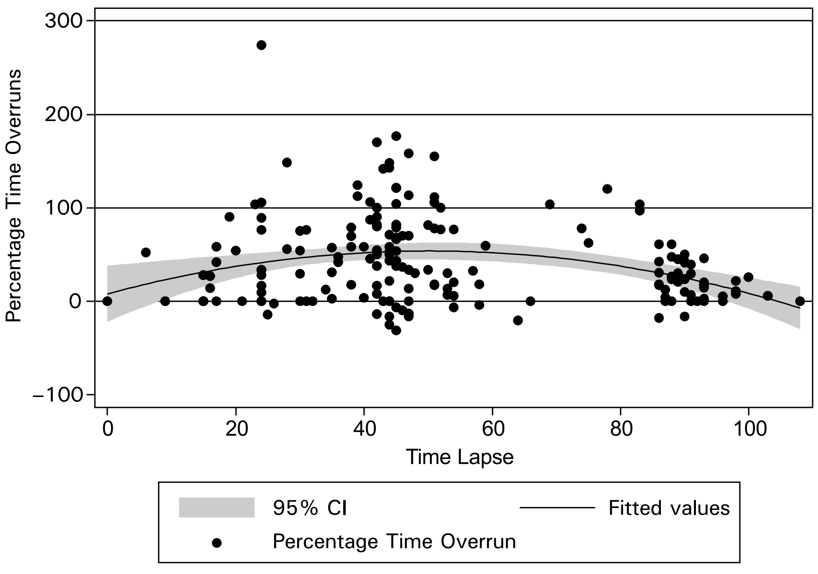
By the very nature of contractual relationship, there cannot be perfect alignment of a contractor's objective with the social objective. Moreover, the nature of infrastructure projects and contracts is such that every desirable term cannot be put in black and white. This, among other things, allows a contractor to reduce his costs at the expense of quality without violating the letter of the contract. The presence of corruption can make this problem all the more serious. Nonetheless, our findings suggest that the choice of the procurement contract and its management subsequently plays very important role in aligning or misaligning of the incentive structure of contractors with the social objective.

More specifically, the results show that the choice of the procurement contract has significant bearing on the level of delays. The traditionally used IR contracts do not provide right kind of incentives; under these contracts, the contractor does not have incentives to make quality investment or to avoid delays. The PPP contracts, by bundling the responsibility of maintenance with construction, motivate the contractor to desist away from quality shading efforts. In fact, he may have incentive to invest in quality in order to reduce his costs during the O&M phase of the project. Further research is needed to test the empirical validity of this conjecture. Moreover, the contractor has strong interest in completing the project as soon as possible. Since, the project revenue flows can start only after its completion. This line of reasoning is amply corroborated by the empirical finding regarding PPP projects on NHs. Compared to non-PPPs, PPP projects have experienced significantly higher cost overruns, but much lower time overruns. In view of the fact that delays are one of leading causes behind cost overruns, these findings on PPP projects imply interesting inferences and policy lessons. One, factors other than delays are largely responsible for cost overruns experienced by the PPP projects. Perhaps future research will indentify the relevant causes. Two, different contracts provide different incentive to the contractor regarding contract management and timely completion of the project. It goes to show that with a suitable choice of contract, it is possible to manage time better and lower the cost overruns (due to delays) in the process. I must emphasize that these merits of PPPs do not per se make a case for them; there are several relevant issues that have not been considered here. Three, the contracts are likely to deliver better outcome if they club the responsibility of project maintenance with that of construction, as is the case under PPPs.

Organizational factors, such as decision-making processes within the project sponsoring department, interdepartmental coordination, etc., also seem to be responsible for delays. Our comparison of road with railways projects confirms this belief. Most of the road as well as railways projects (in MOSPI data) have used IR contracts; so presumably, the incentive structure for contractors in both the sectors is similar. Yet, instances as well as magnitude of delays are much higher for railways projects. As a result, the cost overruns attributable to delays are also higher for railways projects. This is mainly due to three reasons. One, the slow processing of railways projects during tendering and contracting phase. The available data indicates so, though the issue needs to be explored further. Second, the poor contract management by railways. While the NHAI awards most of works to one contractor, the railways award different works to different contractors. This inevitably complicates the coordination process for project works. Third, fund allocation procedure of adopted by the railways. Every railways project is allocated funds each year that too latter half of the year. NHAI procedures do not suffer from these limitations. These findings offer yet another policy lesson: there is need to improve the incentive and resource allocation structures within the government departments.

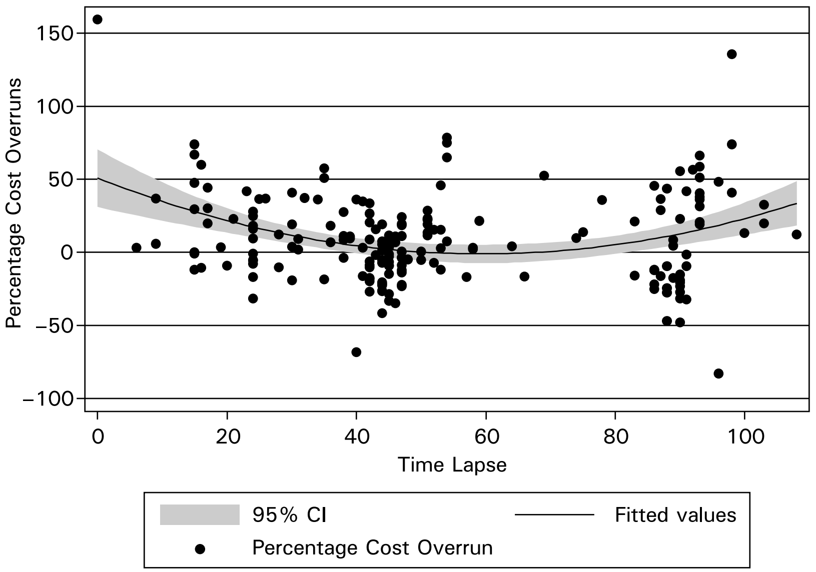
APPENDIX

FIGURE A-1. Percentage Time Overrruns Over the Years (Roads) (Nonlinear Trend)



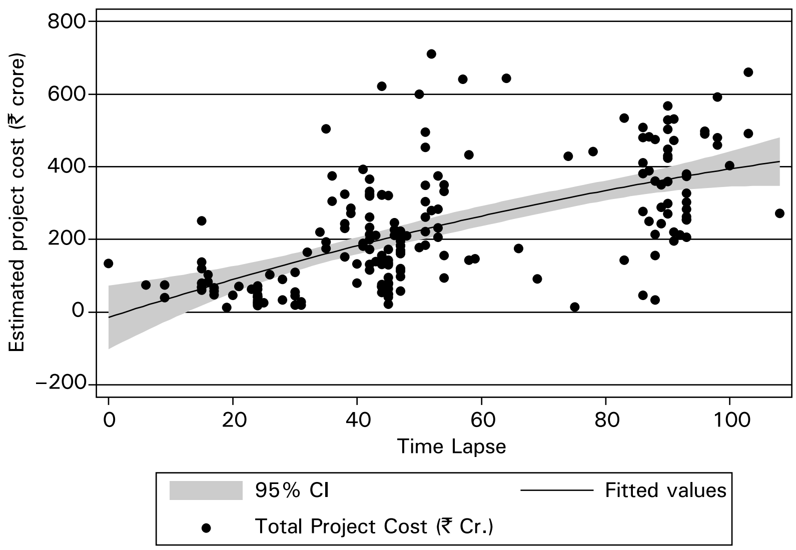
Source: Data discussed in Section 4.

FIGURE A-2. Percentage Cost Overrruns Over the Years (Roads)



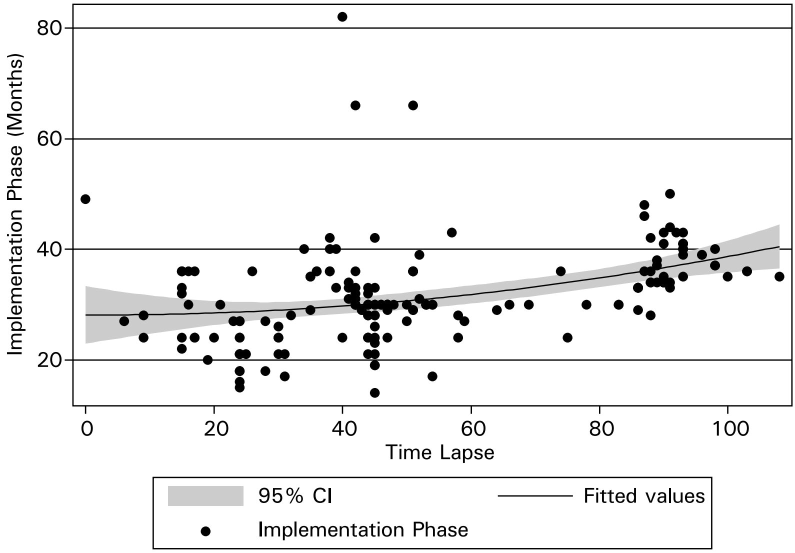
Source: Data discussed in Section 4.

FIGURE A-3. Initial (Estimated) Project Cost Over the Years (Roads)



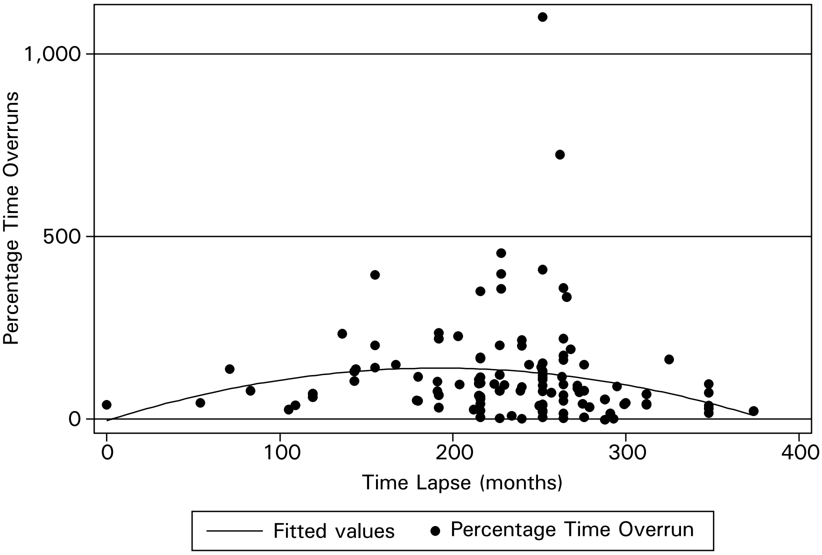
Source: Data discussed in Section 4.

FIGURE A-4. Implementation Phase Over the Years (Roads)



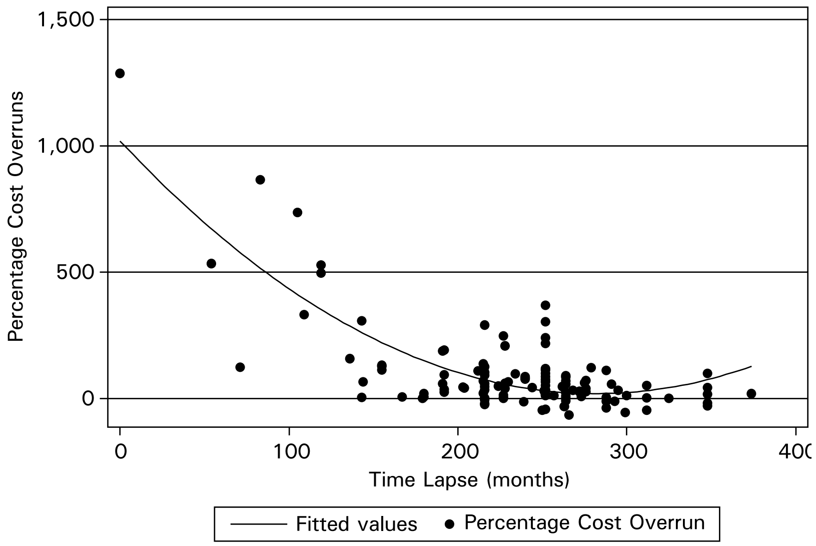
Source: Data discussed in Section 4.

FIGURE A-5. Percentage Time Overrruns Over the Years (Railways)



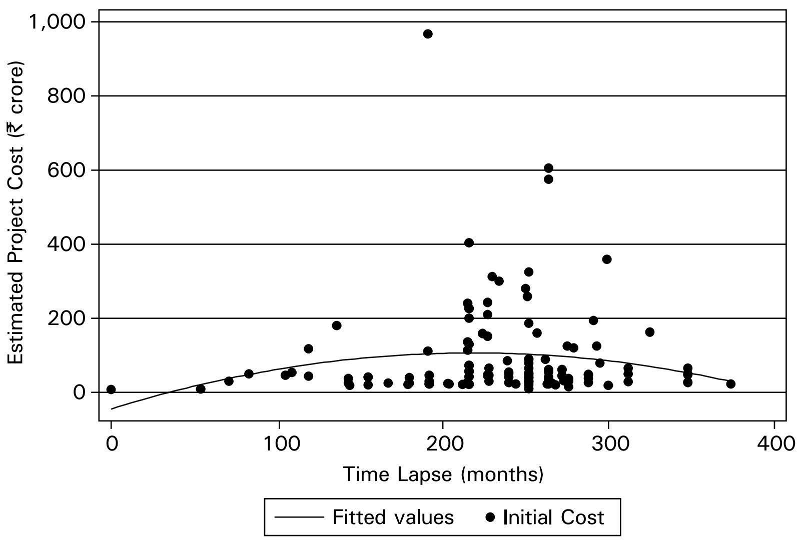
Source: Data discussed in Section 4.

FIGURE A-6. Percentage Cost Overrruns Over the Years (Railways)



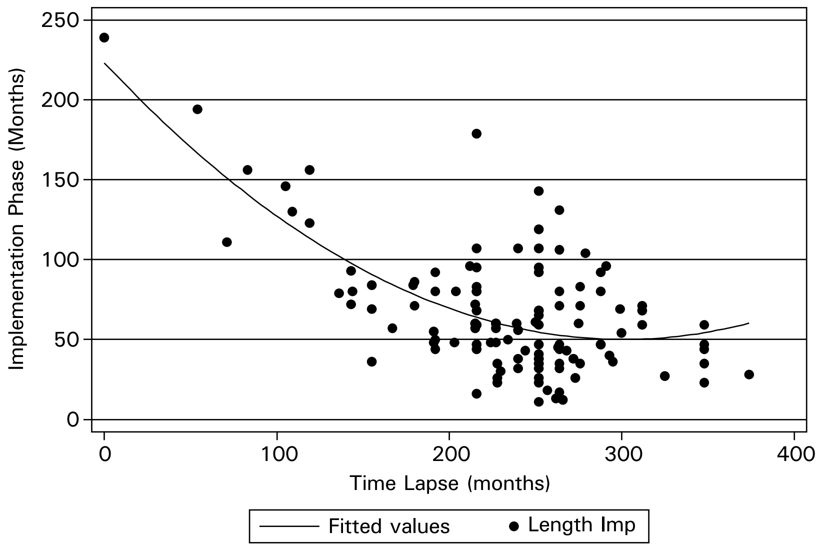
Source: Data discussed in Section 4.

FIGURE A-7. Initial (Estimated) Project Cost Over the Years (Railways)



Source: Data discussed in Section 4.

FIGURE A-8. Implementation Phase Over the Years (Railways)



Source: Data discussed in Section 4.

TABLE A-1. Data: Aspects and Sources

S. no.	*Aspect/variable*	*Description*	*Data source*
1	DATE OF PROJECT START	It is the date of approval of the project.	MOSPI reports and the NHAI.
2	INITIAL/EXPECTED DATE OF COMMISSIONING	It is the initially planned (i.e., expected) date of completion of the project.	MOSPI reports and the NHAI.
3	ACTUAL DATE OF COMMISSIONING	It is the actual date of completion of the project.	MOSPI reports and the NHAI.
4	TIMEOVERRUN	The time difference (in months) between the actual and the initially planned date of completion; Time difference between (3) and (2), above.	OUR CALCULATIONS based on the data collected from MOSPI reports and the NHAI.
5	IMPLEMENTATION PHASE (IMPLPHASE)*	The duration in which a project is planned to be completed, i.e., the duration between the date of approval of the project and its *expected* date of completion.	OUR CALCULATIONS based on the data collected from MOSPI reports and the NHAI.

(*Table A-1 continued*)

(*Table A-1 continued*)

S. no.	*Aspect/variable*	*Description*	*Data source*
6	PCTIMEOVERRUN (PCTO)*	The ratio of the time overrun and the implementation phase for the project (multiplied by one hundred).	OUR CALCULATIONS based on the data collected from MOSPI reports and the NHAI.
7	INITIAL/EXPECTED PROJECT COST (INITIALCOST)	The initially projected (i.e., expected) cost of the project.	MOSPI reports and the NHAI.
8	ACTUAL PROJECT COST	The actual cost at the time of completion of the project.	MOSPI reports and the NHAI.
9	COST OVERRUN	The difference between the actual cost and the initially projected (i.e., expected) cost of the project.	OUR CALCULATIONS based on the data collected from MOSPI reports and the NHAI.
10	PCCOSTOVERRUN (PCCO)	The ratio of the cost overrun and the initially anticipated cost of the project (multiplied by one hundred).	OUR CALCULATIONS based on the data collected from MOSPI reports and the NHAI.
11	TIMELAPSE	It is the time (in months) that has lapsed since the date of approval of the *first* project in the relevant dataset. For all sectors projects it is the time that has lapsed since May 1974. For the set of railways projects it is the same, i.e., May 1974. For the NHAI dataset on projects it is August 1995.	OUR CALCULATIONS based on the data collected from MOSPI reports and the NHAI.
12	SECTOR	The infrastructure sector to which the project belongs.	MOSPI reports.
13	STATE	The state in which the project is located.	MOSPI reports and the NHAI and publications of the Ministry relevant for the sector.

Source: Data discussed in Section 4

Note: *Definition for NHAI dataset is somewhat different and has been explained in the text.

TABLE A-2. Summary Statistics: All Sectors

Sector	Number of projects	% Cost overrun				% Time overrun			
		Mean	Std. dev.	Min	Max	Mean	Std. dev.	Min	Max
Atomic energy	12	15.05	113.12	−84.89	265.12	301.02	570.48	−3.13	2,033.33
Civil aviation	51	−2.07	38.97	−80.32	109.18	67.20	56.01	−12.20	289.29
Coal	102	−11.42	91.72	−99.73	466.23	30.42	69.70	−93.33	359.57
Fertilizers	16	−12.57	28.92	−67.75	50.13	26.53	41.80	−18.18	109.30
Finance	1	132.91	–	132.91	132.91	302.78	–	302.78	302.78
Health and family welfare	2	302.30	92.96	236.56	368.03	268.04	208.63	120.51	415.56
I & B	7	14.00	62.97	−34.60	134.64	206.98	140.57	101.67	491.43
Mines	5	−33.16	20.65	−62.78	−9.88	42.44	36.23	−2.78	98.11
Petrochemicals	3	−12.22	25.92	−28.40	17.68	74.43	3.05	70.91	76.19
Petroleum	125	−15.82	29.12	−80.87	106.77	38.52	50.31	−41.67	242.86
Power	108	51.09	271.36	−61.83	2,603.96	33.55	54.89	−50.00	202.08
Railways	130	94.06	178.33	−65.49	1,287.98	118.05	141.13	−2.17	1,100.00
Road transport and highways	169	14.50	61.09	−93.86	416.72	46.48	54.66	−28.26	317.39
Shipping and ports	61	−1.35	84.35	−90.37	574.38	118.64	276.79	−7.14	2,150.00
Steel	44	−15.41	47.32	−91.85	235.88	50.49	60.08	−25.00	305.56
Telecommunication	74	−33.82	56.22	−98.40	279.46	248.82	253.98	−18.18	1,200.00
Urban development	24	12.31	50.27	−48.81	144.00	66.44	44.58	3.60	166.67
Total	934	15.06	131.26	−99.73	2,603.96	79.46	152.98	−93.33	2,150.00

Source: Data discussed in Section 4.

TABLE A-3. Category-wise Distribution of Projects (All Sectors)

Sectors/States	*Number of projects*
Road, railways, and urban-development	316
Civil aviation, shipping and ports, and power	221
Inter-state; spanning across multiple states	91
Punjab, Haryana, Delhi, Gujarat, Maharashtra	252
Andhra Pradesh, Tamil Nadu, Karnataka, Kerala	222
Northeast and J&K	64

Source: Data discussed in Section 4.

TABLE A-4. Summary Statistics: Aspects Covered (All Sectors)

Variables	*Mean*	*Std. dev.*
PCGECOSTOVRRN	15.06	131.26
PCGETIMEOVRRN	79.50	152.98
TIMELAPSE	290.03	63.59
$TIMELAPSE^2$	88,153.83	34,162.54
INITIAL COST	291.46	619.20
IMPLPHASE	45.39	48.08

Source: Data discussed in Section 4.

TABLE A-5. Summary Statistics: Delays and Cost Overruns (Road and Railways)

	Road (NHAI data)			*Railways (MOSPI data)*		
Sector	*PPPs*	*Non-PPPs*	*All projects*	*PPPs*	*Non-PPPs*	*All projects*
Number of projects	50	145	195	0	130	130
Percentage of projects with positive Time Overrun	74	78.62	77.44	n.a.	97.69	97.69
Mean Percent Time Overrun	17.49	49.30	41.14384	n.a.	116.24	116.24
Percentage of projects with positive Cost Overruns	74	55.172	60	n.a.	82.31	82.31
Mean Percent Cost Overruns	21.39	5.98	9.93	n.a.	90.199	90.199

Source: Data discussed in Section 4.

TABLE A-6. Summary Statistics: Road Projects (NHAI Data)

Variable	*Mean*	*Std. dev.*	*Min*	*Max*
TIME LAPSE (MONTHS)	53.18974	26.17467	0	108
TIME LAPSE Sq (MONTHS Sq)	3,510.749	3,113.801	0	11,664
INITIAL COST	226.9915	164.0463	12.15	710
IMPLEMENTATION PHASE	31.69231	8.373848	14	82
COST OVERRUN (percentage)	9.92837	31.18886	–83.014	159.097
TIME OVERRUN (percentage)	41.68907	46.64695	–31.579	274.0741
TIME OVERRUN Sq	3,902.758	7,654.422	0	75,116.59

Source: Data discussed in Section 4.

TABLE A-7. Summary Statistics: Railways Projects (MOSPI Data)

Variable	*Mean*	*Std. dev.*	*Min*	*Max*
TIME LAPSE (MONTHS)	233.7642	61.07575	0	374
TIME LAPSE Sq (MONTHS Sq)	58,345.63	26,145.37	0	139,876
INITIAL COST	93.63854	130.8549	6.74	968
IMPLEMENTATION PHASE	65.78862	38.10065	11	239
COST OVERRUN (percentage)	94.06268	178.3289	−65.49	1,287.98
TIME OVERRUN (percentage)	118.0493	141.1263	−2.17	1,100
TIME OVERRUN Sq	33,690.33	121,846.7	0	1,210,000

Source: Data discussed in Section 4.

TABLE A-8. All Sectors

	Model 1		*Model 2*	
Variables	*PCGETIMEOVRRN (% Time overrun)*	*PCGECOSTOVRRN (% Cost overrun)*	*PCGETIMEOVRRN (% Time overrun)*	*PCGECOSTOVRRN (% Cost overrun)*
PCGETIMEOVRRN		0.0854		0.0949
		[0.0224]		[0.0220]
		(0.000)		(0.000)
TIMELAPSE	−2.8993	−2.7328	−2.2846	−2.3500
	[0.3714]	[0.3662]	[0.3037]	[0.3782]
	(0.000)	(0.000)	(0.000)	(0.000)
TIMELAPSE Sq	0.0039	0.0043	0.0029	0.0037
	[0.0006]	[0.0006]	[0.0005]	[0.0006]
	(0.000)	(0.000)	(0.000)	(0.000)
INITIAL COST	−0.0016	0.0144		
	[0.0053]	[0.0033]		
	(0.758)	(0.000)		
IMPLPHASE	−1.8848	0.1430	−1.7513	0.2170
	[0.1565]	[0.1117]	[0.1449]	[0.1058]
	(0.000)	(0.201)	(0.000)	(0.041)
DRRU	52.4719	40.0284	51.1584	37.4532
	[5.3119]	[3.4134]	[5.1512]	[3.3739]
	(0.000)	(0.000)	(0.000)	(0.000)
DCSPP	23.1145	20.1239	21.7332	17.5595
	[4.7073]	[3.3279]	[4.6854]	[3.3167]
	(0.000)	(0.000)	(0.000)	(0.000)
DTA	155.6228	−29.5410	159.2271	−33.5075
	[17.3884]	[6.9564]	[17.5965]	[6.6734]
	(0.000)	(0.000)	(0.000)	(0.000)
DSTATES	−9.5303	3.9355	−12.2252	4.7312
	[6.1470]	[4.9466]	[5.6048]	[4.6512]
	(0.121)	(0.427)	(0.029)	(0.309]
DMRICH	−2.6099	−0.4604	−2.9584	1.6575
	[5.5619]	[3.2476]	[5.2901]	[3.2676]
	(0.639)	(0.887)	(0.576)	(0.612)
DRICH	−4.8560	−4.7192	−6.2061	−4.2426
	[5.0631]	[3.0916]	[4.9688]	[3.0811]
	(0.338)	(0.127)	(0.212)	(0.169)
DNE	−2.8802	14.1414	3.1680	15.5355
	[7.4362]	[6.3857]	[11.1237]	[7.9015]
	(0.699)	(0.027)	(0.776)	(0.050)

(*Table A-8 continued*)

(*Table A-8 continued*)

Variables	Model 1 PCGETIMEOVRRN (% Time overrun)	Model 1 PCGECOSTOVRRN (% Cost overrun)	Model 2 PCGETIMEOVRRN (% Time overrun)	Model 2 PCGECOSTOVRRN (% Cost overrun)
CONSTANT	615.0301	383.9315	514.6568	324.6392
	[56.1885]	[55.8855]	[45.2008]	[58.0830]
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	797	797	793	793
R-squared	0.4856	0.4521	0.4698	0.4059

Source: Data discussed in Section 4.

Note: *White's heteroskedastic consistent estimates. Robust standard error in brackets. P-value in parentheses.

TABLE A-9. All Sectors Quantile Regression

Variables	Model 1 PCGETIMEOVRRN (% Time overrun)	Model 1 PCGECOSTOVRRN (% Cost overrun)	Model 2 PCGETIMEOVRRN (% Time overrun)	Model 2 PCGECOSTOVRRN (% Cost overrun)
PCGETIMEOVRRN		0.0238		0.0210
		[0.0135]		[0.0108]
		(0.078)		(0.051)
TIMELAPSE	−1.6575	−3.3612	−1.6125	−3.3535
	[0.1667]	[0.1750]	[0.1631]	[0.1395]
	(0.000)	(0.000)	(0.000)	(0.000)
TIMELAPSE2	0.0019	0.0053	0.0018	0.0053
	[0.0003]	[0.0003]	[0.0003]	[0.0003]
	(0.000)	(0.000)	(0.000)	(0.000)
INITIAL COST	0.0003	0.0048		
	[0.0027]	[0.0030]		
	(0.923)	(0.112)		
IMPLPHASE	−1.3812	0.0511	−1.3557	0.0482
	[0.0389]	[0.0418]	[0.0381]	[0.0333]
	(0.000)	(0.221)	(0.000)	(0.149)
DRRU	42.0435	38.8320	41.5236	37.9306
	[4.3663]	[4.6669]	[4.2510]	[3.6947]
	(0.000)	(0.000)	(0.000)	(0.000)
DCSPP	21.3950	12.6426	21.2230	13.3243
	[4.8514]	[5.1749]	[4.7542]	[4.1366]
	(0.000)	(0.015)	(0.000)	(0.001)
DTA	126.6826	−20.3786	127.7805	−21.3393
	[6.6537]	[7.6012]	[6.5350]	[6.0619]
	(0.000)	(0.007)	(0.000)	(0.000)
DSTATES	−6.7338	9.6266	−7.0454	11.3310
	[5.9723]	[6.3671]	[5.8716]	[5.0564]
	(0.260)	(0.131)	(0.230)	(0.025)
DMRICH	−3.5019	1.7691	−4.4538	1.6225
	[4.3897]	[4.6549]	[4.3183]	[3.7226]
	(0.425)	(0.704)	(0.303)	(0.663)
DRICH	−7.1624	−1.3236	−7.1073	−0.8019
	[4.5287]	[4.7965]	[4.4368]	[3.8363]
	(0.114)	(0.783)	(0.110)	(0.834)

(*Table A-9 continued*)

(*Table A-9 continued*)

Variables	Model 1 PCGETIMEOVRRN (% Time overrun)	Model 1 PCGECOSTOVRRN (% Cost overrun)	Model 2 PCGETIMEOVRRN (% Time overrun)	Model 2 PCGECOSTOVRRN (% Cost overrun)
DNE	2.1731	14.7062	2.3591	16.0438
	[7.2072]	[7.6990]	[7.0501]	[6.1209]
	(0.763)	(0.056)	(0.738)	(0.009)
CONSTANT	404.0795	490.4227	396.2734	490.8609
	[22.5214]	[23.8009]	[22.1004]	[19.0289]
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	928	928	928	928
Pseudo R2	0.1851	0.2143	0.1851	0.2128

Source: Data discussed in Section 4.
Note: *Robust standard error in brackets. P-value in parentheses.

TABLE A-10. Time Pattern of Explanatory Variables

(a) **ROADS**—(Dropping Outliers by Inspection)*

	Time overrun (%age)		Cost overrun (%age)		Initial cost		Implementation phase	
TIME LAPSE (months)	−0.2181	2.0085	0.0249	−1.1738	3.7794	5.5607	0.1388	0.0187
Since first project	[0.0938]	[0.4613]	[0.0864]	[0.3591]	[0.3272]	[1.5707]	[0.0153]	[0.0747]
started	(0.0211)	(0.0000)	(0.7734)	(0.0013)	(0.0000)	(0.0005)	(0.0000)	(0.8028)
TIME LAPSE		−0.0191		0.0103		−0.0153		0.001
Sq (months		[0.0039]		[0.0030]		[0.0139]		[0.0006]
Sq)		0.0000		(0.0008)		(0.2727)		(0.0900)
CONSTANT	52.1228	0.7542	8.063	36.0355	25.9683	−15.0462	23.5376	26.3419
	[6.6649]	[10.5143]	[4.5329]	[9.3683]	[17.0114]	[34.1174]	[0.9854]	[2.0503]
	(0.0000)	(0.9429)	(0.0769)	(0.0002)	(0.1285)	(0.6597)	(0.0000)	(0.0000)
Observations	194	194	191	191	195	195	191	191
R-squared	0.0171	0.097	0.0006	0.0563	0.3636	0.3673	0.3004	0.3096

Note: *Robust standard errors in brackets. Robust *p* values in parentheses.

(b) **RAILWAYS**—Regression Analysis (Outliers Dropped by Inspection)*

	Time overrun (%age)		Cost overrun (%age)		Initial cost		Implementation phase	
TIME LAPSE (months)	−0.2159	1.1153	−1.8012	−7.1276	0.0941	1.1428	−0.354	−1.1845
	[0.1212]	[0.2979]	[0.4904]	[1.3761]	[0.0876]	[0.3320]	[0.0462]	[0.1377]
	(0.0773)	(0.0003)	(0.0004)	(0.0000)	(0.2849)	(0.0008)	(0.0000)	(0.0000)
TIME LAPSE		−0.0032		0.0128		−0.0025		0.002
Sq (months		[0.0007]		[0.0027]		[0.0008]		[0.0003]
Sq)		(0.0000)		(0.0000)		(0.0025)		(0.0000)
CONSTANT	154.2842	30.2869	511.9798	1,013.19	56.3142	−46.429	147.0883	225.2366
	[30.7402]	[31.4458]	[123.1152]	[171.0332]	[20.6245]	[30.8502]	[11.1512]	[15.0652]
	(0.0000)	(0.3373)	(0.0001)	(0.0000)	(0.0072)	(0.1349)	(0.0000)	(0.0000)
Observations	128	127	130	130	127	126	130	130
R-squared	0.019	0.0695	0.3841	0.6105	0.0046	0.0268	0.3148	0.4315

Source: Data discussed in Section 4.
Note: *Robust standard errors in brackets. Robust *p* values in parentheses.

TABLE A-11. Roads

	Ordinary least squares		*Quantile regression*	
Variables	*Cost overrun (%age)*	*Time overrun (%age)*	*Cost overrun (%age)*	*Time overrun (%age)*
TIME OVERRUN	–0.1744	–	–0.1215	–
(%age)	[0.1173]	–	[0.1245]	–
–	(0.1395)	–	(0.3303)	–
TIME OVERRUN Sq	0.002	–	0.001	–
–	[0.0012]	–	[0.0007]	–
–	(0.0866)	–	(0.1604)	–
TIME LAPSE	–2.1936	0.9171	–1.5213	1.2425
(MONTHS)	[0.4325]	[0.6971]	[0.4991]	[0.4690]
–	0.0000	(0.1906)	(0.0026)	(0.0088)
TIME LAPSE Sq	0.0166	–0.0095	0.0116	–0.0108
(MONTHS Sq)	[0.0035]	[0.0056]	[0.0042]	[0.0039]
–	0.0000	(0.0920)	(0.0057)	(0.0065)
INITIALCOST	–0.0214	0.064	–0.036	0.0287
(Rs Cr)	[0.0189]	[0.0268]	[0.0214]	[0.0202]
	(0.2580)	(0.0183)	(0.0947)	(0.1580)
IMPLEMENTATION	1.2234	–1.4963	0.7759	–0.8759
PHASE	[0.3130]	[0.6335]	[0.3457]	[0.2977]
–	(0.0001)	(0.0197)	(0.0260)	(0.0037)
PPP	24.4391	–17.5805	24.2055	–24.9968
–	[4.5762]	[7.5527]	[7.2033]	[6.6570]
–	0.0000	(0.0215)	(0.0009)	(0.0002)
DMRich	–5.9812	–35.0389	–5.8278	–14.9314
–	[4.1281]	[8.1718]	[7.1019]	[7.0723]
–	(0.1498)	0.0000	(0.4129)	(0.0361)
DRich	–3.1267	–9.3567	–3.284	–0.177
–	[3.8764]	[7.1885]	[5.9907]	[5.8975]
–	(0.4214)	(0.1954)	(0.5842)	(0.9761)
Constant	31.4254	68.8723	30.4993	39.2564
–	[15.2501]	[25.7870]	[16.5192]	[15.9488]
–	(0.0414)	(0.0085)	(0.0664)	(0.0147)
Observations	137	137	195	195
R-squared	0.4108	0.2694	0.1152	0.1503

Source: Data discussed in Section 4.
Note: Robust p values in parentheses; robust standard errors in brackets.

TABLE A-12. Railways Projects

	OLS regression		*Quantile regression*	
	Cost overrun (%age)	*Time overrun (%age)*	*Cost overrun (%age)*	*Time overrun (%age)*
PCGETIMEOVERRUN	0.1879	–	0.0676	–
–	[0.0995]	–	[0.0380]	–
–	(0.0615)	–	(0.0778)	–
TIMELAPSE	–6.2047	–1.6047	–3.9913	–1.3732
–	[1.0402]	[0.4244]	[0.4402]	[0.3310]
–	(0.0000)	(0.0003)	(0.0000)	(0.0001)

(*Table A-12 continued*)

(*Table A-12 continued*)

	OLS regression		*Quantile regression*	
	Cost overrun (%age)	*Time overrun (%age)*	*Cost overrun (%age)*	*Time overrun (%age)*
TIMELAPSE Sq	0.0114	0.0013	0.0069	0.0012
–	[0.0020]	[0.0009]	[0.0009]	[0.0007]
–	(0.0000)	(0.1327)	(0.0000)	(0.0855)
INITIALCOST	0.0108	0.0643	0.0805	0.0806
–	[0.1024]	[0.0716]	[0.0444]	[0.0412]
–	(0.9165)	(0.3714)	(0.0723)	(0.0527)
IMPPHASE	1.3053	–2.3793	0.8149	–1.7487
–	[0.3955]	[0.2875]	[0.2327]	[0.1825]
–	(0.0013)	(0.0000)	(0.0006)	(0.0000)
DMRICH	7.366	4.1014	12.2754	–3.8511
–	[22.2515]	[14.0262]	[14.1814]	[12.7301]
–	(0.7412)	(0.7705)	(0.3884)	(0.7628)
DRICH	–14.7929	12.9849	–13.1792	13.6612
–	[18.0243]	[18.6226]	[14.3895]	[12.6318]
–	(0.4135)	(0.4871)	(0.3616)	(0.2816)
DNE	65.4014	–10.3658	29.6939	–4.9475
–	[64.8897]	[38.9132]	[28.4047]	[25.6574]
–	(0.3157)	(0.7904)	(0.2979)	(0.8474)
DCIVILENG	72.0178	30.3371	63.7247	24.3983
–	[17.6513]	[10.8406]	[11.9872]	[10.7387]
–	(0.0001)	(0.0060)	(0.0000)	(0.0249)
Constant	724.786	527.8237	491.9026	432.3361
–	[145.2471]	[65.5411]	[66.1056]	[50.7798]
–	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	122	122	130	130
R-squared	0.76	0.5017	0.2762	0.2663

Source: Data discussed in Section 4.

TABLE A-13. Road and Railways Projects

	OLS regression		*Quantile regression*	
	Cost overrun (%age)	*Time overrun (%age)*	*Cost overrun (%age)*	*Time overrun (%age)*
PCGETIMEOVERRUN	0.2111		0.0748	
	[0.0682]		[0.0397]	
	(0.0022)		(0.0608)	
TIMELAPSE	–2.661	–1.5371	–4.313	–1.3811
	[0.8934]	[0.4691]	[0.3300]	[0.2834]
	(0.0032)	(0.0012)	(0.0000)	(0.0000)
TIMELAPSE Sq	0.0042	0.0016	0.007	0.0014
	[0.0015]	[0.0008]	[0.0006]	[0.0006]
	(0.0070)	(0.0440)	(0.0000)	(0.0145)
INITIALCOST	–0.0284	0.0511	–0.0132	0.0456
	[0.0245]	[0.0263]	[0.0263]	[0.0227]
	(0.2472)	(0.0534)	(0.6146)	(0.0453)

(*Table A-13 continued*)

(*Table A-13 continued*)

	OLS regression		*Quantile regression*	
	Cost overrun (%age)	*Time overrun (%age)*	*Cost overrun (%age)*	*Time overrun (%age)*
IMPPHASE	0.6902	−2.13	0.5561	−1.704
	[0.2075]	[0.2304]	[0.1995]	[0.1443]
	(0.0010)	(0.0000)	(0.0057)	(0.0000)
DMRICH	4.4121	−22.7683	1.0267	−10.0423
	[6.8747]	[7.0347]	[8.9337]	[7.8597]
	(0.5217)	(0.0014)	(0.9086)	(0.2024)
DRICH	3.3794	−8.6586	1.8697	−5.2196
	[5.4331]	[6.2490]	[8.1228]	[7.0547]
	(0.5346)	(0.1673)	(0.8181)	(0.4600)
DNE			18.7574	2.9748
			[20.2666]	[16.5987]
			(0.3555)	(0.8579)
DRAILWAYS	−7.974	42.2872	−0.8883	34.0317
	[7.9671]	[7.9934]	[9.3754]	[7.8898]
	(0.3180)	(0.0000)	(0.9246)	(0.0000)
Constant	386.6825	455.8811	635.6869	409.2738
	[130.8940]	[72.7784]	[52.9052]	[41.6311]
	(0.0035)	(0.0000)	(0.0000)	(0.0000)
Observations	229	229	292	292
R-squared	0.41	0.56	0.2363	0.2896

Source: Data discussed in Section 4.

Comments and Discussion

Shashanka Bhide: The paper is an important contribution towards sorting out and improving the efficiency of infrastructure development in India. I should say that my comments here are actually quibbles on a very good paper. I have three sets of comments on the overall perspective of the paper, conceptual issues, and empirics.

Overall Perspective

While at the micro or project level, the success or failure has a fatal implication to the project, at the aggregate level it translates into some successes and some failures. For example, there is addition to power generation capacity over the years. The capacity addition per year has increased from 308 MW in the 1950s to 6,770 MW in the first decade of the 21st century. This is admittedly the "glass half full" story. The "half empty glass" is that in the first two years of the Eleventh Plan, 2007–08 and 2008–09, the achievements in building power generation capacity were far below even the revised targets. For 2007–08, the target was 15, 000 MW but the realization was 9,263 MW of additional capacity. The performance has been one of improved but below par achievements. This perspective is missing from the micro level focus of the paper. The point is significant as it may provide an explanation for the inefficiency at the micro level.

If the objective of the "sponsor" is the "aggregate," chances are that there would be some prioritization of the portfolio in the presence of capacity constraints: capacity to plan, implement, and monitor. It is not clear if fewer projects were taken up, they may have been executed in time and cost. It is also not clear why certain projects get initiated when in fact there is a backlog of several projects in the portfolio. Is there an aggregate level performance indicator that allows continued poor performance when judged on the basis of individual projects? Further, there may be greater concern with the "cost overrun" as compared to "time overrun" in projects.

A second aspect of the overall perspective is the fact that the government is a party to the contract for the projects considered. Of course the peculiarities of infrastructure projects: land intensive nature or "first in development activity" in any area are important distinctions. The fact that the government is a party to the contract may have different types of risks that the other party has to bear: delays in decisions, proneness to litigation, etc. In other words, the delays and cost overruns that we observe in infrastructure projects may not be any different from other government activity.

Some Conceptual Issues in the Framework of Analysis

The paper distinguishes four stages of project implementation starting from planning to O&M. Consider the reasons for delays in execution of power projects cited by *The Economic Survey (2009–10)*: it says that delays of non-sequential supply of material, shortage of skilled manpower, contractual disputes, delays in the readiness of "balance of plants," design problems, shortage of fuel, and so on were responsible for the delays in completing the projects on time. In the vector of quantities of the contract, there is a risk that is probably understated. The reason may well be deliberate to disallow exaggeration by the contractors. In this sense, the systematic "underestimation" of costs and time needed for the projects may be an outcome of the considerable uncertainty in the process of project execution.

A common cause of delay in the execution of infrastructure projects has to do with land acquisition. There have been changes in the process over the years to help expedite execution. In the national highways (NH) projects now it is expected that 80 percent of the land required would be acquired before the projects are bid. However, even the balance 20 percent can hold up completion of the project. These are uncertainties associated with the infrastructure projects. The paper is an excellent analysis of what has happened to the impact of these uncertainties on the project outcome over time. There seems to be significant learning as the time trend has negative coefficient on the inefficiency in project completion.

The negative trend coefficient, however, hides the other matters. For instance, the rising economic growth momentum has put pressure on available supplies of materials and other resources, particularly labor of all types. The inefficiency in execution performance may increase because of this deficit in key inputs.

At a conceptual level, the paper does not take up the impact of reputation risks either for the sponsor or for the contractor from the inefficiency of project execution. Poor execution record may attract only poor performing contractors who may not worry about reputation risks. The poor execution record may also similarly attract only poor planners on the part of the government as well, unless there are incentives for better performance.

Empirical Analysis

The paper provides a number of valuable insights. But it also raises many other issues.

The estimated overall model of inefficiency in time and cost of execution provides results in line with the prior expectations of the paper. One unresolved issue which the paper refers in passing is the endogeneity of some of the variables on the right hand side. The reference is mainly to the PP dummy used in the analysis of inefficiency of execution in the NH projects.

For instance, in the main equation, the "Initial Cost" is taken as an indicator of "complexity" of the project. The potential for renegotiation may also be larger in the larger projects. But "Initial Cost" may also reflect greater care taken by the designers and planners, greater care taken in monitoring and so on affecting the performance and influenced by performance. Similarly the "Implementation phase" may also incorporate some responses to likely efficiency outcomes. Longer implementation phase may be provided to projects that are likely to face execution constraints.

There is also the issue of interaction between explanatory variables, particularly the dummy variables and the other variables. For instance, in the main equation the impact of Initial Cost or Trend may differ across sectors. This would have given some important insights. Does the inefficiency of railways increase as they handle large projects as compared to the NHAI? Or the power sector players? Have the railways learnt less than the road builders over time? Are the richer states able to handle bigger projects better than the economically weaker or poor states?

This issue of interaction terms is important because the regression equation includes a variety of projects. Even in the case of roads projects where comparison is only between PP and other roads projects, the paper argues that differences arise in the way contracts are structured: PP projects include O&M operations that potentially raise the costs in Stages 1 through 3 to derive benefits in the O&M Stage. If the larger PP road projects less inefficient than the smaller PP projects, the difference between PP and non-PP projects may be minimal in large projects.

Now to the quibbles. It makes more sense to normalize the initial cost to a constant price value rather than leave it at the nominal value. Secondly, there are macro-economic conditions that may affect project execution performance. Since the data set includes projects that have been executed in different decades over time, they have gone through very different conditions of inflation, trade regimes, forex controls, and industrial licensing regimes to say very little about the fiscal pressures. All of this may have nothing to do with project performance. But it is worth a test. All the learning effect we see in the trend coefficient may be a result of improved macroeconomic conditions.

Kenneth Kletzer: Investment in infrastructure in India is widely viewed as lagging and has become an important policy concern. The Government of India has undertaken significant moves towards increasing the stock of public capital, and the share of infrastructure investment in the public sector budget has been growing. Ram Singh's paper on public procurement is a timely contribution to the IPF. As experience and theory demonstrate, incentives in public sector contracts are critical for performance and costs. An expansion in public investment in India increases the importance of understanding how well the procurement and contracting process works in India and whether or how incentives in public contracting might be improved. This paper makes a good start in this direction using recent data on construction projects to look at contract performance.

The empirical study is motivated by the extent of cost overruns and delays to completion of publicly funded infrastructure projects in India. A highlighted observation is that mean cost overruns and time delays are positive suggesting systematic errors in project design, contract specification, or cost estimation. The variances in percentage cost overruns and time delays are also very large and the distributions are skewed to the right. Singh argues that if deviations of costs and construction time were simply due to unforeseen events, estimates would be reasonably good predictors of expected costs and completion time. Systematic cost increases suggest that incentives in contracts or in the public sector proposal process are inadequate for eliciting unbiased estimates and bids. The paper explores the sources of these cost and time overruns that can be found in the data available.

A large share of the theoretical and empirical literature on public procurement concentrates on the problem of contractor performance and incentives. Another aspect concerns agency within the government side of procurement decision making and oversight. That is, public procurement is about imperfect information and incomplete contracting. Renegotiation of contracts during the period of construction or manufacture takes place as information about actual costs is revealed. A basic lesson of this literature is that the assignment of responsibility for cost increases and input decisions between the procurer and contractor affects the magnitude of cost overruns and project quality. The choice of contract form (e.g., a fixed price or cost plus contract) will depend on the importance of contractor discretion over project quality, as demonstrated by Bajari and Tadelis (2001) cited in this paper. Singh uses this background in his estimation of what causes cost and time overruns in infrastructure projects in India. Variations in the excess of actual costs over projected costs can be caused by incompleteness in optimal contracting or by poor contract design, specification, and implementation. Suboptimal design includes such problems as vulnerability to corruption and fraud.

The paper does a really nice job of explaining the basics of public sector contracts in India. In the data used, IR contracts, which are a form of cost plus contracts, are prevalent for construction projects. Many of the road projects are PPPs which include post-construction operation by the contractor. Because the builder of a partnership project receives revenues and pays for maintenance of the finished roadway, the builder has an incentive to substitute higher quality construction for lower maintenance costs. It also faces a trade-off between construction expense and revenues by choosing to speed up construction and generate income sooner. These contracts internalize the benefits of completing a high quality project to the contractor. The test of this hypothesis is the primary result of the econometric model in the paper in my view.

The large (and significant) positive effect of a partnership contract on percentage cost overruns and negative effect on project completion delays are consistent with the theory of the incentives generated by these arrangements. As noted in the paper, most construction-related cost risks and all maintenance related risks are borne by the contractor under PPP projects. Ignoring the difference between "most" and "all" construction costs, this eliminates the wedge between the marginal construction costs and maintenance costs present in standard IR or FP construction contracts. The empirical test relies on the assumption that costs estimates by the NHAI do not take account of whether the contract includes post-construction operation and maintenance or not. If the planners estimate construction costs independently of whether the contract is a standard IR one or a partnership, then the positive coefficient estimate indicates that PPP contracts have an overall cost reducing impact. This seems to be a reasonable assumption, and the results indicate that these types of projects reduce overall costs.

A small issue is that planners probably form cost estimates on the basis experience of recently completed projects. As the composition of projects changes with a shift toward internalizing maintenance costs, initial cost estimates should rise and projected construction completion delays decrease over time. If learning leads to differentiation in estimates and bids by project type, the effect on cost and time overruns would disappear even though the incentive effects of the contracts are still working. Data that directly compares maintenance costs for partnership and non-partnership roads would be useful for confirming the positive impact of these contracts.

In the model, the controls include the initial projected cost and completion time. Projected completion time (the implementation phase) has a positive effect on the percentage cost overrun for road and railroad projects (Tables A-11, A-12, and A-13) and a negative effect on time delays. Initial cost has a positive effect on road projects alone and in the combined railroad and road regression. The implementation phase is interpreted as a proxy for the complexity of the project and the initial cost estimate measures the size of the project. The theoretical hypothesis is that more complex projects are more difficult to estimate or create more opportunities for costs increasing surprises. The result can only be suggestive in the absence of a model of why mean overruns are positive to begin with. A more complex project could have a higher variance of the difference between actual and estimated cost, but why should the mean cost overrun be higher for these projects? Perhaps, complexity and longer project implementation periods are associated with more opportunities for renegotiation. In this case, the result could indicate an escalation of the costs of incomplete contracting for the government with implementation time. If the upward bias in mean cost overruns and time delays reflects inefficiencies of the procurement process taking into account information imperfections (i.e., contracts are not constrained efficient), then an increase in project complexity could raise the welfare cost of inadequate or distorted policies.

More is said in the paper about these variables. In particular, Singh explains that the negative effect of projected implementation time on completion delays is consistent with errors in estimation. With unbiased estimates of the time to build a road with some true cost, we should find that higher time estimates are associated with negative time overruns and conversely. Given that initial cost and implementation phase are highly correlated in the data, the estimated effects of both cost overruns and time delays on the implementation phase variable are some unknown combination of the effect of project characteristics it measures and of this simple error in estimation of uncertain future costs. That said, the coefficient would be negative in both the cost and time regressions if the estimated completion time were uncorrelated to project characteristics that matter. The implementation phase does measure something about projects, but we have no idea what.

One of the major differences appearing in the data and regressions is that cost overruns and time delays are much more pronounced in railroad construction than in road construction. Indeed, it is worth emphasizing that the paper shows that the outcomes of project development, implementation, and contract administration are very different between road construction and railway construction in India. The empirical analysis in the paper demonstrates this difference, but the data do not allow the author to explain the sources of the difference between rail and road construction.

Two significant differences are revealed by the data. One is that the mean implementation phase (the estimated of time to completion) is twice as long for rail projects as for road projects. These are larger projects and expected to take longer to build. The raw data also reveals a substantial decrease in cost overruns in railroad construction over the sample period. The significance of this decline is verified by the econometric model for both cost and time overruns for rail projects (Table A-12) and for all road and rail projects (Table A-13).

First, the difference between railroad and road projects may hold a key insight into how the procurement process leads to cost and time overruns. In the paper, the rail sector appears to be the nexus of overruns, but the data does not offer measures that could explain why. Not only are overruns more frequent and larger for rail projects, but the decrease in overruns over time is impressive. This seems to me, to be the big question for understanding how contract negotiation and renegotiation, as well as project implementation and administration, affect performance in public construction procurement in India. The difference between the two sectors really suggests that procedures for putting out bids, accepting bids, and renegotiating contracts matter. I would strongly suggest trying to figure this out in future policy analysis.

The improvement in estimate accuracy over time arises for both railroads and roads in both datasets used. It might suggest experiential learning by procuring agencies, bidding contractors, and project engineers. This explanation is favored in the paper. The decrease in time could reveal procedural changes that are indirectly revealed in the data set by their effect on cost overruns and completion delays. It could be that the procuring and contracting parties are doing a better job as they learn how to build roads and railroads to expected standards. Experience can certainly lead to clearer understandings of how interim renegotiation of incomplete contracts proceeds enabling the negotiation of more sophisticated *ex-ante* incomplete contracts. I wonder if there are institutional changes that may be shortening the delays starting and finishing projects that may apply across sectors or be specific to railroad construction procurement during this period. This is another empirical regularity in the paper that suggests that contractual innovation could matter that could be related to a more detailed look at whether and how contract negotiation and execution have changed.

As it stands, the only policy experiment in the econometrics is the comparison of outcomes for PPPs. The NHAI dataset allows that. The result on the time reduction of overruns and the difference between railroad and highway projects suggests that more policy implications might be uncovered with a closer look at procurement practices or cases. A major contribution to cost and time overruns in construction projects, especially transportation projects, in India is land acquisition. The cumbersome and burden legal system and the absence of uniform procedures for acquisition are frequently credited with responsibility for delays in the initiation of construction and completion leading to consequent cost increases. It is possible that differences in site acquisition procedures could explain the divergence between overruns for railroad and road projects.

Another aspect of the contracting process could also be considered in future work. This is the role of agency on the public sector side of the procurement process. The incentives provided to project planners and engineers who oversee private contractors and renegotiate project work and costs could help explain the frequency of cost overruns and the differences across sectors. This includes corruption in the procuring agent and contractor relationship, as well as more benign incentive concerns. The datasets available do not allow the investigation of these incentive effects.

It may be useful to place the cost overruns and completion delays in Indian infrastructure projects in international perspective. Overruns and delays are commonplace in public construction projects in advanced industrialized, as well as other emerging market, economies. Some of the references in this paper study cost overruns in public procurement in advanced industrialized economies. For the sample of public sector construction projects in 20 countries over a nearly 80-year period used by Flyvbjerg, Holm, and Buhl (2003), 90 percent of all transportation projects exceeded estimated cost. For the European countries in their sample, the mean cost overrun is 22 percent for road projects and 34 percent for rail projects. Underestimation also does not decline over time for that entire sample.

In the samples of Indian projects used in this paper, cost overruns are a bit less frequent: 60 percent of road projects in the NHAI data and 82 percent of the rail projects in the MOSPI data experienced cost overruns. Further, the average cost overrun for the Indian road construction projects was just

10 percent and for rail projects was 82 percent. Time delays are particularly large in the Indian data with nearly all rail projects overdue with an average time overrun of more than 100 percent. It is also interesting to note that over the eight-decade horizon, cost and time overruns do not decline for the industrialized countries but do decline significantly over less than two decades for the Indian data.

This could be a cause for optimism. Cost overruns and completion delays in highway projects compare very favorably. The empirical finding of the paper that PPPs in road construction reveal incentive effects consistent with cost reduction also suggest a positive policy outcome. Clearly, the cost overruns and delays in railroad projects deserve a closer look and could offer some insights into contract incentives that generate possible policy reforms.

General Discussion

Rakesh Mohan (session chair) opened by noting that it will be useful to have some international comparison of PPP performance and evaluate the performance in India against it. He also noted that since the PPPs are of a relatively recent origin, it would be useful to check if there is some learning-by-doing.

T. N. Srinivasan raised three issues. First, incompleteness is a catchall term but its forms with very different implications may differ greatly. Effort may be unobservable and therefore incapable of being contracted, leading to incompleteness. There are different forms of contingencies that may arise but they may be too many to be exhaustively incorporated into the contract, leading to another form of incompleteness. Second, if we think of the paper as an exercise in pure positive economics, then it can be seen as trying to predict cost and time delays for different forms of contracts. But if it is a normative, policy exercise, then we might ask why in each situation the chosen one is the right form of the contract? Finally, we have the issue whether we can use the data to reasonably predict the cost overruns for various forms of contracts. If yes, we can anticipate the cost overruns in the future contracts and build them into the initial cost estimates in the first place. This is an issue Robert Summers had once analyzed at the Rand Corporation with respect to the military contracts.

Rohini Pande cautioned against over emphasizing the complexity and incompleteness as the source of delays and overruns. She mentioned her ongoing work on the impact of e-procurement in road projects in India and Indonesia. In India, this research looks at all the rural roads constructed under the PMGSY [Pradhan Mantri Gram Sadak Yojna] between 2000 and 2009. Over this period, 10 states moved to e-procurement at different points in time and for a subset of these states bidding data, allowing the observation of the entire tendering process, are available. What is found is that exactly the same road, if built under e-procurement as against traditional procurement holding everything else fixed, exhibits a significant decline in time overrun and better quality though no difference in cost overruns.

Abhijit Banerjee echoed Srinivasan stating that since the types of contracts are not randomly assigned to different projects, comparing outcomes without a theory of how the contracts are chosen is problematic. He also noted that cost overruns are the outcomes of the bidding process. Bidders typically understate the costs to win the contracts.

Dilip Mookherjee raised the issue that in evaluating the contracts, it is important to know the variable on which what the bidding is taking place. For instance, in the BOT type of projects, the bidding may be taking place on the eventual price the contractor would charge the customer. If so, cost overruns will impact the price charged and directly impact the customer. The social welfare implications of such cost overruns will be quite different from those on conventional projects in which the contractor bids on the delivery price only.

Suman Bery echoed Abhijit Banerjee suggesting that the overruns perhaps reflect underbidding by contractors to win the contract. Once they have won the contract, they are in a better position to renegotiate with the government since the game now becomes bilateral instead of one of winning the contract under competitive bidding against several other bidders. The fact that the negotiator at the other end happens to be the government perhaps works further to the advantage of the contractor in the bilateral bargaining.

Ritu Anand pointed out that the way to avoid the apples and oranges problem in doing the comparison would be to confine the sample to road, ports, and airports and then compare PPP and non-PPP projects. There now exist sufficiently many projects that one can obtain sufficiently large sample within each project category to make such comparison possible.

Urjit Patel pointed out that one of the reasons for establishing PPP contract in contrast with the EPC [Engineering, Procurement, and Construction] was that it gives you better value for money on a life-cycle basis. In comparing the PPP and non-PPP (e.g., EPC) projects, you need to consider the costs over the entire life cycle in both cases. In the case of PPP, costs automatically include O&M costs but the same is not true of the EPC-type non-PPP contract. The comparison must incorporate the O&M costs in the latter case. It is also useful to bear in mind that the PPP construction is higher quality because the contractor has an incentive to do so to minimize the O&M costs.

Ram Singh responded that when analyzing the PPP projects, he had restricted the sample to road projects only, thereby minimizing the apples and oranges problem. Regarding the point by Abhijit Banerjee, he stated that cost overrun in his case did not represent underbidding since he had measured them by comparing the actual costs to the costs estimated by the government officials rather than the contracted cost. Banerjee contested this, however, noting that often the bidders use the estimated cost as the focal point leading to very high correlation between the estimated and contracted prices. Ram Singh disagreed saying that in his case the estimated and contracted prices were different. Finally, Ram Singh agreed with the point made by Suman Bery that part of the problem with overruns related to the government being one of the contracting parties. He supported this by noting that the overrun problem was more severe in the railway rather than road contracts and this was perhaps because the railway ministry was much larger and poorly managed.

References

Anant, T. C. A and Ram Singh. 2009. "Public private partnership contracts in roads: Key legal and economic determinants," Working Paper No. 100, CDDRL, Stanford University.

Arvan, Lanny and Antonio P. N. Leite. 1990. "Cost Overruns in Long-Term Project," *International Journal of Industrial Organization*, 8 (3): 443–67.

Bajari, Patrick and Steven Tadelis. 2001. "Incentives Versus Transaction Costs: A Theory of Procurement Contracts," RAND Journal of Economics, The RAND Corporation, 32 (3, Autumn): 387–407.

Bajari, Patrick, Stephanie Houghton, and Steven Tadelis. 2009. "Bidding for incomplete contracts: an empirical analysis of adaptation costs," Working paper number w12051, NBER, Cambridge, MA.

Belsley, David A., Edwin Kuh, Roy E. Welsch. 1980. *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*. New York: Wiley.

Dalvi, Qasim. 1997. *Transport Planning and Policy in India*. Mumbai: Himalaya Publishing House.

Flyvbjerg, Bent, Melte K. Skamris Holm, Séven L. Buhl. 2002. "Cost Underestimation in Public Works Projects: Error or Lie?," *Journal of the American Planning Association*, 68 (3): 279–95.

Flyvbjerg, B., M. K. S. Holm, and S. L. Buhl. 2003. "How Common and How Large are Cost Overruns in Transport Infrastructure Projects?," *Transport Reviews*, 23 (1): 71–88.

Flyvbjerg, B., M. K. S. Holm, and S. L. Buhl. 2004. "What Causes Cost Overrun in Transport Infrastructure Projects?" *Transport Reviews*, 24 (1): 3–18.

Ganuza, Juan Jose. 2007. "Competition and Cost Overruns in Procurement," *International Journal of Industrial Organization*, 55 (4): 633–60.

Gaspar, Vitor and Antonio P. N. Leite. 1989. "Selection Bias Induced Cost Overruns," *International Journal of Industrial Organization*, 8 (3): 443–67.

Government of India (GoI). 2006. "Financing of the National Highway Development Programme," *Report of the Core Group,* Planning Commission, Government of India.

Government of India (GoI). 2007. "The report of The Committee on Infrastructure Financing," Deepak Parekh Committee. Available online at www.pppinindia.com (accessed on 19 June 2010).

Government of India (GoI). 2008. "Railway Budget 2008-2009", Ministry of Railways, Government of India. Available online at http://www.hindu.com/nic/railbudget2008-09.pdf (accessed on April 29, 2011).

Jonston, Paul and David Santillo. 2007. "The Dhamra-Chandbali Port Expansion Project, Critique of the Environmental Impact Assessment," Greenpeace Research Laboratories, Bangalore.

Kain, John F. 1990. "Deception in Dallas: Strategic Misrepresentation in Rail Transit Promotion and Evaluation," *Journal of the American Planning Association*, 56 (2): 184–96.

Laffont, Jean-Jacques and Jean Tirole. 1993. *A Theory of Incentives in Procurement and Regulation*. MA: MIT Press and MIT Cambridge MA.

Lewis, Tracy R. 1986. "Reputation and Contractual Performance in Long-Term Projects," *The RAND Journal of Economics*, 17 (2): 141–57.

LEA International Ltd. 2008. *Suggestion for Improvement of the PWD Costing Methods, Processes, Centralize Costing/Estimating Policy Function, Upgrade Cost Estimating Tools, Skills*, Report No 9. Submitted to Public Works Department, Government of Uttar Pradesh, Lucknow, India.

Lok Sabha. 2006. *Fourteenth Report*, *Committee on Public Undertakings (2006–2007)*. New Delhi: Lok Sabha Secretariat.

McKinsey and Company. 2009. *Building India: Accelerating Infrastructure*. Available online at http://www.mckinsey.com/locations/india/mckinseyonindia/pdf/Building_India_Executive_Summary_Media_120809.pdf (last accessed on 29 April 2011).

Merewitz, Leonard. 1973. "Cost Overruns in Public Works," in W. Niskanen, A. C. Hansen, R. H. Havemann, R. Turvey, and R. Zeckhauser (eds), *Benefit Cost and Policy Analysis*, pp. 277–295. Chicago: Aldine.

Morris, Sebastian. 1990. "Cost and Time Overruns in Public Sector Projects," *Economic and Political Weekly*, XXV (47): M-154–M-168.

Morris, Sebastian. 2003. "Public Investment in India: Delays and Cost Overruns," *India Infrastructure Report* 2003, Chapter 5.1. New Delhi: Oxford University Press.

Morris, Peter W. G. and George H. Hough. 1987. *The Anatomy of Major Projects: A Study of the Reality of Project Management*. New York: John Wiley and Sons.

Odeck, James. 2004. "Cost overruns in road construction—what are their sizes and determinants?" *Transport Policy*, 11 (1): 43–53.

Pickrell, Don H. 1990. *Urban Rail Transit Projects: Forecast versus Actual Ridership and Cost*. Washington, DC: U.S. Department of Transportation.

Raghuram, G., Samantha Bastian, and Satyam Shivam Sundaram. 2009. "Mega projects in India: Environmental and land acquisition issues in the road sector," Working Paper No. 2009-03-07, Indian Institute of Management, Ahmedabad.

Singh, Ram. 2010a. "Delays and Cost Overruns in Infrastructure Projects: Extents, Causes and Remedies," *Economic and Political Weekly*, XLV (21): 43–54.

Skamris, Melte K. and Bent Flyvbjerg. 1997. "Inaccuracy of Traffic Forecasts and Cost Estimates on Large Transport Projects," *Transport Policy*, 4 (3); 141–46.

Sriraman, S. 2003. "Capital Expenditure Budgeting Process in the Indian Railways," *India Infrastructure Report 2003*, Chapter 5.2. New Delhi: Oxford University Press.

Thomas, Michael K. 2000. *Public Sector Transport in India in the New Millennium: A Historical Perspective*. Pune: Ebenezer Publishers.

Wachs, Martin. 1989. "When Planners Lie with Numbers," *Journal of the American Planning Association*, 55 (4): 476–79.

Data/Information Sources:

CAG: Various reports
CSO: Various publications
Economic Survey: Various issues
EPW: *Economic and Political Weekly*
MOSPI: Various quarterly reports and other publications.
NHAI: Various reports and other publications.