# Impact of Inter Firm Cooperation on Social Welfare under Demand Uncertainty

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## Abstract

*Fair sharing and efficient allocation of risks, returns and resources are considered cornerstones of Public Private Partnerships. However, allocation of certain risks, like demand risks, have emerged as pain points. This paper examines the impact of demand uncertainty on a firm's bidding behavior. Applying econometric models, to check for inconsistencies in firm behavior, on bid data of toll roads awarded by the National Highway Authority of India, the paper identifies firm pairs which cooperate. Then, the paper illustrates that higher leverage and GDP growth volatility leads to a higher propensity to cooperate. In general, it is shown that firms which cooperate tend to bid more aggressively. Adjusted for probability of failure, bids by cooperating firms generate additional revenue of INR 2.8 million per kilometer for the government, and lead to a higher net social surplus. Finally, it is shown that had inter firm cooperation been nonexistent, net revenue to the government would have been 35 % lower.*

## Introduction

Inter firm cooperation, of any kind, was once considered anti competitive (Kuhn & Vives, 1995) (Novshek & Thoman, 1998), however, nowadays regulators and academia seem to acknowledge that a certain degree of horizontal or vertical cooperation could, at times, be beneficial (Nielsen, 1988) (Combs & Ketchen, 1990) (Hauenschild, 2003) (Teece, 1992). This conditional acceptance of inter firm cooperation is restricted to cases wherein firms cooperate to mitigate or diversify risks, or when firms cooperate to reduce uncertainty, typically, innovation, technology and R&D intensive industries like software, pharma and semi conductor (Shan,

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Walker, & Kogut, 1994) (Ang S, 2008) (Rothaermel, 2001) (Baumol, 2001). In most other industries inter firm cooperation continues to be viewed with suspicion. However, if firms truly cooperate to mitigate risks, parallels would exist in other industries too.

Public private partnerships, as a mode of procurement and as a tool for development, are fast gaining acceptance with Governments world over. Fair sharing and efficient allocation of risks, returns and resources are considered as cornerstones of PPP. However, at the very core striking dichotomies exists between public good and private profit, between free riding and universality, between the private sphere and the public domain, coupled multi stakeholder interests, influences and opinions. Collectively these issues severely impair the ability of the private developer to maneuver, react and respond, as they normally do while managing businesses. For example, the private party, often, has limited influence on price setting. Price cannot be set to merely maximize revenue; in fact they are often set at levels which achieve the goals of inclusion and universality, that is, at levels which maximize demand and meet the participation constraint of the project developer (Towards Fair and Efficient Pricing in Transport) (Tsai & Chu, 2003). Prices, once set, have tendency to be downwards sticky, and any upward revision meets with a lot of resistance, both from users as well as local government agencies and politicians (Estache, Gausch, & Trujillo, 2003) (Alexander, Mayer, & Weeds, 1996) (Public Private Infrastructure Advisory Facility, 2007) (Engel, Fischer, & Galetovic, Privatizing Highways in Latin America- Is it Possible to Fix what went wrong, 2003). Also, the passive nature of these services make demand highly exogenous (the firm can do very little to influence demand), the upfront costs is very high and the payback period is very long exposing the firm to interest rate risk & inflation risk (Harris & Tadimalla, 2008), and given the criticality of these projects to citizen welfare the concessionaire is also exposed to significant interference from local governments, citizen groups, politicians, regulators, policy makers (Leigland, 2008) (Eberhard, 2007) (Monsalve, 2009) (Engel, Fischer, & Galetovic, Highway Franchising: Pitfalls and Opportunities, 1997) (PPIAF-Annual Report, 2009). All of the above factors, cumulatively, make these projects riskier than the conventional engineering projects. Coupled with the above, demand and cost uncertainty has been notoriously high in such projects (Flyvberg, Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure, 2007) (Flyvberg, Curbing Optimism Bias and Strategic Misrepresentation in Planning - Reference Class Forecasting in Practice, 2008) (Flyvberg, Holm, & Buhl, What Causes Cost Overrun in Transport Infrastructure Projects, 2004) (Flyvberg, Holm, & Buhl, How Common and How Large are Cost Overruns in Transport Infrastructure Projects, 2003). For example, if we consider the case of toll roads, a study by Flyvberg et al estimates that average inaccuracy in traffic estimation is + 9.5% with a standard deviation of 44.3, with 50% of road traffic forecasts wrong by more than 20%, the inaccuracy is found in all 14 countries and 5 continents covered by his study, the inaccuracy remains constant over the last 70 years and the number of roads wherein traffic was under estimated seems to equal the number of roads wherein traffic was over estimated (Flyvberg, Holm, & Buhl, Inaccuracy in Traffic Forecasts, 2006) (Flyvberg, Holm, & Buhl, How (in) accurate are demand forecasts in Public Works Projects, 2005). Studies by Standard & Poor also result in similar conclusions. Thus, PPP projects (especially where demand risks rests with the private developer and the ability to set and revise prices rests with the government) seems to be indicative of scenarios entailing high risks and uncertainties for the private investors. In the light of the above, if inter firm cooperation is indeed considered inevitable in the face of high risk and uncertainty; it would not be surprising if firms are indeed found to be cooperating while bidding for such PPP projects. Further, it would be interesting to study the key motivations leading to cooperation (profit maximization, or market share, or risk mitigation), and the impact of the cooperation on social surplus.

Generally, the services discussed above are procured through auctions, as they are considered to be a fair and efficient method of procurement. However, In a common value auction in which bidders are differently informed, generally, the auction winner would be the bidder who had the most optimistic signal and thus the highest *ex ante* valuation (Hendricks, Porter, & Boudreau, Information, Returns, and Bidding Behavior in Ocs Auctions: 1954 - 1969, 1987) (Bulow & Klemperer, 2002). Thus such auctions are accompanied by the existence of a winner’s curse, which becomes severe as the number of bidders increase (Athias & Nunez, The More the Merrier? Number of Bidders, Information Dispersion, Renegotiation, and Winner's Curse in Toll Road Concessions). The above coupled with the fact demand forecasts have been notoriously inaccurate world over, data seems to suggest that even if the the right to construct, maintain and operate the above toll roads were to be fairly and efficiently auctioned, and even if all the bidders bid at the mean value of traffic estimated, almost half of them would fail (Athias & Nunez, Winner's Curse in Toll Road Concessions, 2008) while the other half could make super normal profits. If these were monopoly toll roads, like the national highway network in India, both failure and super normal profits would be unviable and undesirable.

The high risks have had several manifestations. For example, renegotiations have become a common phenomenon, reducing the credibility of the auction process and concession agreements. Often, it is suspected that bidders deliberately bid aggressively when they are confident of getting concession terms altered through renegotiations (Gausch, Granting and Renegotiating Infrastrcuture Concessions Doing it Right, 2004) (Gausch, Laffont, & Straub, Concessions of Infrastructure in Latin America: Government - Led Renegotiation, 2007). Also, there have been times when governments have unfairly appropriated profits or renegotiated concession terms if the firm appeared to earn super normal profits. While, at times renegotiations may be necessary, an abnormally high rate of renegotiation (about 70% (Gausch, Granting and Renegotiating Infrastrcuture Concessions Doing it Right, 2004) ) may indicate inherent weaknesses in the concession design or award process (Engel, Fischer, & Galetovic, Competition In or Competion For the Field: Which is Better?, 2002). Governments have often tried to mitigate demand risks through traffic guarantees (Vassallo & Solino, 2006); however these methods have been criticized as they essentially lead to demand risk being retained by the government and also due to adverse selection issues. The hypothesis that efficient risk allocation leads to efficiency gains, the concept of user pays, and the utility of PPP often comes in to question if all demand risks are loaded on to the government. Also, if all demand risks are loaded on to the private developer, developers while bidding are known to bid less aggressively to factor in the demand risks (Athias & Nunez, The More the Merrier? Number of Bidders, Information Dispersion, Renegotiation, and Winner's Curse in Toll Road Concessions).

Thus, considering that firms tend to prefer to cooperate when faced with high risk and uncertain environments , and given that demand risks are notoriously high even in some monopoly concessions, we attempt to identify the factors that causes such firms form cooperate. We also prove that these firms cooperate to mitigate risks rather than to rig prices in auction. In fact we demonstrate that firms which cooperate tend to bid higher than firms which do not, and adjusted for probability of failure and the event that the government may have to bail out these firms, the net social surplus is higher when firms cooperate.

The paper is divided into the following sections. In section 1, we give a brief introduction of India's National Highway Development Program (NHDP). In section 2, we discuss the bid process adopted by the National Highway Authority of India (NHAI). In section 3, the bid data and the data used for analysis is discussed. In section 4, using statistical methods, we identify firm that could have entered into cooperative arrangements with other firms. In section 5, we identify the parameters which influence the chances that firms enter into cooperative arrangements. In section 6, using each bid value, we determine the overall social surplus generated when firms cooperate and compare it with scenarios in which firms do not cooperate. In section 7, we discuss the motives behind inter firm cooperation and provide a theoretical framework to verify that inter firm cooperation, at times, does indeed result in higher social surplus.

## Description of the National Highway Development Program

For a country of India's size, an efficient road network is necessary both for national integration as well as for overall socio – economic development (PPP India: Sector Highways, 2011). India has an extensive road network of 3.3 million kilometers, the second largest in the world. The National Highway Authority of India (NHAI), the nodal agency responsible for the development, maintenance and management of national highways in India, manages a total length of 66, 950 kilometers handling 70 % of freight traffic and 85 % of the passenger traffic in India. About a decade ago, the NHAI embarked on a huge mission to build, rehabilitate, develop and augment the national highway network. The salient features of NHAI's National Highway Development Program (NHDP) are;

First, the extent of private sector involvement is unparalleled (India Leads Developing Nations in private Sector Investment , 2008). NHAI has earmarked 45, 974 kilometers to be developed through Public Private Partnerships (Financing of the National Highway Development

Programme, 2006). Planned government outlays for the National Highway Development Program is US $ 52.4 billion of which it is estimated that public private partnership projects would account for more than US $ 30 billion (Opportunities in Infrastructure and Resources in India, 2008).

Second, the Government actively tries to inculcate the discipline of 'user pays' for the provision of these services (Scheme and Guidelines for India Infrastructure Project Development Fund). The auction process clearly stipulates that every stretch of road should be first offered as a special purpose vehicle, wherein the private developer would be required to design, finance, build and operate the road, in lieu of which the developer may collect tolls at pre determined rates. Only if the road is found to be unviable, that is, the project receives no bids, would NHAI consider awarding the road on the basis of fixed annuity payments or on an EPC basis. In fact in a meeting held under the Chairmanship of the Hon'ble Prime Minister of India it was decided that (Financing of the National Highway Development Programme, 2006);

"*As regards the issue of EPC vs. BOT, 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 and onwards, all contracts for provision of road services would be awarded only on BOT basis (either based on Toll or Annuity or a suitable Toll/Annuity hybrid), with EPC awards being made in specified exceptional cases only*"

Third, the concessions awarded are monopolies, that is NHAI or the private developer do not provide competing free roads, instead, the concession agreement stipulates that no competing roads would be constructed during the concession period.

Fourth, Regulation is primarily by contract, that is, ex ante. All concessions are based on a single model concession agreement, which amongst others, details the toll to be charged per kilometer, the annual escalation, the project design, cash flow waterfall (Model Concession Agreement for Projects Above Rs 100 crore, 2010) (Overview of the MCA ) (Manual of Specifications and Standards, 2010) (Overview of the MCA - Six Laning) (Overview of the MCA - Operations and Maintenance).

Finally, the possibility of renegotiation is very low, as any changes to the concession agreement needs an approval from the cabinet committee of infrastructure and involves the opinions of multiple ministries. Thus, NHAI cannot unilaterally modify the concession agreement. Also, the concession agreement cannot be modified on a case to case basis, that is, any change in one agreement typically applies to all concession contracts. Thus, aggressive bidding with the hope of opportunistic renegotiation is minimized.

Generally, infrastructure projects are characterized by high initial capital investments, long gestation and long pay back periods. Also, demand depends primarily on exogenous factors and the providers of the infrastructure service have very little influence on demand. Additionally, unique to NHAI's highway development program, the private developers do not have the ability to fix toll prices[4] (http://morth.nic.in, 2010) (Review of oll Policy for National Highways, 2009),

[4] The toll that can be charged is fixed and constant for all NHAI projects and no deviations are permitted.

or alter the concession period[5] or renegotiate the concession contract[6]. In the light of the above, the accuracy of demand and cost estimates becomes very critical for the project developers.

## Description of the Bid Process

NHAI follows a sealed bid, first price, two stage bid process. While NHAI may award projects as an EPC contract, or an annuity[7] contract or a toll contract, in this paper we consider, only Build, Operate and Transfer Toll (BOT Toll) projects[8]. In such projects developers are required to build/ upgrade/ rehabilitate and maintain the highway stretch during the concession period.

First, NHAI announces a project through a NIT (Notice Inviting Tenders). At this stage the prospective bidders are required to purchase a document called the RfQ, 'Request for Qualification'. The prospective bidders at this stage are aware of the geographical location of the road, the length of the road, and NHAI's estimated cost (Formulation, Appraisal and Approval of Public Private Partnership Projects, 2009). From amongst the bidders who submit the RfQ, NHAI issues a list of bidders qualified to bid in the next round. The qualification is done on the basis of guidelines on net worth (financial) and project management expertise (technical) (Guidelines for Investment in Road Sector, 2009).

Next, the qualified bidders purchase the RfP, Request for Proposal. At this stage the bidders are informed of the target traffic (from which the current traffic can be calculated), the physical location of toll booths, tollable distance, design parameters and the concession period.

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[5] The concession period is fixed and known to prospective bidders. NHAI is not authorized to make any changes to the concession period apart from those already mentioned in the model concession agreement.
[6] Individual concessions cannot be modified.
[7] In an annuity contract the project developer gets semiannual annuity payments from NHAI in lieu for building, rehabilitating and maintaining the road during the concession period.
[8] In EPC or Annuity Contracts there are no demand risks for the private player.

Based on these inputs and based on their internal feasibility studies, firms may submit the financial bid as a part of the RfP. Not all firms who are eligible to bid (first stage qualified) necessarily bid, in fact almost half of the firms drop out at this stage.

The financial bids submitted by the firms can be of two types, premium and grant. Premium is the revenue that the firm would be willing to share with NHAI in lieu of the right to operate the road, during the concession period. The premium is quoted as an absolute number, is escalated by 5% annually. Firms are expected to begin paying the premium once construction is completed and tolling commences. Firms may also request for a grant (Financial Support to Public Private Partnerships in Infrastructure, 2006) if they find that the potential revenues of the road do not match required capital investment. Grants are paid upfront by NHAI to the private developer. A 'premium' bid is preferred over a 'grant' bid, and firms may quote only a premium or a grant. The firm that quotes the highest premium wins the contract, in the absence of a premium quote, NHAI considers quotes for grants and the firm which requests for the lowest grant is declared the winner.

## Detecting Inter firm Cooperation

In order to detect inter firm cooperation; we take the help of existing literature. Empirical methods to detect collusion rely mainly on four criterions (Harrington, 2005); Is behavior inconsistent with competition (Bajari & Ye, Deciding Between Competition and Collusion, 2003)? Is there a structural break in behavior (Funderburk, 1974)?; Does the behavior of suspected colluding firms differ from that of competition firms (Porter & Zona, Ohio School Milk Markets: An Analysis of Bidding, 1999) (Porter & Zona, Detection of Bid Rigging in Procurement Auctions, 1993)? Does a collusive model fit the data better than a competitive model (Porter H. , 1983) (Ellison, 1994) (Baldwin, Marshall, & Richard, 1997) ? While the first two methods could be used for detection, the next two can be used for validation, once the firms that colluded have been detected. To identify firms that cooperate we follow a statistical method developed by Bajari and Ye (2003). Assuming such auctions to be conditional independent private value auctions, the paper states that after having accounted for common information, bids should be independent (that is after accounting for all publically know information, the unexplained part of one firms bid should not be correlated to another firms bid) and that bid values should be exchangeable (a particular combination of all publicly available information should uniquely predict a bid).

The NHAI bid process involves two stages. At the first stage firms are qualified on the basis of technical and financial parameters. On qualifying, the firms are eligible to put in financial bids in the next stage. Not all firms who qualify in the first stage bid for the next stage. Typically, having qualified the first stage, firms conduct surveys to determine the actual traffic, the costs, and then based on these studies if they find a project to be profitable they put in financial bids in the second stage. Thus, we first set up regression equations (logit) to predict the entry decision of firms, that is, to bid or not to bid in the second stage.

$$\text{Log}(\text{enternotenter}_{i,p}) = \beta_0 + \beta_{1,i}\ \text{ieec}_{i,p} + \beta_{2,i}\ \text{districtgdp}_{i,p} + \beta_{3,i}\ \text{logdieselstd}_{i,p} + \beta_{4,i}\ \text{totalscbcredit}_{i,p} + \beta_{5,i}\ \text{roadensity}_{i,p} + \varepsilon_{i,p} \quad (1)$$

Firm varying coefficients are used in the above equation. ‘enternotenter’ takes values 1/0 and refers to the decision of the firms to bid (=1) or to not bid (=0) after having qualified in the first stage. ‘ieec’ refers to the independent engineer’s cost estimate, which is provided by NHAI to all firms prior to the first stage. ‘districtgdp’ refers to the average of the GDP of the districts through which the project road passes. ‘logdieselstd’ refers to the logarithm of the the standard deviation of diesel consumption in the districts through which the project road passes. ‘totalscbcredit’ refers to the total number of bank accounts in the branches of the scheduled commercial banks located in the districts through which the project road passes, this could serve as a proxy to the industrial/ commercial activity in the district. ‘roadensity’ refers to the kilometers of road for every 1, 000 square kilometer area within the state in which the project road exists, this would serve as an indicator to the number of alternate routes available. ‘i’ and ‘p’ refer to the individual company and project, respectively. A similar method was also used to differentiate between the behavior of cartel firms and non cartel firms while analyzing the data from New York State Department of Transportation (Porter & Zona, Detection of Bid Rigging in Procurement Auctions, 1993).

Next, we use heckman regression to determine the actual bid per kilometer. The bids are normalized by dividing the bid per kilomenter by the independent engineer’s cost estimate per kilometer, and the selection that happens in the first stage is also accounted for in the selection equation.

$$\text{bidperkmbyieec}_{i,p} = \beta_0 + \beta_{1,i}\ \text{currentpcu}_{i,p} + \beta_{2,i}\ \text{logdeiselstd}_{i,p} + \beta_{3,i}\ \text{loggdgrwthrate}_{i,p} + \beta_{4,i}\ \text{stdevroaddensity}_{i,p} + \varepsilon_{i,p} \quad (2)$$

‘currentpcu’ refers to the current passenger car equivalent of traffic as estimated by NHAI’s independent engineer. ‘loggdpgrwthrate’ refers to the logarithm of the GDP growth rate of the district through which project road passes. ‘stdevroadensity’ refers to the standard deviation of the road density over the last ten years.

The selection equation for the above regression consists of the standard deviation of the length of state roads in which the project road lies, the road density, the standard deviation of the road density, the average of the GDPs of the district through which the project road passes, the standard deviation of the district GDPs, the population of the district, the total number of bank accounts in the branches of scheduled commercial banks in the district, the total outstanding credit of scheduled commercial banks in the district, the total outstanding credit and the number of accounts in the branches of scheduled commercial banks in the district belonging to construction and transport companies, the total kilometers and the total cost of NHAI awarded projects already won by company 'i' and the independent engineer's cost estimate.

Conditional independence involves testing the hypothesis that correlation between $\varepsilon_{i,p}$ and $\varepsilon_{i,j}$ where $i \neq j$. Exchangeability would require that $\beta_{k,i} = \beta_{k,i}$ where $i \neq j$. We apply the two tests to each of the two equations and as a conservative measure, only those pairs which are identified in at least 3 of the 4 tests are designated as cooperating pairs. The pairs thus identified are listed below;

**Table 1: Illustrating Firm Pairs Which Cooperate**

| | | | | Heckman | | | Enter or Not | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Exchangeability | Conditional Independence | | Exchangeability | Conditional Independence | |
| Sr No | FirmA | FirmB | n | Prob > Chi2 | r | z | Prob > Chi2 | r | z |
| 1 | Firm1 | Firm2 | 15.00 | 0.17 | 0.73 | 3.51 | 0.03 | 0.49 | 1.99 |
| 2 | Firm1 | Firm3 | 10.00 | 0.00 | -0.85 | -3.72 | 0.98 | 0.67 | 2.42 |
| 3 | Firm4 | Firm5 | 12.00 | 0.01 | -0.59 | -2.24 | 0.76 | 0.76 | 3.32 |
| 4 | Firm6 | Firm7 | 21.00 | 0.00 | -0.65 | -3.46 | 0.03 | 0.48 | 2.34 |
| 5 | Firm6 | Firm8 | 17.00 | 0.03 | 0.85 | 4.96 | 0.29 | 0.55 | 2.46 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Firm9 | Firm10 | 12.00 | 0.00 | 0.79 | 3.57 | 0.04 | 0.33 | 1.13 |
| 8 | Firm9 | Firm11 | 20.00 | 0.05 | -0.31 | -1.39 | 0.03 | -0.49 | -2.31 |
| 9 | Firm12 | Firm3 | 11.00 | 0.00 | 0.80 | 3.46 | 0.11 | 0.62 | 2.41 |
| 10 | Firm12 | Firm11 | 17.00 | 0.00 | -0.85 | -5.02 | 0.04 | -0.40 | -1.66 |
| 11 | Firm13 | Firm7 | 6.00 | 0.00 | -0.96 | -4.35 | 0.24 | -0.72 | -2.01 |
| 13 | Firm8 | Firm11 | 15.00 | 0.02 | 0.94 | 6.55 | 0.05 | 0.12 | 0.45 |

**Factors Impacting Inter firm Cooperation**

Having identified firms which enter into cooperative arrangements with other firms, we analyze the factors that cause such cooperation amongst firms. Firms that do cooperate were designated as ‘1’ and the rest as ‘0’ and a logit regression was performed.

It is observed that the probability that firms cooperate seems to be strongly influenced by the number of shortlisted bidders. With every additional bidder, the probability that a firm may enter into a cooperative arrangement increases by 5%.

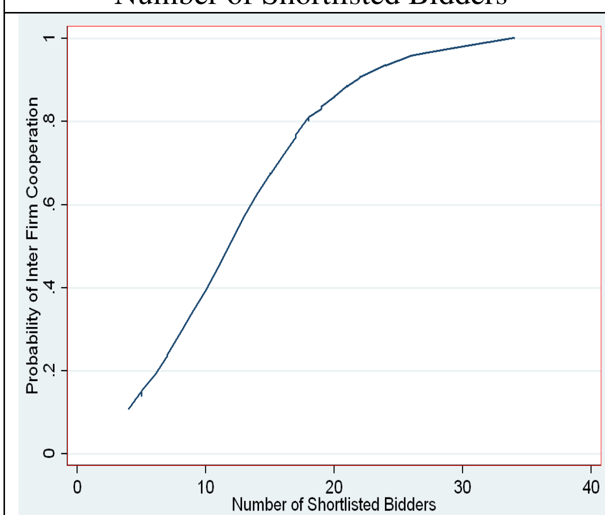
Total project cost of all NHAI projects won by a firm, could serve as a proxy to the experience that the firm may have acquired of bidding for, of constructing and of managing NHAI toll roads. Thus as the experience of the firm increases, it is quite probable that the firm may not require additional inputs from peers. Also, if firms actually enter into cooperative arrangements to hedge risks, as the firm’s own portfolio of roads increases, significant intra firm hedging of the risks occurs. Both the factors may deter firms from cooperating with other firms.

The fact there is a decline in the probability that firm cooperates with the rise of interest coverage ratio, could also be another indicator of the fact that inter firm cooperation is often used as a tool for risk mitigation. Firms with high interest coverage ratios have a higher ability to absorb demand shocks. As the ability to absorb demand shocks increases, the marginal utility of being very accurate in demand estimation decreases, which could deter firms from cooperating with other firms.

Finally, as the variation of the GDP Growth rate increases, so does the demand uncertainty and so does the propensity to form inter firm cooperative networks. Typically, commercial traffic accounts for majority of the revenue (more than 70% in India) on national highways. Movement of commercial vehicles generally mirrors the state of the economy. For example, the recent slowdown had led to significantly lower truck traffic in India. Thus, a high variance in GDP growth rate, would also translate into a high variance in traffic growth rate, making demand estimation difficult and inaccurate.

All of the above factors seem to indicate that as demand uncertainty increases or as the ability of the firm to absorb demand shocks decreases, firms increasingly prefer to cooperate with their competitors.

<table>
<tr><td>Probability of Inter Firm Cooperation<br>Vs<br>Number of Shortlisted Bidders</td><td>Probability of Inter Firm Cooperation<br>Vs<br>Square of Log GDP Variance</td></tr>
<tr><td>

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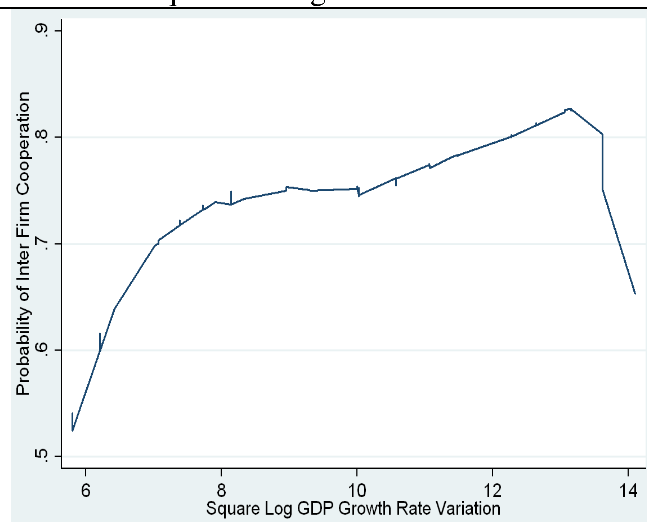


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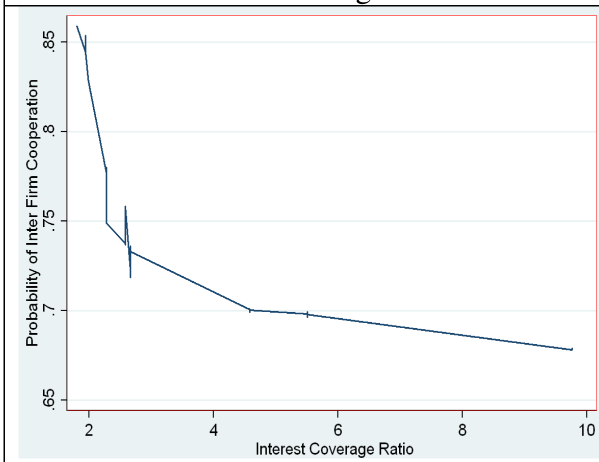
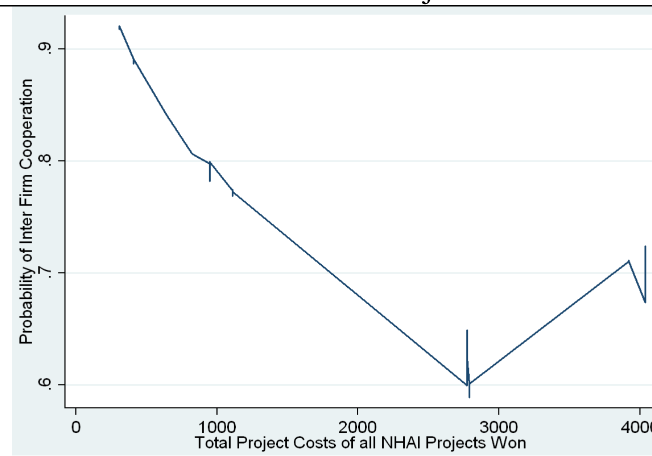
Probability of Inter Firm Cooperation
Vs
Interest Coverage Ratio




Probability of Inter Firm Cooperation
Vs
Total Cost of NHAI Projects Won




## Social Impact of Inter Firm Cooperation

When monopoly franchises are auctioned, the primary aim of the auctioneer is to maximize consumer welfare. Then, the auctioneer would try and maximize revenue to the government or minimize subsidy payment from the government.

The monopoly nature of these roads, and the fact that they form a critical part of the national highway network, makes any disruption in the availability of the road politically and economically unviable. Politically, it would be fair to assume that even if the road is 'privatized', given that there are no viable alternatives, the ultimate responsibility for the provision of the service would continue to remain with the government. Also, failure of the road due to poor maintenance, would not only affect the local population, but would also impact transnational movement of goods and people as they road is a part of the national highway network. Thus, we could assume that there exists an implicit guarantee on the continued availability of the road. However, we do not assume that the private developer would necessarily be bailed out by the government. In fact, we assume that if a road fails to generate the expected revenues, such that even the operations and maintenance costs cannot be met, then the government would provide for the O&M expenses, and the private developer would be allowed to fail. This assumption manifests two levels of failure;

Failure 1: The project cash flows cannot sustain the O&M expenses. Since O&M expenses have the senior most claim on the project cash flows, a failure to such an extent would imply that the project IRR is almost 0%. In such a scenario, the government has to provide for the shortfall.

Failure 2: The project generates sufficient cash to cover O&M expenses but does not generate adequate equity returns. In this scenario, the road would be maintained as per the concession agreement. However, since revenue share with the government eventually happens from the project cash flows, the ability of the project developer to share revenue with the government would be reduced. Thus, this type of failure leads to a scenario wherein the road is maintained, operational and available to the public but the revenue generated by the government is lower than that anticipated at the time of award of the concession.

Using the above rational, we estimate the net social surplus (consumer plus + revenue share of the government) generated. In case of toll roads, the government's payoff would be;

Net Revenue to the Government ($NR_g$) = Total Revenue Share – Total Grant (3)

Consider a project i, wherein the winning bidder, quotes a revenue share (premium) $RS_i$. The revenue to the government from project i ($R_i$) would be;

$$R_i = \int_0^t RSi * e^{-rt} \quad dr = RS_i * \int_0^t e^{-rt} \quad dr \quad (4)$$

Where ‘r’ is the discounting rate and‘t’ is the concession period minus the construction time. In NHAI auctions, the toll and the concession period is fixed by the government. The total revenue from project i would be;

$$RP_i = \int_0^t P * Q * e^{-rt} \; dr = P * Q * \int_0^t e^{-rt} \; dr \tag{5}$$

Where ‘P’ is the toll charged and Q is the total number of vehicles. Now if for project ‘I’ the net present value of the total operations cost is ‘$O_i$’, the Maintenance cost is ‘$M_i$’, ‘$D_i$’ is the debt repayment and ‘$E_i$’ is the net cash flow to equity;

$$P * Q * \int_0^t e^{-rt} \; dr = R_i + O_i + M_i + D_i + E_i \tag{6}$$

If there are n demand states, the revenue equation in state ‘s’ which occurs with a probability $\prod_s > 0$ can be written as;

$$P * Qs * \int_0^t e^{-rt} \; dr = R_{is} + D_{is} + E_{is} + O_i + M_i$$

As discussed, O&M costs are demand state independent while revenue to government, equity returns and debt repayment is demand state dependent. The exact demand state would be known only after the project construction finishes and commercial operations commence. However, in order to estimate *ex ante* the net revenue to the government, we assume that traffic growth follows a Random Brownian Motion with a growth rate equal to the district GDP growth rate and a standard deviation equal to the standard deviation of district GDP in which the project road is situated.

For every bid, in each project, we know NHAI’s estimated cost and NHAI’s estimated traffic. Since, these are typically low technology projects; the cost difference between individual project developers is minimal. In such a scenario, with common costs and common estimates of current traffic, the chief differentiator in the individual bid amounts would be the assumed growth rate of traffic. Using a excel spreadsheet model with NHAI's estimated costs (both capital and O&M), and current traffic as inputs, for each bid we calculated the implied growth rate (the growth rate assumed by the bidder). The target Project IRR is maintained at 12% and Equity IRR is maintained at 16% in line with NHAI guidelines (Guidelines for Investment in Road Sector, 2009). By plugging in the implied growth rate in the Random Brownian Motion equation, using District GDP growth rate and standard deviation as historic growth rate and standard deviation, we calculate the probability that the project would; a) fail such that the project cash would not be sufficient to service the premium quoted by the winner bidder (Equity IRR < 16%) but would be able to carry out operations and maintenance (denoted by $\prod_{f1}$) ; b) fail such that the project would not be able to carry out even routine maintenance and operations (Project IRR = 0%) and the government would have to bailout the project (denoted by $\prod_{f2}$).

Hence, the actual revenue share ($AR_i$) of the government from project 'i' would now be equal to;

$$AR_i = (1 - \prod_{f1}) * R_i - \prod_{f2} * (O_i + M_i) \quad (8)$$

Net Social Surplus = Consumer Surplus + Net Revenue to the Government - Grant[9]

Net Social Surplus = Consumer Surplus + $[ (1 - \prod_{f1}) * R_i - \prod_{f2} * Ri ]$ - Grant

Given that toll and concession period remains fixed, coupled with the assumption of continued availability of the road implies that consumer surplus would remain constant till congestion traffic occurs. NHAI stipulates that if the actual traffic exceeds the design capacity of

[9] Since grant is quoted and paid up front, it is demand state independent

the road, the concessionaire would have to build additional lanes. Building of additional lanes would be treated as a separate project and the concessionaire would be compensated such that Equity IRR remains 16%. Hence, we observe that once the road gets build, the consumer surplus remains constant in all scenarios. That is, consumer surplus is both independent of demand state and independent of the actual bid by any of the bidders. Thus, to estimate net social surplus, it would sufficient to compare net revenue to the government generated by different bids.

Using the method described above, we calculated the net revenue per kilometer to the government for every bid. Adjusting for probability of winning, we calculated the net social surplus for all bids and then categorized it into the net social surplus for bids by firms which cooperated with other firms and net social surplus for bids by firms which did not cooperate with other firms. The comparison is detailed below;

Table 2: Impact of Inter Firm Cooperation on Net Social Surplus

| Type | Average Premium Quoted (INR Crore) | Total Subsidy Requested (INR Crore) | Consumer Surplus | Net Social Surplus per kilometer (INR Crore) |
|---|---|---|---|---|
| Cooperative Firms | + 0.91 | - 2.06 | Constant = X | 0.02 + X |
| Non Cooperative Firms | + 1.09 | - 2.37 | Constant = X | -0.30 + X |

## Discussion

The above analysis suggests that firms which do cooperate tend to bid more aggressively than firms which do not cooperate. If the bid winners were selected on the criteria of lowest subsidy quoted (this occurs if there are no 'premium' quote and all bidders request for subsidy), the subsidy payment is done upfront, that is, during the construction phase of the project. Since, the subsidy payment is done upfront (prior to revelation of demand state), the net outflow of the government (subsidy paid) can be determined with certainty (subsidy requested is equal to subsidy paid). We observe that firms which cooperated requested for a subsidy 37 % of the times, whereas firms which did not cooperate, requested a subsidy 55% of the times they bid. Also when the firms bid for a subsidy, firms which cooperated requested for a subsidy of Rs 2.06 crore per kilometer as against firms which did not cooperate who requested for a subsidy of Rs 2.37 crore per kilometer. Thus, even without any adjustments, it can be seen that when firms cooperate, they are much less likely to request for subsidy, and even if they do request for a subsidy, the amount of subsidy requested is generally lower.

The results for 'revenue share' bid are also equally interesting. Firms which cooperated are more likely to share revenue with the government (63 % of the times) as compared to firms which did not cooperate (45% of the times). However, firms which cooperated also tend to quote a marginally lower revenue share ( Rs 0.91 crore per kilometer) as compared to the firms which did not cooperate (Rs 1.09 crore per kilometer).

When the average revenue quoted and the average subsidy requested are weighted with the probability that the two scenarios occur, we observe the firms which cooperated on an average would have bid for a subsidy of Rs 0.19 crore per kilometer, as compared to firms which did not cooperate who would have on an average bid for a subsidy of Rs 0.81 crore per kilometer. Thus, the net revenue to the government would have been lower if firms did not cooperate.

Another way to look at the same analysis would be to weigh each bid with the probability of winning. After weighing by probability of winning, each bid was adjusted to account for revenue losses due to both types of failures. Then, if we add all the bids by firms which do cooperate and by firms which do not cooperate, the resulting sums can be compared to estimate the net revenue to the government. The net revenue to the government for firms which cooperate is estimated to be Rs 0.02 crore per kilometer, that is, the government would on a net basis, earn Rs 0.02 crore per kilometer. On the other hand, the net revenue to the government for firms which did not cooperate, would be – Rs 0.30 crore per kilometer, that is, on a net basis, based on bids by firms which did not cooperate, the government would end up spending Rs 0.30 per crore in the form of subsidies. Hence, even if all the bids are adjusted for probabilities of failure and probability of winning, we observe that bids by firms which cooperate tend to have a social surplus than firms which do not cooperate.

Further, we estimated the effect of inter firm cooperation using matching techniques. We considered only those projects which had firms belonging to both categories, that is, firms which cooperate, and firms which do not cooperate. Using 'interfirm' ('1' to indicate firms which cooperate and '0' to indicate firms which do not cooperate) as a treatment variable and estimating the mahalanobis distance between project specific parameters, we estimated the bid per kilometer of the firms which cooperated had they not cooperated. The results obtained are listed below;

| Average Bid of Firms which Cooperated | If the same firms had not cooperated, their average bid would have been | Difference due to inter firm cooperation |
| --- | --- | --- |
| Rs 4.62 per kilometer | Rs 1.312 crore per kilometer | Rs 3.304 per kilometer |

Thus, we observe that cooperation amongst firms leads to significantly higher bids. We replaced the actual bids of firms which cooperated and won, with bid the predicted bid amounts had they not cooperated. After the replacement, we designated the new highest bid as the winning bid and using methods discussed earlier we estimated the net revenue to the government. We observed that the net revenue to the government in such cases would have been 35 % lower, had the winning firms not cooperated.

Overall, we may conclude that firms which cooperate tend to bid higher, and adjusting for their probability of failure, the social surplus is higher when firms cooperate.

## Conclusion

Auctions are widely used by governments to procure goods and services. Traditionally, it has been believed that firm collusion or cooperation while bidding adversely impacts government revenue and hence considerable academic attention has been devoted to study the impact of collusion (Robinson, 1985) (Mcafee & Macmillan, 1992) (Hendricks & Porter, Coullusion in Auctions, 1989) (Genesove & Mullin, 2001) (Roller & Steen, 2006).

Profit maximization (price ~ cost margin) is generally considered as the primary motive behind inter firm collusion (Genesove & Mullin, 2001) (Mcafee & Macmillan, 1992). In low technology businesses like road construction most firms would have similar cost structures. Also, the price (toll) that firms may charge from users is fixed by the government (NHAI) and is uniform across the country. The only parameter that firm cooperation or collusion can materially affect is the bid, which is the revenue share quoted or the subsidy sought. As observed above, firms that cooperated generally bid higher and more aggressively than firms that did not cooperate. Thus, it could be concluded that firms which did cooperate did not do so with the intention of artificially maximizing price ~ cost margin.

Many cartels also function with the primary motive of maintaining market share of its cartel members (Roller & Steen, 2006) (Porter & Zona, Ohio School Milk Markets: An Analysis of Bidding, 1999). However, in the case of NHDP, the total kilometers of road to be auctioned exceed 30, 000 kilometers, which coupled with projects awarded at state and district level, indicate that demand is very high. According to Government estimates, India would require a total investment of US $ 80 billion in roads in the next 3- 4 years, of which US $ 45 billion is expected to come from the private sector (India Opportunites, 2011). Overall, it is estimated that India would require an investment of US $ 513.55 billion in the infrastructure sector in the period 2007 – 2012, of which private sector would be required to mobilize US $ 185 billion (India Infrastructure Debt Fund: A Concept Paper, 2010). The private developers would thus have opportunities in other sector also, like EPC in power, aviation and oil & gas. Hence, the Indian market is unique in the sense there are no dearth of opportunities. However, over the last decade and a half, India has already made significant investments in infrastructure development. Government reports estimate that US $ 227 billion was invested in the period 2002 – 2007, of which the private sector alone invested US $ 129 billion (India Infrastructure Debt Fund: A Concept Paper, 2010) (Scheme for Financing Infrastructure Projects through the India Infrastructure Finance Company Limited, 2009). Over the last decade, the infrastructure companies have grown rapidly, most have consistently maintained order book to revenue ratios of 3 or higher, most are highly leveraged and thus have limited capacity to take more projects or raise debts. The ability of the debt market to finance more projects is limited and the Government expects a debt gap of US $ 50 billion over the next five years. In the light of the above, NHAI with help from the Government of India is actively trying to attract foreign investors and project developers (Guidelines for Investment in Road Sector, 2009)[10]. In the light of the above, the excess demand, the shortage in capacity, and the limited ability to raise debt, it is highly unlikely that firms would enter into cooperative or collusive arrangements merely to maintain market share.

Hence, the motivation for inter firm cooperation has to be something other than maximizing profit margins or maintaining market share. As discussed, the major factor that causes variations in firm bids (after controlling for common information) is the assumed growth rate of traffic. However, as discussed earlier, estimating traffic growth rates can be difficult has proven to be notoriously inaccurate. It could then be possible, firms which routinely share traffic data and growth estimates, are the firms which have been identified by the statistical methods as probable 'cooperating' firms. Such information sharing to mitigate, minimize or identify risks is common in various industries like insurance (fraud data), banking (default data), automobile (sales data), IT services (earnings guidance) (Derrig, 2002) (Cummins & Tennyson, 1992) (Doyle & Snyder, 1999) (Genesove & Mullin, 2001) (Novshek & Thoman, 1998). Typically, such sharing of information happens through trade bodies, or industry journals, or media or in very rare cases through direct communication (Doyle & Snyder, 1999) (Baldwin, Marshall, & Richard, 1997) (Ellison, 1994) (Funderburk, 1974) (Genesove & Mullin, 2001). This type of information sharing has been often deemed to be collusive and anti competitive (Kuhn & Vives, 1995) (Novshek & Thoman, 1998).

[10] A tax break of 10 years is provided, 100% FDI is permitted through automatic route, and exemptions on custom duties, VAT etc have also been provided.

However, as illustrated in this paper, firms which share information, not only bid more aggressively, but also adjusted for probability of failure, their bids yielded a higher consumer surplus. By sharing individual demand estimates, a method of peer validation, firms could have effectively increased their confidence of the demand estimate and thus bid more aggressively. Also, such peer validation could also ensure that firms which were earlier overly optimistic of the demand may have pared down their optimism. Thus, bids resulting as a result of this peer validation could be more reasonable and realistic. Through other studies, it has been demonstrated that increased information does indeed lead efficiency gains (Novshek & Thoman, 1998), lowers the cost for the government and increased chances of survival of new entrants (Silva, Kosmopoulou, & Lamarche, The effect of information on the bidding and survival of entrants in in procurement auctions, 2009) (Silva, Dunne, Kankanamge, & Kosmopoulou, 2008).

In the light of the above, and the fact that Governments need to maximize revenue and consumer surplus while maintaining reasonability (minimize probability of failure), it would make sense to provide legal mechanisms to promote information sharing. This could be done by providing menu based auctions, wherein for different levels of traffic the bidders quote differently. The winner could be selected on the basis of the net expected revenue to the government after assigning probability weights to each demand level. Also, the government could provide for data banks, making it mandatory for each participant to share traffic and tolling data with all other participants. Given that the ultimate responsibility of the provision of public services rests with the government, it could make sense to provide guarantees to that effect. Guarantees have often been criticized due to issues related to pricing, and cost of such guarantees. However, our contention is that in monopoly franchises, with the responsibility there exists an implicit guarantee of continued services, by the government in any case. Overall, since demand uncertainty is the main cause for higher inter firm cooperation; auction design should factor in elements to minimize uncertainty. Reduction in demand uncertainty, through any route, would yield higher social surplus and lower dead weight losses.

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**Appendix 1**

**Description of the Bid Data**

The study focuses on BOT contracts awarded by NHAI in the year 2009 and 2010. In order to test for conditional independence, only those firms which participated in a minimum of 5 bids were considered. In case of joint ventures, the bid was attributed to the firm which had a majority stake and management control in the joint venture. Totally the data consists of 21 firms bidding for 36 projects.

The data consists of 404 unique observations at the first stage, that is, firms which purchased and submitted the RfQ document. Table 1 gives a brief description of the data that is made available to the participants by NHAI at the time of bidding.

Table 1: Information Available to the Prospective Bidders

| Sr No | Variable & Description | Unit | Max | Min | Mean | Standard Deviation |
|---|---|---|---|---|---|---|
| Stage 1 | | | | | | |
| 1 | 'lt': The length of the road | Kilometers | 273 | 40 | 110 | 54 |
| 2 | 'ieec': NHAI appointed independent engineer's cost estimate | Crore / Kilometer | 23 | 2.65 | 10.6 | 4.4 |
| Stage 2 | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | 'currentpcu'[11]: Current traffic | Passenger car equivalent units | 77605 | 9100 | 25543 | 13440 |
| 4 | 'noofshortlistedbidders' : The number of bidders qualified to bid in the second stage (RfP stage). | Number | 34 | 4 | 16 | 7.2 |

In order to analyze firm behavior, the paper considers the following firm related aspects;

| Table 2: Firm Specific Parameters | | | | | | |
|---|---|---|---|---|---|---|
| Sr No | Variable & Description | Unit | Max | Min | Mean | Standard Deviation |
| 1 | 'networth': The net worth of the firm | INR crore | 12459 | 124 | 2115 | 3453 |
| 2 | 'tpcprojectswon': The total project costs of all NHAI NHDP projects won by the firm | INR crore | 8232 | 0 | 2185 | 2368 |
| 3 | 'kmroadswon': The total length in kilometers of all NHAI NHDP road projects won by the firm | Kilometers | 725 | 0 | 265 | 234 |
| 4 | 'projectswon': The total number | Number | 8 | 0 | 3.3 | 2.6 |

[11] NHAI publishes the 'Target Traffic' in the RfP document. The target traffic is the expected traffic 10 years after the concession commences. It is calculated by escalating the current traffic 5% annually. For the purpose of our analysis we have back calculated the current traffic from the actual traffic.

| | | | | | | |
|---|---|---|---|---|---|---|
| | of NHAI NHDP road projects won by the firm | | | | | |
| 5 | ‘list’: Indicates whether the firm is listed (1) or not (0) | 1/0 Binary | 15 of the 21 firms are listed | | | |
| 6 | ‘marpbdit’: The PBDIT margin of the firm | Percentage | 84.53 | 7.93 | 23.66 | 21.40 |
| 7 | ‘marpat’: The PAT margin of the firm | Percentage | 80.14 | 6.3 | 11.88 | 19.68 |
| 8 | ‘roce’: The Return on Capital Employed by the firm | Percentage | 17.97 | 2.6 | 8.08 | 4.90 |
| 9 | ‘intcov’: The interest coverage ratio of the firm | Ratio | 23.45 | 1.06 | 4.25 | 4.79 |
| 10 | ‘der’: The debt equity ratio of the firm | Ratio | 3.66 | 0.07 | 1.18 | 0.90 |

In order to account for all common information amongst the bidders the paper considers the following data;

| Table 3: Project Specific Parameters | | | | | | |
|---|---|---|---|---|---|---|
| Sr No | Variable & Description | Unit | Max | Min | Mean | Standard Deviation |
| 1 | ‘petrolgrtrt[12]’: The growth rate of petrol consumption in the state in | Percentage | 9.86 | -0.20 | 5.60 | 2.15 |

12 Does not include data from newly formed states like Jharkhand

| | | | | | | |
|---|---|---|---|---|---|---|
| | which the project road is situated | | | | | |
| 2 | 'petrolstdev': The standard deviation of petrol consumption in the state in which the project road is situated | Percentage | 17.74 | 3.15 | 5.5 | 2.60 |
| 3 | 'dieselgrtrt': The growth rate of diesel consumption in the state in which the project road is situated | Percentage | 7.53 | -3.1 | 2.45 | 2.72 |
| 4 | 'dieselstdev': The standard deviation of petrol consumption in the state in which the project road is situated | Percentage | 15.89 | 3.33 | 8.94 | 2.95 |
| 5 | Number Plate Growth Rate and Standard Deviation of Growth Rate: Measures the growth rate in number plate registrations in the state in which the project road is situated. | Percentage | Light Commercial Vehicle[13] | | Cars and SUV | Bus and Trucks |
| | | *This data was considered but not used as data for new states in not available. Also, the data seems to be unreliable, with some states witnessing growth spikes of more than 30%.* | | | | |
| 6 | State Wise Vehicle Population: Gives the number of vehicles registered in each state *(Data Not* | Number | Cars & SUV | LCV | Bus | Trucks |

[13] Data for West Bengal not available.

| | | | | | | |
|---|---|---|---|---|---|---|
| | *used)* | Mean | 637270 | 199638 | 58349 | 172131 |
| 7 | 'stateprojectroads': Shows the average length of roads under construction in the state in which the project road exists | Kilometers | 37423 | 120 | 17784 | 12033 |
| 8 | 'stdstateprojectroads': The standard deviation of state project roads. Shows the variance in the construction activity in the state in which the project road is being constructed. | Percentage | 132% | 6.3% | 17.5% | 29.8% |
| 9 | 'grtrateofstateprojectroads': The growth rate of state project roads | Percentage | 37.3% | 3.4% | 5.48% | 8.63% |
| 10 | 'lenofstateroads': The cumulative length of roads in the state in which the project road is situated | Kilometers | 202492 | 7664 | 124906 | 58209 |
| 11 | 'grthratelenofstateroads': The growth rate of the length of state roads. | Percentage | 12.3% | -4.8% | 2.31% | 3.62% |
| 12 | 'stdoflenofstateroads': The standard deviation of growth rate of the length of state roads. | Percentage | 37.4% | 5.1% | 6.6% | 7% |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | ‘roadensity’: The kilometers of road in the state in which the project road is situated per 1000 square kilometer of area of the state. | Number | 5269 | 501 | 1286 | 874 |
| 14 | ‘stdevroadensity’: The standard deviation of road density in state over the last ten years. | Percentage | 41.3% | 0.6% | 8.8% | 10.6% |
| 15 | ‘districtgdp’: The GDP of the District in which the project road is situated. | INR Rs Million | 244756 | 27310 | 87655 | 61566 |
| 16 | ‘gdpgrwthrate’: The growth rate of the GDP of the District in which the project road is situated. | Percentage | 12.8% | 1.3% | 7.06% | 2.69% |
| 17 | ‘gdpgrwtstdev’: The standard deviation of the growth rate of the GDP of the District in which the project road is situated. | Percentage | 21.2% | 1.5% | 5.68% | 4.46% |
| 18 | ‘population’: The population of the District in which the project road is situated. | Number (in Thousands) | 7943 | 918 | 3136 | 1706 |
| 19 | ‘totalscbscredit’: The total | Number | 58980 | 2057 | 13138 | 11231 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | number of credit accounts in scheduled commercial banks in the District in which the project road is situated. | *The data is further subdivided into total number of credit accounts of the mining, transport, construction and manufacturing sectors.* | | | | |
| 20 | 'scbindustryoutstanding': The industry outstanding in scheduled commercial banks in the District in which the project road is situated. | Number | 2000000 | 6590 | 227928 | 402868 |
| | | *The data is further subdivided into total number of credit accounts of the mining, transport, construction and manufacturing sectors.* | | | | |
| 21 | Indices: Taken from Indicus Database. These indices were not used. | Name | Max | Min | Mean | Std Dev |
| | | Riot Index | 447 | 27 | 152 | 124 |
| | | Affluence Index | 343 | 19 | 161 | 99 |
| | | Growth Index | 564 | 69 | 273 | 132 |
| | | Economic Risk | 573 | 25 | 226 | 151 |
| | | District Risk | 556 | 70 | 295 | 122 |

**Appendix 2**

## Detecting Inter Firm Cooperation

The paper uses econometric models devised and described by Bajari and Ye in their paper "Deciding between Competition and Collusion" (Bajari & Ye, Deciding Between Competition and Collusion, 2003) . All bidders are allowed to be ex ante asymmetric. Many sources may create asymmetries, like, firm capacity and project pipeline, leverage, cost structure, revenue estimation, and local presence. However, since the current traffic estimate is provided by the auctioneer to the prospective bidders, and tariff is fixed by the auctioneer, the current revenue estimate would be common information to all bidders. Also, the estimated cost (estimated by an auctioneer appointed engineer) is provided to all bidders. Given that we are considering only rehabilitation, expansion and maintenance of existing highway stretches of the national highway, such jobs are not be very technology intensive and a marginal difference in cost estimate would not have a very big impact in bid amount. Also, these jobs are typically executed by local contractors appointed by the project developers after winning the concession, which leads to similar costing for most players. As all the projects are implemented on a non recourse basis, the providers of capital have a claim on the project cash flows only and have no recourse to the parent company. Hence, the financing cost is similar for all the participants. Given that the current revenue estimate, the cost estimate and the cost of capital are similar for all participants, the biggest cause of asymmetry while bidding would be the demand (revenue) growth estimates assumed by the individual bidders. For the purpose of our model we believe that the bidders are indeed ex ante asymmetric and the growth estimates as assumed by the firms is the single most important contributor to the asymmetry.

1. **Bid Function:** N Firms with independent private growth estimates ($g_i$) are considered. While a firm 'i' is aware of its own growth estimate, the estimates of the other firms ($g_{-i}$) is unknown. $g_i$ is drawn from a cumulative distribution function $F_i(\circ)$ and density function $f_i(\circ)$, which are common knowledge to the firms before bidding starts. It is assumed that $g_i$ has the same support [g, g] for all i. Under assumptions of risk neutrality, Firm i's strategy is a function of $B_i(\circ)$ : [g, g] $\rightarrow R_+$. If there exists an increasing equilibrium, such that $B_i(\circ)$ is strictly increasing and differentiable on the support of $g_i$ for all i; the the inverse bid function $Ø_i(\circ)$ would also be strictly increasing and differentiable on the support of the bids. If all competing firms follow strategies $B_{-I}$; then if firm i bids $b_i$, its probability of winning is Pr($c_j$ > $Ø_j(b_i)$ for all $j \neq i$). Firm i's expected profit can thus be written as;

$$\Pi_i(b_i, g_i ; B_{-I}) = (b_i - g_i) Q_i(b_i), \quad (9)$$

Where,

$$Q_i(b_i) = \prod_{j \neq i} [1 - F_j(Ø_j(b_i))] \quad (10)$$

2. **Model:** Information sharing through trade magazines (automobile industry), trade bodies (cooperatives), or through legitimate data banks (credit history) is common amongst industry participants. Given the high demand uncertainty, we believe that firms compare individual growth estimates with other competitors in order to arrive at reasonable bids. If such cooperating firms frequently bid against each other using standard folk theorem arguments it can be demonstrated that efficient cooperation can be sustained in repeated games. For

asymmetric auction models, equilibrium properties have been well established in the theoretical literature. The simplified bid function may be written as;

$$b_i = S_i ( R_i - C_i) \tag{11}$$

Where;

$R_i$ is the revenue as estimated by firm 'i'.

$C_i$ is the cost as estimated by firm 'i'.

Si is a strategic factor by which firm 'i' modifies its bid.

As explained earlier, $C_i = C$, as small variations in C do not effect $b_i$, and that the costs are similar for all firms. Also, $R_i = P * T_{PV}$, where P is the toll rate as fixed by the government, $T_{PV}$ is the present value of traffic. Current traffic is estimated by the auctioneer and is known to all the prospective bidders, the growth rates of traffic is individually estimated by each firm and may depend on various factors like the local GDP growth rate and the correlation between the local GDP growth rate and traffic growth rate. Assuming that the distribution each firms revenue can be parameterized by θ, a vector of parameters, and $Z_i$, as set of covariates unique to firm 'i', the cumulative distributive function of firm i's revenue may be written as $F(R_i| Z_i, \theta)$. The firms revenue function may be written as;

$$R_i = \gamma + \beta N_i + \varepsilon_i , \tag{12}$$

γ captures the common factors affecting all firms, such as the current traffic, cost as estimated by the auctioneer, the number of shortlisted bidders, local GDP growth rate and variance. $N_i$ represents the factors affecting a firm individually, but observable by all, for example, a firm's inventory, it's leverage, it's profitability, that is, factors which would determine the strategic factor $S_i$. $\varepsilon_i$ represents the idiosyncratic shock, which is private information to firm 'i' only. Under the assumption that $\varepsilon_i$ is distributed as Normal $(0, \sigma^2)$, the distribution of revenue would depend on $\theta = (\gamma, \beta, \sigma^2)$, common to all firms. If $Z_i = N_i$; then Z = (Z1, ……., $Z_N$) is observable by all firms. If $G_i(b; z)$ is the cumulative distribution of firm i's bids, and $g_i(b; z)$ is the associated probability function, the following equilibrium conditions must hold;

**A1.** Conditional on Z, firm i's bids and firm j's bids are independently distributed.

**A2.** The support of each distribution $G_i(b;z)$ is identical for each i.

Controlling for common signals, since each firm observes independently, bids by each firm should be independently distributed. However, when firms cooperate, as illustrated by various auction models (Porter & Zona, Detection of Bid Rigging in Procurement Auctions, 1993) (Porter & Zona, Ohio School Milk Markets: An Analysis of Bidding, 1999), the bids would appear to be correlated even after controlling for common signals. Conversely, it implies that if bidding was truly independent, condition A1 must hold.

Assuming that for all i, the distribution of revenue $F_i(\circ)$ has support [R, R] and the probability density function $f_i(\circ)$ is continuously differentiable. Also, for all i, $f_i(\circ)$ is bounded away from zero on [R, R]. Under these assumptions, there exists an equilibrium in pure strategies, furthermore the equilibrium bid function is strictly monotone and differentiable (Lebrun, Auctions, Existence of an Equilibrium in First Price, 1996), (Maskin & Riley, Equilibrium in Sealed High Bid Auctions, 2000b) (Bajari & Ye, Deciding Between Competition and Collusion, 2003). Additionally, under the above assumptions, the equilibrium bid inverse functions may be characterized as solutions to the system of N differential equations with the following boundary conditions (Lebrun, First Price Auction in the Asymmetric N Bidder Case, 1999) (Maskin & Riley, Asymmetric Auctions, 2000a) (Bajari & Ye, Deciding Between Competition and Collusion, 2003) (Bajari, The First - Price Auction with Assymetric Bidders: Theory and Applications, 1997) (Bajari, Comparing Competition and Collusion: A Numerical Approach, 2001);

For all i, $Ø_i$ (R) = R; and For all i, $Ø_i$ (β) = R for some constant β

**A3.** The equilibrium distribution of bids is exchangeable (Bajari & Ye, Deciding Between Competition and Collusion, 2003).

For any permutation Π (Π denotes a permutation, that is, one to one mapping from the set {1, ….., N} onto itself), and any index 'i' the following equality must hold;

$$G_i(b; Z_1, Z_2, Z_3, \ldots Z_n) = G_{\Pi(i)}(b; Z_{\Pi(1)}, Z_{\Pi(2)}, Z_{\Pi(3)}, \ldots Z_{\Pi(n)}) \quad (13)$$

The above implies that if the revenue distributions are permuted by Π, then the empirical distributions must also be permuted by Π. That is, if $Z_1$ and $Z_2$ are permuted, holding all else fixed, exchangeability would require that the distribution of bids by firm 1 and firm 2 also permute. However, if firms cooperate it would be reasonable to assume that exchangeability would not hold true as firms may not bid aggressively against each other as compared to a control group of non cooperating firms.

**A4.** For all i and b in support of $G_i(b; Z)$, the function ζ(b,z) is strictly monotone (Bajari & Ye, Deciding Between Competition and Collusion, 2003).

Assuming that firms follow a Bayes – Nash equilibrium in pure strategies, an equilibrium would imply a collection of functions $B_1$, ........, $B_N$ such that $B_i(R_i)$ maximizes $\Pi(b_i, R_i; B_{-i})$ in $b_i$ for all i and $R_i$ in its support. The first order condition for an equilibrium would then be;

$$\frac{\delta}{\delta bi}\ \Pi_i(b_i, R_i; B_{-i}) = (b_i - c_i)\ Q'_i\ (b_i) + Q_i\ (b_i) = 0 \tag{14}$$

Where $Q_i\ (b_i)$ is given by (10).

The first order condition may be rewritten as,

$$C_i = b - \frac{1}{\sum_{j \neq i} \frac{f(\emptyset j(b;z)|Zj)\emptyset' j(b;Z)}{1 - F(\emptyset j(b;Z)|Zj)}} \tag{15}$$

And,

$$G_i(b; Z) = F(\emptyset_i(b; Z)|Z_i) \tag{16}$$

$$g_i(b; Z) = f(\emptyset_i(b; Z)|Z_i)\ \emptyset'_i(b; Z) \tag{17}$$

In equilibrium, the bid functions are strictly monotone and an equivalent condition to the monotonicity of the bid function is the monotonicity of the the function $\zeta_i(b,z)$ in b, defined as;

$$\zeta_i(b,z) = b - \frac{1}{\sum_{j \neq i} \frac{gi(b; Z)}{1 - Gi(b; Z)}} \tag{18}$$

**A5.** From the characterization theorem as discussed in A2, it follows that (Bajari & Ye, Deciding Between Competition and Collusion, 2003);

$\zeta_i(b; z) = R$, and $\zeta_i(b; z) = R$ for $i = 1, \ldots\ldots..N$. (19)

3. **Testing for Cooperation :** Using conditions A1 to A5, we test if the given distribution of bids is consistent with the model of competitive bidding. Regression based methods were used to estimate $G_i(b_i; Z)$ and then test for conditional independence and exchangeability (Bajari & Ye, Deciding Between Competition and Collusion, 2003) (Porter & Zona, Detection of Bid Rigging in Procurement Auctions, 1993) (Porter & Zona, Ohio School Milk Markets: An Analysis of Bidding, 1999).

   From (1) we obtain the regression equation;

   $$Log(enternotenter_{i,p}) = \beta_0 + \beta_{1,i}\ ieec_{i,p} + \beta_{2,i}\ districtgdp_{i,p} + \beta_{3,i}\ logdieselstd_{i,p} + \beta_{4,i}\ totalscbcredit_{i,p} + \beta_{5,i}\ roadensity_{i,p} + \varepsilon_{i,p}$$

   In the above equation, we test if the firms independently decide to bid or not. Controlling for common information (cost as estimated by NHAI, local district GDP, historic variance of traffic using variance in diesel consumption as a proxy, commercial activity using number of local credit accounts as a proxy and state road density), and applying the competitive model, we hypothesize that the actual decision to bid or not should be independent. That is, we check for the null hypothesis that $þ_{i,j} = 0$.

   $H_0 : þ_{i,j} = 0$ (20)

   In order to test for conditional independence, we first estimate the correlation coefficient pair wise, $r_{i,j}$ to which is applied the Fischer Z transformation, given by;

   $Z = 0.5 \ln \{ (1 + r) / (1 - r) \}$ (21)

If the firm pairs (i, j) bid against each other n times, then the test statistic Z (n-3)^0.5 is employed. The results are reported in Table 1.

The same regression equation was tested for exchangeability, which implies that, the common information would impact a firm's decision to bid or not in a symmetric way. Thus the test for exchangeability would require that;

$H_0 : \beta_{i,k} = \beta_{j,k}$ for all i, j, $i \neq j$ and for all k = 1, 2, 3, 4 and 5.

The results of the above tests are also reported in Table 1.

In order to ensure robustness and that the results have both, economic and statistical, significance the same tests were extended to equation (2).

$$bidperkmbyieec_{i,p} = \beta_0 + \beta_{1,i}\, currentpcu_{i,p} + \beta_{2,i}\, logdeiselstd_{i,p} + \beta_{3,i}\, loggdgrwthrate_{i,p} + \beta_{4,i}\, stdevroaddensity_{i,p} + \varepsilon_{i,p}$$

The above equations represent the actual bid per kilometer by each firm normalized by the cost per kilometer as estimated by the auctioneer. In order to control for bids not observed due to firms not participating in the bidding process (that is dropping out after being qualified to put a financial bid) we use a Heckman type of regression. The above equation also controls for common information using parameters like the current traffic on the road which is estimated by the auctioneer and made known to all the prospective bidders. Private information, like estimated traffic growth rate, would enter the '$\varepsilon_{i,p}$' of the equations, and hence any correlation in ε across bids between firm pairs would indicate sharing of information or cooperation.

## Appendix 3

Regression Results: Logit – To Bid or Not To Bid

```
. logit enternotenter ieec districtgdp logdieselstd totalscbscredit roadensity

Iteration 0:   log likelihood = -267.01481
Iteration 1:   log likelihood = -251.17057
Iteration 2:   log likelihood = -250.77945
Iteration 3:   log likelihood = -250.77649
Iteration 4:   log likelihood = -250.77649

Logistic regression                               Number of obs   =        404
                                                  LR chi2(5)      =      32.48
                                                  Prob > chi2     =     0.0000
Log likelihood = -250.77649                       Pseudo R2       =     0.0608
```

| enternoten~r | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ieec | .0811809 | .0243688 | 3.33 | 0.001 | .033419 | .1289429 |
| districtgdp | 7.52e-06 | 2.30e-06 | 3.28 | 0.001 | 3.02e-06 | .000012 |
| logdieselstd | -.9686421 | .3238945 | -2.99 | 0.003 | -1.603464 | -.3338206 |
| totalscbsc~t | -.0000437 | .0000149 | -2.93 | 0.003 | -.000073 | -.0000145 |
| roadensity | -.000391 | .0001781 | -2.19 | 0.028 | -.0007402 | -.0000419 |
| _cons | -3.363105 | .876929 | -3.84 | 0.000 | -5.081854 | -1.644356 |

# Appendix 4

Regression Results: Logit – To Bid or Not To Bid (Firm Specific Coefficients)

```
. logit enternotenter _pnamXieec_*   _pnamXdist_*   _pnamXlogd_*    totalscbscredit roadensity, difficult

Iteration 0:   log likelihood = -267.01481
Iteration 1:   log likelihood =  -222.1614
Iteration 2:   log likelihood =   -220.338
Iteration 3:   log likelihood = -220.23585
Iteration 4:   log likelihood = -220.23427
Iteration 5:   log likelihood = -220.23426

Logistic regression                               Number of obs   =        404
                                                  LR chi2(62)     =      93.56
                                                  Prob > chi2     =     0.0059
Log likelihood = -220.23426                       Pseudo R2       =     0.1752
```

| enternoten~r | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| _pnamXieec_2 | -.0241983 | .0835539 | -0.29 | 0.772 | -.187961 | .1395644 |
| _pnamXieec_3 | .0249653 | .0889259 | 0.28 | 0.779 | -.1493263 | .1992569 |
| _pnamXieec_4 | .0637283 | .0908897 | 0.70 | 0.483 | -.1144122 | .2418688 |
| _pnamXieec_5 | .1139254 | .0919273 | 1.24 | 0.215 | -.0662489 | .2940996 |
| _pnamXieec_6 | .1325082 | .129 | 1.03 | 0.304 | -.1203272 | .3853435 |
| _pnamXieec_7 | .22453 | .1214338 | 1.85 | 0.064 | -.0134759 | .4625358 |
| _pnamXieec_8 | .1879832 | .0943677 | 1.99 | 0.046 | .0030259 | .3729404 |
| _pnamXieec_9 | -.1260847 | .1348069 | -0.94 | 0.350 | -.3903015 | .138132 |
| _pnamXiee~10 | .066387 | .0871167 | 0.76 | 0.446 | -.1043586 | .2371327 |
| _pnamXiee~11 | .1486004 | .1623348 | 0.92 | 0.360 | -.16957 | .4667707 |
| _pnamXiee~12 | -.0499309 | .1409368 | -0.35 | 0.723 | -.3261619 | .2263002 |
| _pnamXiee~13 | .0318206 | .106712 | 0.30 | 0.766 | -.1773311 | .2409724 |
| _pnamXiee~14 | .0239555 | .1112992 | 0.22 | 0.830 | -.1941869 | .2420978 |
| _pnamXiee~15 | .1537504 | .1057357 | 1.45 | 0.146 | -.0534877 | .3609886 |
| _pnamXiee~16 | -.0754958 | .1679178 | -0.45 | 0.653 | -.4046087 | .2536171 |
| _pnamXiee~17 | -.0667633 | .1288003 | -0.52 | 0.604 | -.3192073 | .1856808 |
| _pnamXiee~18 | -.3780618 | .3133134 | -1.21 | 0.228 | -.9921448 | .2360211 |
| _pnamXiee~19 | .1593246 | .0951719 | 1.67 | 0.094 | -.0272089 | .3458581 |
| _pnamXiee~20 | .0443625 | .0815264 | 0.54 | 0.586 | -.1154263 | .2041514 |
| _pnamXiee~21 | .0273023 | .0835393 | 0.33 | 0.744 | -.1364316 | .1910363 |
| _pnamXdist_2 | -1.93e-07 | 8.39e-06 | -0.02 | 0.982 | -.0000166 | .0000162 |
| _pnamXdist_3 | 7.80e-06 | 7.72e-06 | 1.01 | 0.313 | -7.34e-06 | .0000229 |
| _pnamXdist_4 | 1.07e-06 | 7.30e-06 | 0.15 | 0.884 | -.0000132 | .0000154 |
| _pnamXdist_5 | 1.78e-06 | 7.00e-06 | 0.25 | 0.799 | -.0000119 | .0000155 |
| _pnamXdist_6 | 1.39e-06 | 7.86e-06 | 0.18 | 0.860 | -.000014 | .0000168 |
| _pnamXdist_7 | -.0000178 | .0000162 | -1.10 | 0.273 | -.0000496 | .000014 |
| _pnamXdist_8 | .0000162 | 7.41e-06 | 2.19 | 0.028 | 1.73e-06 | .0000308 |
| _pnamXdist_9 | 4.50e-06 | 8.42e-06 | 0.53 | 0.593 | -.000012 | .000021 |
| _pnamXdis~10 | .0000257 | 9.52e-06 | 2.70 | 0.007 | 7.07e-06 | .0000444 |
| _pnamXdis~11 | -8.01e-06 | .0000231 | -0.35 | 0.729 | -.0000533 | .0000373 |
| _pnamXdis~12 | 6.77e-06 | 9.30e-06 | 0.73 | 0.466 | -.0000115 | .000025 |
| _pnamXdis~13 | .0000143 | 7.46e-06 | 1.92 | 0.055 | -3.23e-07 | .0000289 |
| _pnamXdis~14 | 7.97e-06 | 8.45e-06 | 0.94 | 0.345 | -8.58e-06 | .0000245 |
| _pnamXdis~15 | .0000165 | 8.65e-06 | 1.90 | 0.057 | -4.85e-07 | .0000334 |
| _pnamXdis~16 | .0000322 | .0000225 | 1.43 | 0.152 | -.0000118 | .0000763 |
| _pnamXdis~17 | -9.80e-07 | .0000121 | -0.08 | 0.935 | -.0000246 | .0000227 |
| _pnamXdis~18 | .0000346 | .0000175 | 1.98 | 0.048 | 2.66e-07 | .0000689 |
| _pnamXdis~19 | -5.07e-08 | 7.22e-06 | -0.01 | 0.994 | -.0000142 | .0000141 |
| _pnamXdis~20 | -4.63e-06 | 7.44e-06 | -0.62 | 0.534 | -.0000192 | 9.95e-06 |
| _pnamXdis~21 | -7.48e-06 | .0000116 | -0.64 | 0.520 | -.0000303 | .0000153 |
| _pnamXlogd_2 | -.6865344 | .442631 | -1.55 | 0.121 | -1.554075 | .1810064 |
| _pnamXlogd_3 | -.0638096 | .5178266 | -0.12 | 0.902 | -1.078731 | .951112 |
| _pnamXlogd_4 | -.4297663 | .430814 | -1.00 | 0.318 | -1.274146 | .4146137 |
| _pnamXlogd_5 | -.3535605 | .4197546 | -0.84 | 0.400 | -1.176264 | .4691435 |
| _pnamXlogd_6 | .0124434 | .5423862 | 0.02 | 0.982 | -1.050614 | 1.075501 |
| _pnamXlogd_7 | -.1632555 | .5453204 | -0.30 | 0.765 | -1.232064 | .9055529 |
| _pnamXlogd_8 | .8872073 | .5444994 | 1.63 | 0.103 | -.1799919 | 1.954406 |
| _pnamXlogd_9 | -1.273402 | .6459572 | -1.97 | 0.049 | -2.539455 | -.0073488 |
| _pnamXl~d_10 | .7050363 | .5642868 | 1.25 | 0.212 | -.4009455 | 1.811018 |
| _pnamXl~d_11 | -.5562783 | 1.01077 | -0.55 | 0.582 | -2.537352 | 1.424795 |
| _pnamXl~d_12 | -.133291 | .5723706 | -0.23 | 0.816 | -1.255117 | .9885347 |
| _pnamXl~d_13 | .5401031 | .6534199 | 0.83 | 0.408 | -.7405765 | 1.820783 |
| _pnamXl~d_14 | -.4470162 | .536154 | -0.83 | 0.404 | -1.497859 | .6038262 |
| _pnamXl~d_15 | .2005235 | .4190093 | 0.48 | 0.632 | -.6207196 | 1.021767 |
| _pnamXl~d_16 | .2420182 | .7713607 | 0.31 | 0.754 | -1.269821 | 1.753857 |
| _pnamXl~d_17 | -.9591999 | .5114423 | -1.88 | 0.061 | -1.961608 | .0432086 |
| _pnamXl~d_18 | -.6060755 | .6368237 | -0.95 | 0.341 | -1.854227 | .642076 |
| _pnamXl~d_19 | -.0797093 | .45287 | -0.18 | 0.860 | -.9673183 | .8078996 |
| _pnamXl~d_20 | -.7827622 | .4047541 | -1.93 | 0.053 | -1.576066 | .0105413 |
| _pnamXl~d_21 | -.3654168 | .4627982 | -0.79 | 0.430 | -1.272485 | .5416511 |
| totalscbsc~t | -.0000481 | .0000177 | -2.72 | 0.007 | -.0000828 | -.0000134 |
| roadensity | -.0001183 | .0001817 | -0.65 | 0.515 | -.0004744 | .0002378 |
| _cons | -1.291992 | .5155662 | -2.51 | 0.012 | -2.302483 | -.2815011 |

## Appendix 5

Regression Results: Heckman – Estimating Bid Per Kilometer by Independent Engineer's Cost Estimate

```
. heckman  bidperkmbyieec currentpcu logdieselstd loggdpgrwthrate stdevroadensity, select (  stdoflenofstater
> oads roadensity stdevroadensity districtgdp gdpgrwtstdev population scbcreditmining scbcreditconstruction s
> cbcredittransporters scbindustryoutstanding  scboutstandingconstruction scboutstandingtransport tpcprojects
> won kmroadswon projectswon ieec) twostep

Heckman selection model -- two-step estimates   Number of obs      =       404
(regression model with sample selection)        Censored obs       =       253
                                                Uncensored obs     =       151

                                                Wald chi2(4)       =     41.10
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
bidperkmby~c |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
bidperkmby~c |
  currentpcu |   .0000162   3.26e-06     4.98   0.000     9.85e-06    .0000226
logdieselstd |  -.6990252    .152078    -4.60   0.000    -.9970925   -.4009579
loggdpgrwt~e |   .4370994   .1582984     2.76   0.006     .1268402    .7473586
stdevroade~y |   .3666211    .134765     2.72   0.007     .1024866    .6307557
       _cons |   -.397158   .3771527    -1.05   0.292    -1.136364    .3420477
-------------+----------------------------------------------------------------
select       |
stdoflenof~s |   7.205122   2.138921     3.37   0.001     3.012915    11.39733
  roadensity |   .0003938   .0001473     2.67   0.008      .000105    .0006825
stdevroade~y |  -1.265279   .3158116    -4.01   0.000    -1.884258   -.6462998
 districtgdp |  -.0000274   5.65e-06    -4.85   0.000    -.0000385   -.0000163
gdpgrwtstdev |   7.472404   1.861313     4.01   0.000     3.824298    11.12051
  population |   .0007623   .0001428     5.34   0.000     .0004824    .0010422
scbcred~ning |   .0062043    .001437     4.32   0.000     .0033877    .0090208
scbcreditc~n |   -.000185   .0000534    -3.47   0.001    -.0002896   -.0000804
scbcreditt~s |  -.0010357    .000193    -5.37   0.000     -.001414   -.0006574
scbindustr~g |   2.12e-06   5.43e-07     3.90   0.000     1.05e-06    3.18e-06
scboutstan~n |   .0000268   6.01e-06     4.46   0.000      .000015    .0000386
scboutstan~t |   .0001705    .000038     4.49   0.000     .0000961    .0002448
tpcproject~n |  -.0002854   .0000918    -3.11   0.002    -.0004653   -.0001055
  kmroadswon |   .0030543   .0010855     2.81   0.005     .0009268    .0051818
 projectswon |  -.1257099   .0630165    -1.99   0.046    -.2492199   -.0021999
        ieec |   .0984664   .0188222     5.23   0.000     .0615756    .1353572
       _cons |  -2.362436   .4522613    -5.22   0.000    -3.248852    -1.47602
-------------+----------------------------------------------------------------
mills        |
      lambda |  -.4360666   .1265554    -3.45   0.001    -.6841106   -.1880225
-------------+----------------------------------------------------------------
         rho |   -0.73533
       sigma |  .59302521
      lambda | -.43606655   .1265554
------------------------------------------------------------------------------
```

## Appendix 6

Regression Results: Heckman – Estimating Bid Per Kilometer by Independent Engineer's Cost Estimate (Firm Specific Coefficients)

```
. heckman  bidperkmbyieec  _pnamXcurr_*  _pnamXlogd_* _pnamXlogg_*  _pnamXstde_*, select (  stdoflenofstatero
> ads roadensity stdevroadensity districtgdp gdpgrwtstdev population scbcreditmining scbcreditconstruction sc
> bcredittransporters scbindustryoutstanding  scboutstandingconstruction scboutstandingtransport tpcprojectsw
> on kmroadswon projectswon ieec) twostep
note: _pnamXstde_12 omitted because of collinearity

Heckman selection model -- two-step estimates   Number of obs      =       404
(regression model with sample selection)        Censored obs       =       253
                                                Uncensored obs     =       151

                                                Wald chi2(79)      =    281.75
                                                Prob > chi2        =    0.0000
```

| bidperkmby~c | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| **bidperkmby~c** | | | | | | |
| _pnamXcurr_2 | .000035 | .0000293 | 1.20 | 0.231 | -.0000223 | .0000924 |
| _pnamXcurr_3 | .0000309 | .0000526 | 0.59 | 0.557 | -.0000723 | .0001341 |
| _pnamXcurr_4 | .0000185 | 9.91e-06 | 1.87 | 0.061 | -8.83e-07 | .000038 |
| _pnamXcurr_5 | -6.07e-06 | 8.90e-06 | -0.68 | 0.496 | -.0000235 | .0000114 |
| _pnamXcurr_6 | 7.06e-06 | .000013 | 0.54 | 0.586 | -.0000184 | .0000325 |
| _pnamXcurr_7 | 4.15e-06 | 9.71e-06 | 0.43 | 0.669 | -.0000149 | .0000232 |
| _pnamXcurr_8 | .0000153 | 8.45e-06 | 1.81 | 0.071 | -1.29e-06 | .0000318 |
| _pnamXcurr_9 | .0000291 | 9.20e-06 | 3.16 | 0.002 | .0000111 | .0000472 |
| _pnamXcur~10 | 1.83e-06 | 8.36e-06 | 0.22 | 0.827 | -.0000146 | .0000182 |
| _pnamXcur~11 | 7.52e-06 | .0000728 | 0.10 | 0.918 | -.0001351 | .0001502 |
| _pnamXcur~12 | -.0000151 | .0001 | -0.15 | 0.880 | -.0002111 | .0001809 |
| _pnamXcur~13 | .0000228 | .0000231 | 0.99 | 0.322 | -.0000224 | .000068 |
| _pnamXcur~14 | .0000238 | 8.23e-06 | 2.89 | 0.004 | 7.63e-06 | .0000399 |
| _pnamXcur~15 | .0000286 | 8.44e-06 | 3.39 | 0.001 | .0000121 | .0000451 |
| _pnamXcur~16 | -.0000291 | .0000654 | -0.45 | 0.656 | -.0001573 | .0000991 |
| _pnamXcur~17 | -.0000266 | .000021 | -1.27 | 0.205 | -.0000677 | .0000145 |
| _pnamXcur~18 | -.0000228 | .0000417 | -0.55 | 0.585 | -.0001046 | .000059 |
| _pnamXcur~19 | 4.90e-06 | 8.66e-06 | 0.57 | 0.571 | -.0000121 | .0000219 |
| _pnamXcur~20 | .0000154 | .0000113 | 1.36 | 0.173 | -6.76e-06 | .0000376 |
| _pnamXcur~21 | .0000249 | .0000235 | 1.06 | 0.290 | -.0000212 | .0000709 |
| _pnamXlogd_2 | -1.088484 | .4544198 | -2.40 | 0.017 | -1.97913 | -.1978373 |
| _pnamXlogd_3 | -1.852985 | 5.3084 | -0.35 | 0.727 | -12.25726 | 8.551287 |
| _pnamXlogd_4 | -1.617153 | .6131703 | -2.64 | 0.008 | -2.818945 | -.4153616 |
| _pnamXlogd_5 | .218803 | .4397602 | 0.50 | 0.619 | -.6431111 | 1.080717 |
| _pnamXlogd_6 | -1.982495 | .4852651 | -4.09 | 0.000 | -2.933597 | -1.031392 |
| _pnamXlogd_7 | 1.031248 | 1.079763 | 0.96 | 0.340 | -1.085048 | 3.147545 |
| _pnamXlogd_8 | -.3651789 | .4492313 | -0.81 | 0.416 | -1.245656 | .5152983 |
| _pnamXlogd_9 | -2.985246 | .6506273 | -4.59 | 0.000 | -4.260452 | -1.71004 |
| _pnamXl~d_10 | .2412221 | .3276786 | 0.74 | 0.462 | -.4010162 | .8834603 |
| _pnamXl~d_11 | 1.530434 | 1.939443 | 0.79 | 0.430 | -2.270803 | 5.331672 |
| _pnamXl~d_12 | -2.136146 | 1.79233 | -1.19 | 0.233 | -5.649048 | 1.376756 |
| _pnamXl~d_13 | -4.404885 | 1.420114 | -3.10 | 0.002 | -7.188257 | -1.621513 |
| _pnamXl~d_14 | .3367454 | .654696 | 0.51 | 0.607 | -.9464352 | 1.619926 |
| _pnamXl~d_15 | -.5129919 | .3412207 | -1.50 | 0.133 | -1.181772 | .1557883 |
| _pnamXl~d_16 | 2.818863 | 4.047752 | 0.70 | 0.486 | -5.114585 | 10.75231 |
| _pnamXl~d_17 | .0909493 | .3032746 | 0.30 | 0.764 | -.503458 | .6853566 |
| _pnamXl~d_18 | -.7199094 | .9541577 | -0.75 | 0.451 | -2.590024 | 1.150205 |
| _pnamXl~d_19 | .1666462 | .6467806 | 0.26 | 0.797 | -1.101021 | 1.434313 |
| _pnamXl~d_20 | -2.790463 | .687873 | -4.06 | 0.000 | -4.13867 | -1.442257 |
| _pnamXl~d_21 | -.360232 | .3866506 | -0.93 | 0.352 | -1.118053 | .3975892 |
| _pnamXlogg_2 | 1.306494 | .414393 | 3.15 | 0.002 | .4942985 | 2.118689 |
| _pnamXlogg_3 | 2.434537 | 6.278371 | 0.39 | 0.698 | -9.870844 | 14.73992 |
| _pnamXlogg_4 | 1.859075 | .5633409 | 3.30 | 0.001 | .7549474 | 2.963203 |
| _pnamXlogg_5 | -.2437939 | .4745455 | -0.51 | 0.607 | -1.173886 | .6862981 |
| _pnamXlogg_6 | 1.955576 | .4147395 | 4.72 | 0.000 | 1.142702 | 2.76845 |
| _pnamXlogg_7 | -.6120702 | 1.059058 | -0.58 | 0.563 | -2.687785 | 1.463645 |
| _pnamXlogg_8 | .6695045 | .4201985 | 1.59 | 0.111 | -.1540694 | 1.493078 |
| _pnamXlogg_9 | 2.856394 | .5812087 | 4.91 | 0.000 | 1.717246 | 3.995542 |
| _pnamXl~g_10 | .0804778 | .2887574 | 0.28 | 0.780 | -.4854762 | .6464319 |
| _pnamXl~g_11 | -1.220246 | 1.7435 | -0.70 | 0.484 | -4.637443 | 2.196952 |
| _pnamXl~g_12 | 1.903015 | .8521281 | 2.23 | 0.026 | .2328747 | 3.573155 |
| _pnamXl~g_13 | 4.236242 | 1.470095 | 2.88 | 0.004 | 1.354909 | 7.117575 |
| _pnamXl~g_14 | .0854714 | .5283831 | 0.16 | 0.871 | -.9501404 | 1.121083 |
| _pnamXl~g_15 | .873594 | .3409096 | 2.56 | 0.010 | .2054234 | 1.541765 |
| _pnamXl~g_16 | -3.046821 | 4.92796 | -0.62 | 0.536 | -12.70545 | 6.611803 |
| _pnamXl~g_17 | -.0156257 | .3611232 | -0.04 | 0.965 | -.7234142 | .6921629 |
| _pnamXl~g_18 | .6331787 | .6103298 | 1.04 | 0.300 | -.5630457 | 1.829403 |
| _pnamXl~g_19 | -.0960939 | .6240845 | -0.15 | 0.878 | -1.319277 | 1.127089 |
| _pnamXl~g_20 | 2.965926 | .6429834 | 4.61 | 0.000 | 1.705701 | 4.22615 |
| _pnamXl~g_21 | .61846 | .3300552 | 1.87 | 0.061 | -.0284364 | 1.265356 |
| _pnamXstde_2 | -.564634 | 1.580013 | -0.36 | 0.721 | -3.661403 | 2.532135 |
| _pnamXstde_3 | 16.24603 | 55.76953 | 0.29 | 0.771 | -93.06025 | 125.5523 |
| _pnamXstde_4 | 1.177071 | 4.540582 | 0.26 | 0.795 | -7.722306 | 10.07645 |
| _pnamXstde_5 | -5.840656 | 3.204892 | -1.82 | 0.068 | -12.12213 | .4408173 |
| _pnamXstde_6 | 5.412274 | 5.82358 | 0.93 | 0.353 | -6.001733 | 16.82628 |
| _pnamXstde_7 | 1.931375 | 4.272904 | 0.45 | 0.651 | -6.443362 | 10.30611 |
| _pnamXstde_8 | .2624124 | .2762919 | 0.95 | 0.342 | -.2791099 | .8039346 |
| _pnamXstde_9 | -6.7964 | 5.643271 | -1.20 | 0.228 | -17.85701 | 4.264208 |
| _pnamXstd~10 | .4294145 | .8391787 | 0.51 | 0.609 | -1.215346 | 2.074174 |
| _pnamXstd~11 | -34.81144 | 143.1519 | -0.24 | 0.808 | -315.3839 | 245.761 |
| _pnamXstd~12 | (omitted) | | | | | |
| _pnamXstd~13 | 12.68331 | 6.672266 | 1.90 | 0.057 | -.3940929 | 25.76071 |
| _pnamXstd~14 | -1.761549 | 1.043039 | -1.69 | 0.091 | -3.805867 | .282769 |
| _pnamXstd~15 | -.2549754 | .6811864 | -0.37 | 0.708 | -1.590076 | 1.080125 |
| _pnamXstd~16 | -24.48706 | 35.91287 | -0.68 | 0.495 | -94.87498 | 45.90087 |
| _pnamXstd~17 | 5.581271 | 1.20672 | 4.63 | 0.000 | 3.216143 | 7.946399 |
| _pnamXstd~18 | 1.859716 | 2.134486 | 0.87 | 0.384 | -2.3238 | 6.043232 |
| _pnamXstd~19 | -2.072792 | .8868902 | -2.34 | 0.019 | -3.811065 | -.3345191 |
| _pnamXstd~20 | 3.13102 | 3.555524 | 0.88 | 0.379 | -3.837679 | 10.09972 |
| _pnamXstd~21 | -.7387568 | .894716 | -0.83 | 0.409 | -2.492368 | 1.014854 |
| _cons | .9179509 | .1726305 | 5.32 | 0.000 | .5796013 | 1.256301 |
| **select** | | | | | | |
| stdoflenof~s | 7.205122 | 2.138921 | 3.37 | 0.001 | 3.012915 | 11.39733 |
| roadensity | .0003938 | .0001473 | 2.67 | 0.008 | .000105 | .0006825 |
| stdevroade~y | -1.265279 | .3158116 | -4.01 | 0.000 | -1.884258 | -.6462998 |
| districtgdp | -.0000274 | 5.65e-06 | -4.85 | 0.000 | -.0000385 | -.0000163 |
| gdpgrwtstdev | 7.472404 | 1.861313 | 4.01 | 0.000 | 3.824298 | 11.12051 |
| population | .0007623 | .0001428 | 5.34 | 0.000 | .0004824 | .0010422 |
| scbcred~ning | .0062043 | .001437 | 4.32 | 0.000 | .0033877 | .0090208 |
| scbcreditc~n | -.000185 | .0000534 | -3.47 | 0.001 | -.0002896 | -.0000804 |
| scbcreditt~s | -.0010357 | .000193 | -5.37 | 0.000 | -.001414 | -.0006574 |
| scbindustr~g | 2.12e-06 | 5.43e-07 | 3.90 | 0.000 | 1.05e-06 | 3.18e-06 |
| scboutstan~n | .0000268 | 6.01e-06 | 4.46 | 0.000 | .000015 | .0000386 |
| scboutstan~t | .0001705 | .000038 | 4.49 | 0.000 | .0000961 | .0002448 |
| tpcproject~n | -.0002854 | .0000918 | -3.11 | 0.002 | -.0004653 | -.0001055 |
| kmroadswon | .0030543 | .0010855 | 2.81 | 0.005 | .0009268 | .0051818 |
| projectswon | -.1257099 | .0630165 | -1.99 | 0.046 | -.2492199 | -.0021999 |
| ieec | .0984664 | .0188222 | 5.23 | 0.000 | .0615756 | .1353572 |
| _cons | -2.362436 | .4522613 | -5.22 | 0.000 | -3.248852 | -1.47602 |
| **mills** | | | | | | |
| lambda | -.4345047 | .1363445 | -3.19 | 0.001 | -.7017351 | -.1672743 |
| rho | -0.93455 | | | | | |
| sigma | .4649326 | | | | | |
| lambda | -.4345047 | .1363445 | | | | |

**Appendix 7**

Regression Results: Factors Impacting Probability of Inter Firm Cooperation

```
. logit  interfirm  noofshortlistedbidders sqloggdpgrwtvar marpbdit intcov tpcprojectswon

Iteration 0:   log likelihood = -130.46175
Iteration 1:   log likelihood = -93.478497
Iteration 2:   log likelihood = -88.771958
Iteration 3:   log likelihood = -88.730731
Iteration 4:   log likelihood = -88.730724

Logistic regression                               Number of obs   =        232
                                                  LR chi2(5)      =      83.46
                                                  Prob > chi2     =     0.0000
Log likelihood = -88.730724                       Pseudo R2       =     0.3199
```

| interfirm | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| noofshortl~s | .2611039 | .0404067 | 6.46 | 0.000 | .1819082 | .3402996 |
| sqloggdpgr~r | .126066 | .057985 | 2.17 | 0.030 | .0124174 | .2397146 |
| marpbdit | 3.646018 | 1.705233 | 2.14 | 0.033 | .3038227 | 6.988213 |
| intcov | .5083226 | .1924008 | 2.64 | 0.008 | .1312239 | .8854212 |
| tpcproject~n | -.0013704 | .0004207 | -3.26 | 0.001 | -.0021949 | -.0005459 |
| _cons | -4.474381 | 1.03299 | -4.33 | 0.000 | -6.499004 | -2.449758 |

## Appendix 8

N Matching

```
. psmatch2 interfirm, mahalanobis ( currentpcu nbid stateprojectroads loggrtrateofstateprojectroads districtg
> dp population totalscbscredit scbindustryoutstanding timelapse  logdieselstd logstdofstateprojectroads logp
> etrolstdev logpetrolgrtrt) outcome (bidperkm)
```

| Variable | Sample | Treated | Controls | Difference | S.E. | T-stat |
|---|---|---|---|---|---|---|
| bidperkm | Unmatched | 4.61694117 | 1.59296297 | 3.0239782 | 1.14489217 | 2.64 |
| | ATT | 4.61694117 | 1.31270591 | 3.30423525 | 1.29705974 | 2.55 |

Note: S.E. does not take into account that the propensity score is estimated.

| psmatch2: Treatment assignment | psmatch2: Common support On suppor | Total |
|---|---|---|
| Untreated | 54 | 54 |
| Treated | 85 | 85 |
| Total | 139 | 139 |

```
. pstest bidperkm
```

| Variable | Sample | Mean Treated | Mean Control | %bias | %reduct \|bias\| | t-test t | t-test p>\|t\| |
|---|---|---|---|---|---|---|---|
| bidperkm | Unmatched | 4.6169 | 1.593 | 46.8 | | 2.64 | 0.009 |
| | Matched | 4.6169 | 1.3127 | 51.2 | -9.3 | 3.90 | 0.000 |