The cost of road infrastructure in low and middle income countries

Paul COLLIER[a]

Martina KIRCHBERGER[b]*

Måns SÖDERBOM[c]

[a] *University of Oxford*

[b] *Columbia University*

[c] *University of Gothenburg*

January 2015

Abstract:

The connections between transport infrastructure and economic development have been extensively analyzed in previous research, but little is known about the cost of infrastructure investments in poor countries. This paper examines drivers of unit costs of construction and maintenance of transport infrastructure in low and middle income countries, and documents that: (i) there is a large dispersion in unit costs for comparable road work activities; (ii) after accounting for environmental drivers of costs, residual unit costs are significantly higher in conflict countries; (iii) there is evidence that costs are higher in countries with higher levels of corruption; (iv) these effects are robust to controlling for a country's public investment capacity and business environment. Our findings have implications for governments aiming to increase connectivity in poor countries.

Keywords: construction, infrastructure, transport.

JEL classification: O1, L7, H5, R4.

---

*We are grateful to three anonymous referees and the editor for very helpful comments and suggestions. We would like to thank Orazio Attanasio, Steve Bond, Stefan Dercon, Kirsten Hommann, Francisco Ferreiro, Sergio Oliete Josa, Clare Leaver, Marta Troya Martinez, Guy Michaels, Elias Papaiannou, Gerhard Toews, Tony Venables, Greg Yetman as well as participants at the IGC workshop on Fragile States, CSAE Conference, ESOP (Oslo) Seminar, Tanzania Roads Fund Workshop, DFID Lunchtime Seminar, European Economic Association Annual Conference 2014, World Bank Africa Economics Seminar and the OXCARRE brownbag seminar for helpful comments and discussions. We are particularly grateful to Rodrigo Archondo-Callao for providing detailed information on the ROCKS database and to Michael Agyapong for providing excellent research assistance. This work was supported by the International Growth Centre. Kirchberger acknowledges funding from the AXA Research Fund. All errors are our own. Correspondence: 475 Riverside Drive, Suite 253, New York, NY 10115, UK; Email: martina.kirchberger@columbia.edu.

1 Introduction

Roads are archetypal of public economic infrastructure. While telecoms, power and railways are often privately financed, the practical scope for private financing of roads in developing countries has proved to be extremely limited. Yet over recent decades donors have shifted their support from such infrastructure, which was the initial rationale for aid, to social priorities, as exemplified by the Millennium Development Goals. In low-income counties this may have contributed to the deterioration in provision: for example, there is evidence that since the 1980s the African road stock has actually contracted (Teravaninthorn and Raballand 2009).

If poor countries must self-finance much of their road networks, their costs of construction and maintenance become more important. Where costs are unusually high, it is useful to discover why. If the cause of high costs is readily remediable, then it can become an objective of policy. But even if high costs are attributable to factors that are beyond influence, there are important implications. Connectivity is essential for economic development. It enables trade, which in turn enables people to harness the productivity gains that come from specialization and scale. However, the density of a national road network necessary to achieve a given level of connectivity depends upon population dispersion. Connectivity can potentially be increased either by building more roads for a given dispersion, or by encouraging people to relocate into larger settlements. A country in which roads are unalterably very expensive should give greater priority to reducing dispersion. Hence, in studying variation in the unit cost of roads, it is useful to discover both the extent of variation, and the likely reasons for that variation.

Given this research agenda, the contribution of this paper is twofold. First, it provides quantitative evidence on unit costs of road construction and maintenance across a large sample of low and middle income countries. We use a dataset which consists of 3,322 unit costs of work activities across 99 countries obtained from the World Bank (World Bank 2006). To make meaningful comparisons of unit costs of construction data, one needs detailed information on the year and location of the work activity, type of costs (estimated, actual or contracted) and the specificities of the construction or maintenance activity (what type of road work activity it is). All these variables are present in our dataset. Second, we examine whether there is residual variation in unit costs once we control for potential cost drivers such as terrain ruggedness and access to markets. We focus on two dimensions of the environment a firm operates: conflict and corruption.

Our analysis yields four main findings. First, we show that there is a large dispersion in unit costs across countries for comparable road work activities. For example, the difference between countries of an asphalt overlay of 40 to 59 mm amounts to a factor of three to four. Second, we find that after accounting for environmental drivers of costs such as terrain ruggedness and proximity to markets, residual unit costs are 30% higher in conflict countries on average. This result is robust to different measures of conflict and political instability. Third, we also find evidence that costs are higher in countries with higher levels of corruption. Moving a country from the 75th percentile of corruption to the 25th percentile of corruption is associated with 6.8% lower unit costs. Countries with corruption levels as measured by the Worldwide Governance Indicators above the median in the sample have about 15% higher costs. Fourth, these effects are robust to controlling for a country's public investment management capacity and business environment.

A growing literature highlights the effects of transport infrastructure on transport costs, trade volume, market development, productivity, and poverty and consumption (Casaburi et al. 2013; Dercon et al. 2009; Donaldson 2013; Faber 2014; Gertler et al. 2014; Jacoby and Minten 2009; Limao and Venables 2001; Mu and van de Walle 2011; Shiferaw et al. 2011; Stifel et al. 2012). However, while substantial progress is being made on evaluating the benefits of infrastructure, research on the cost side is lagging behind. Our paper contributes to the recent effort in collecting and analyzing data on unit costs of different types of infrastructure investments across countries (AFRICON 2008; Alexeeva et al. 2008; Alexeeva et al. 2011). In addition to coverage of contracts of all regions worldwide, an advantage of our paper is that with a large number of contracts we can control for systematic differences in the cost of construction by including fixed effects at the very detailed work activity level.

When exploring the correlates of costs, we focus on conflict and corruption. The focus on conflict is motivated by the fact that 1.5 billion people live in conflict-affected or fragile states, and these states lag behind on measures like poverty reduction and other developmental outcomes (World Bank 2011b).[1] Understanding the cost of public infrastructure is important in particular for these countries in which resources for public investment are often scarce. Further, public work contracts, including roads, are subject to substantial levels of corruption. According to Transparency International's Bribe Payers Survey of over 3,000 business executives worldwide, public works contracts and construction is the sector with the highest propensity of paying bribes to officials and other firms (Transparency International 2011). As this paper attempts to establish a first set of facts on differences in costs in low and middle income countries, a focus on the link between corruption and costs is a natural priority.[2]

A review by the World Bank's Transport Research Support Program on the roads sector in conflict countries states that *"...projects that take place in conflict settings would almost always be more costly than in other settings because of challenges such as insecurity and low government capacity"* (Rebosio and Wam 2011). Higher costs can be due to the costs of monitoring of the security situation of an area, potentially undergoing substantial risks to visit the construction site, and the associated limited planning possible. In addition to protection of the staff working on the particular roads project, firms also risk that supplies are cut off due to disruptions of transport networks.[3] Not only the construction but also the procurement process can be riskier in conflict countries. Rebosio and Wam (2011) and Benamghar and Iimi (2011) give evidence for these effects on risks and costs from Nepal: a government employed road engineer was killed in the Terai regions; road construction teams were constantly monitoring the security situation and adjusting their operations accordingly; in certain regions violence and intimidation were employed during the bidding process to prevent firms from submitting a bid for profitable project.

Allegations of fraud, corruption or collusion were made in about one fourth of the 500

[1]If road construction and maintenance costs are significantly higher in conflict countries, this is a further mechanism through which conflict negatively affects economic development.

[2]See Kenny (2007) for a discussion of corruption in the construction industry in developing countries.

[3]If conflict takes place along ethnic lines, road construction firms might need to ensure to employ an ethnically balanced workforce, in order not to further fuel the conflict or becoming targets of violence themselves. Consultations with communities, while helpful, are also significantly adding to the cost of construction.

approved World Bank financed projects with a road component between 2000-2010 (World Bank 2011a). Roads contracts procured through the World Bank are usually awarded in a one stage sealed bid auction, with the lowest bidder winning the auction. Alexeeva et al. (2011) find that in about 20% of the auctions in their sample of 200 contracts in Europe and Central Asia, at least 50% of firms who acquired bidding documents do not bid, the winning bid is not selected for detailed examination, or there is a time overrun of more than 30% of the contracted period. The estimates of costs of collusion and cartels in the road sector are large and range between 8% and 60% of the contract value (World Bank 2011a). Considering that substantial resources are allocated to road construction and maintenance (US$56 billion between 2000-2010 by the World Bank alone), this represents a massive waste of funds. Further evidence from investigations discussed in World Bank (2011a) is striking: in Bangladesh, companies paid officials up to 15% of the contract value in exchange for award of the contract; evidence from Africa indicates that fraudulent claims such as cement contents and thinner layers than specified accounted for 15-20% of the bid price.[4]

To our knowledge, the only study quantitatively investigating the link between conflict and the cost of transport infrastructure is Benamghar and Iimi (2011) who use data on 157 rural road projects in Nepal and show that the number of security incidents is significantly and positively correlated with the value of submitted bids, cost overruns, and project delays. Considering corruption in transport infrastructure, Olken (2007) finds that missing expenditures amounted to on average 24% of the total cost of the road in his experiment in Indonesia. Burgess et al. (2013) show that road expenditures are substantially higher in districts which share the ethnicity of the president than what would be predicted by their population share. See Blattman and Miguel (2010) for a recent review on the literature on conflict and Olken and Pande (2012), Zitzewitz (2012) and Banerjee et al. (2012) on corruption in developing countries.

Finally, the paper relates to a fairly recent literature on government procurement pro-

[4]The use of substandard materials imposes costs ex-post through higher maintenance costs and costs on vehicle drivers due to worse road conditions and might eventually lead to even negative rates of return of a particular project (Kenny 2009).

cesses and waste associated with it (Bandiera et al. 2009; Di Tella and Schargrodsky 2003; Estache and Iimi 2009; Estache and Iimi 2010; Huysentruyt 2011; Hyytinen et al. 2007; Krasnokutskaya and Seim 2011; Lewis and Bajari 2011; Lewis-Faupel et al. 2014; Tran 2011). While we do not have detailed information on government procurement processes, we explore differences in unit cost as a function of who finances road work activities, and whether there is an association between public investment management capacity and unit costs.

Our paper has clear limitations. One facet of corruption is that one would build "bridges to nowhere" and one feature of conflict is that one may not build at all. We do not make claims in this paper regarding the economic feasibility of projects; neither do we have information on projects that would have taken place in the absence of conflict and leave these topics to future research.

The paper is organized as follows. Section 2 presents a theoretical framework for analyzing the correlates of unit costs of road construction and maintenance. Section 3 describes our data. Section 4 outlines the econometric specification; Section 5 discusses the results; the final section concludes.

2 Theoretical Framework

This section develops a simple theoretical framework with the purpose of guiding the empirical analysis. Consider a particular type of road work activity, for example, a construction of a new two lane highway. Denote the length of the highway as q. Firms employ labor x_1 and capital x_2 in the production of highways and minimize a cost function

$$\min_{x_1,x_2} w_1 x_1 + w_2 x_2 \text{ subject to } q = f(x_1, x_2) \tag{1}$$

where w_1 is the price of labor and w_2 is the price of capital. Firms are assumed to be price takers in input markets. Further, assume that the firm has a Cobb-Douglas production function so that $f(x_1, x_2) = A^{-\delta} x_1^{\alpha} x_2^{\beta}$, where $A^{-\delta}$ is an inefficiency parameter, $0 < \alpha < 1$, and $0 < \beta < 1$.[5] The average cost per kilometer can then be obtained by simply dividing the cost function by the kilometers of road built:

$$\frac{C(w_1, w_2, q)}{q} = A^{\frac{\delta}{\alpha+\beta}} \, q^{\frac{1-(\alpha+\beta)}{\alpha+\beta}} \, \theta \, w_1^{\frac{\alpha}{\alpha+\beta}} \, w_2^{\frac{\beta}{\alpha+\beta}} \tag{2}$$

where $\theta = \left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}$. We can use (2) to test several hypotheses. Only the second term in equation (2) depends on q, and $\alpha + \beta$ indicates returns to scale in construction projects. If $\alpha + \beta > 1$, $\frac{\partial(\frac{C(w_1,w_2,q)}{q})}{\partial q} < 0$ so that an increase in the quantity of road produced will lower average costs. Unit costs are lower in countries in which the price of labor is low. Similarly, unit costs will depend on the price of capital. Given that developing countries often have to import machinery and equipment, we expect the price of capital to be higher in countries facing high transportation costs.

We use $A^{\frac{\delta}{\alpha+\beta}}$ to examine two dimensions of the environment in which a construction firm operates which potentially affect their costs: state fragility and corruption. Firms operating in a conflict or post-conflict country have to take into account the risks associated with termination of their contract, expropriation, and default on the side of the government to deliver their obligations of the contract. Assume that the cost function for this typical road in equation (2) gets shifted by an amount $A^{\frac{\delta}{\alpha+\beta}}$. Alternatively, if the firm needs to pay a bribe to government officials to get a construction permit, $A^{\frac{\delta}{\alpha+\beta}}$ can also represent these additional costs. We assume that both A and δ are exogenous to the firm's minimization problem; they are determined by the level of state fragility and corruption prevailing in the country the firm is operating in. Both bribe payments and the risk premium required by firms to operate in conflict countries will drive up unit costs.[6]

Conflict can also affect prices through changes in the market structure when firms are driven out of business, or through a price boom following the end of a conflict as demand for reconstruction increases. Further, corruption in the roads sector can be at three levels, with varying effects on efficiency. First, it can take place at the level of the government when

[5] The choice of a Cobb-Douglas production function is for expositional simplicity and to shape our thinking, rather than reflecting the precise production technology underlying road work activities.

[6] For example, Compte et al. (2005) argue that "...as firms expect to be paying a bribe, a mechanical effect of corruption is to increase the contract price by an amount corresponding to the anticipated bribe".

government officials receive side-payments to either select a contract from a particular firm, or to process documents of the operating firm. This results in higher unit costs and allocative inefficiency if contracts are not awarded to the most competitive firm. Second, individuals working for companies in the construction sector might inflate costs and use part of of these resources to extract side payments for themselves. The higher unit cost in turn decreases the likelihood of the project to be selected ex-ante by lowering the net present value or rate of return. Third, companies might not respect the contracted standards by using fewer or inferior materials. Here we only focus on the first level.[7]

3 Data

We use unit cost data from the Roads Cost Knowledge System (ROCKS), Version 2.3, developed by the World Bank's Transport Unit.[8] Motivated by the lack of comparable information on costs of road work activities across countries, the database was started in 2001 with the aim of developing "an international knowledge system on road work costs - to be used primarily in developing countries - to establish an institutional memory, and obtain average and range unit costs based on historical data that could ultimately improve the reliability of new cost estimates and reduce the risks generated by cost overruns" (World Bank 2006). The focus of this section is on describing the data; we discuss issues due to selection in detail in the next section. The data is collected in collaboration with road agencies in the respective countries using information from Implementation Completion Reports, Pavement Management Systems Review Reports, Works Contracts, Appraisal Reports and Highway Development and Management Studies. It includes road work activities financed

[7]It is also worth highlighting several issues relevant to the procurement of roads which we do not consider in our simple model. First, the market structure of the road construction sector and tender procedures affect how many firms will submit bids for a project, thereby determining *ex-ante competition* and the value of bids (Li and Zheng 2009). Second, if firms collude in the tendering phase, they can affect the price of the road contract (Pesendorfer 2000). Third, once a government has signed a contract with a firm for a road construction project, the firm can extract rents from the government, a problem referred to as hold-up in the literature (Board 2011). In the absence of data on the market structure, values of submitted bids for work activities as well as the difference in costs between contracted and actual costs for each work activity, we are not able to uncover these effects. The main rationale for the simple cost minimization framework is to inform our way of thinking about the deeper determinants of costs and input prices in an economy and to serve as a guide for the estimation. See Moavenzadeh (1978) for a discussion how the construction sector generally differs from other sectors.

[8]For access to the data see `http://go.worldbank.org/ZF1I4CJNX0`.

by the World Bank, other multilateral donors, bilateral donors and governments.

The data collection exercise was first conducted in five pilot countries, Bangladesh, India, Thailand, Viet Nam, Philippines; in 2002 a second set of countries was added including Ghana, Uganda, Poland, Armenia; in 2004, Lao, Kyrgyz, Kazakhstan, Ethiopia, Nigeria, and Serbia and Montenegro were added. As Table 1 shows, the current version of the database contains data from 3,322 work activities in 99 low and middle income countries out of which 23% are located in low income countries.[9] Contracts date between 1984 and 2008, with 82% of contracts taking place between 1996 and 2006. Table A.1 in the Appendix shows the distribution of projects by country over time.

The ROCKS database is based on 5 concepts (World Bank 2006). First, to allow for comparability of similar activities, road works are classified into categories: road development works and road preservation works. Within these two categories, projects are further divided into work class, work type and work activity. Second, comparisons are made possible through unit costs which are defined either as costs per square meter or costs per km. Third, the ROCKS database defines a minimum data requirement[10] which is required to make the data comparable. Fourth, to add flexibility, road agencies are able to enter highly recommended data and optional data.[11] Unit costs include civil works costs such as mobilization, pavement drainage, major structures and line markings; they exclude agency costs such as design, land acquisition, resettlement and supervision. Fifth, these costs are deflated to the year 2000 using the domestic consumer price index, and then converted into US$ using the exchange rate in 2000.[12] Bringing unit costs back to the same reference year and the same

[9]We exclude duplicates of 31 contracts for which we have the same entry for country, date, cost per km, cost type, work activity, length, width, shoulder and lanes. We also drop two contracts for Reconstruction Bituminous (one in India and one in Bangladesh) for which the recorded costs were US$218 and US$2,289; the median cost of the 595 Reconstruction Bituminous work activities of our database is US$195,516 per km so these two entries are likely to be incorrect.

[10]For example, country, date, project or source name, currency, unit cost, work type, cost type.

[11]Highly recommended data include the predominant work activity, total cost, length and duration, carriage width, terrain type. Optional data include number of bidders, value of individual bids, unit costs of asphalt concrete, Portland cement concrete.

[12]As the database does not contain consumer price indices and exchange rates after 2004, we recalculate all conversions using the official exchange rate (LCU per US$, period average) and the consumer price index from the World Development Indicators 2012. Projects denominated in currencies other than US$ were first deflated or inflated to the reference year 2000, and then converted into US$. Projects denominated in US$ were deflated to the reference year 2000 using the consumer price index of the United States. The costs are very similar to the ones provided in the database, with 93% (91%) of costs per km (square meter) lying within 2% of the original data provided. Azerbaijan, Ghana and Venezuela devalued their currencies since 2000, so

currency is crucial to allow for comparison across projects.

Unit costs are provided for programs or sections; a program is a part of a loan or credit, or a number of road sections combined. Sections define unit costs for road works on particular segments of a road. In either case, we have information on the name of the project the program or section is part of. Considering that a range of reports is used for the data collection, 44% of entries are estimated costs, 27% are contracted costs, and 29% are actual costs.[13] Unit costs from these different sources often differ by a large extent, so knowledge of the source is critical to compare unit costs. Individual road works activities also sometimes form part of a larger roads project. In order to account for the fact that there might be various costs types for the same projects, as well as various different work activities for the same project, we cluster the standard errors by country to allow for arbitrary correlation of costs within the same country. Table A.2 in the Appendix shows the mean, median, maximum and minimum cost of various work types and work activities for both preservation and development works. The most expensive development work type is a new six lane expressway followed by a four lane expressway, while for preservation works the most expensive work type is concrete pavement restoration followed by strengthening.

Table 2 shows the range of average unit costs for a precisely defined work activity: asphalt overlays between 40 to 59 mm between 1996-1998 and 2006-2008 ranked by the cost in US$ per km. We limit the time window in order not to conflate differences in unit costs with changes in input prices which might affect economies differently. What is striking is that even for a narrowly defined time window and work activity, there are differences in unit costs of a factor between three to four. Using these unit costs, an asphalt overlay for a length of 100 km would cost US$3,300,000 in the Dominican Republic in 1997, compared to US$11,000,000 in Tanzania in 1996, or US$10,500,000 in Pakistan in 1998. Two sources of heterogeneity remain. While costs per square kilometer of a precisely defined work activity in a short time window are likely to be comparable, one could argue that different road widths might contribute to higher unit costs. The ranking is largely unaffected when we

for these countries we use the unit cost data provided in the database.

[13] For some projects the database contains costs on all of the three categories. We include all of the available cost data.

use unit costs per square meter in 1996-1998.[14] Second, we pool across different sources of costs here, so the costs could be estimated, contracted or actual costs. However, the difference in unit costs of a factor of three to four is unlikely to be due to just differences in the source of costs.[15] We do not have enough observations for narrow work activities within these different cost types to separately show the differences for a large set of countries. To account for systematic differences across cost types, we have also compared the cost of construction projects, after partialling out the effects of cost types in a regression. The order of countries as well as range of unit costs remains substantively the same.

Table 3 lists the variables we use from the ROCKS database and the main additional variables we have compiled. Table A.3 shows the descriptive statistics.[16]

Measures of corruption and conflict employed in the empirical literature are to varying degrees subjective measures, based on perceptions of individuals working in the private and public sector. To test whether the results are sensitive to the particular measure employed, we use measures from three sources. If we find patterns that are robust across a range of indicators, we are more confident that the results reflect a particular pattern.

First, our most direct measure for conflict episodes comes from the version 4-2012 of the UCDP/PRIO Armed Conflict Dataset, published by the Uppsala Conflict Data Program (UCDP) and the International Peace Research Institute, Oslo (PRIO).[17] Readers are referred to Gleditsch et al. (2002), Themnér and Wallensteen (2012) and the Dataset Codebook for

[14]Costs per square meter are missing for many observations in 2006-2008, so we only use unit costs of work activities from the earlier period.

[15]Flyvbjerg et al. (2003) find average cost overruns for roads are about 20% for projects in Europe and North America; Alexeeva et al. (2008) find average cost overruns by country for the DRC, Malawi, Tanzania, Mozambique, Ghana and Nigeria to be between 12.05% and 39.72%; Alexeeva et al. (2011) find average cost overruns by country for Georgia, Serbia, Estonia, Armenia, Macedonia, Albania, Azerbaijan and Kazakhstan to be between 6% and 47%.

[16]Some variables are not available for the year of the construction project. We therefore distinguish between the following cases: first, if the variable is only available at one point of time we assign the available value to the construction project; second, if the variable is available for at least two years we distinguish between the following three cases: (i) when the construction project took place before the year the variable becomes available, we use data from the first year of the variable; (ii) when the construction project took place after the last time the explanatory variable is recorded, we then use the value of the last available observation; (iii) if the construction project took place in a year for which there are data points both before and after, we linearly interpolate the explanatory variable.

[17]The other potential conflict data set is the Correlates of War data set. Due to concerns over transparency and consistency as well as a high threshold of deaths (Miguel et al. 2004) we prefer the Armed Conflict Dataset (ACD).

details.[18] We follow Miguel et al. (2004) and focus on internal armed conflicts between the government and an internal party with and without outside intervention which accounts for 88.5% of the conflicts recorded in the database. We define a project as being carried out in a conflict state if the state is in conflict in the year the road work activity is recorded; a country is likely not to return to full stability after the end of a conflict, so we also create a variable that defines the country as being in a post conflict period for 5 years after the end of a conflict, or until the country reverted back into conflict. There are 187 conflict and post-conflict periods in the countries covered in our data.

Second, we use data from the Worldwide Governance Indicators (WGI) which are based on data from household and firm surveys, commercial business information providers, non-governmental organizations and public sector organizations. Six indicators capture different aspects of governance in 200 countries since 1996. We use the variables on 'control of corruption' and 'political stability and absence of violence/terrorism'.[19] These indicators are measured between -2.5 and 2.5 where higher numbers reflect lower levels of corruption and political instability. We multiply the variables by (-1) and rename the variables 'Corruption' and 'Political Instability' so that higher numbers reflect higher levels of corruption and political instability.

Third, we use Transparency International's 2008 Corruption Perception Index which allocates scores to countries from 1 to 10, where 0 equals the highest level of perceived corruption and 10 equals the lowest level of perceived corruption. We rescale the variable so that 10 is the highest level of corruption. Graf Lambsdorff (2005) and Thompson and Shah (2005) underscore that the Corruption Perception Index is inappropriate for comparison of countries across time, due to changes in methodology as well as data sources underlying the index. We use 2008 because this is the first year with the highest number of countries covered. We have also assembled the index for the years 1998-2011 and our results are

[18] UCPD defines conflict as "a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths".

[19] The control of corruption variable measures "perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests" and the variable political stability and absence of violence/terrorism reflects "perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism" (Kaufmann et al. 2010).

robust to using the indicator from earlier years (1998-2007) and later years (2009-2012).[20]

The correlation between the WGI political instability indicator and the ACD conflict dummy is 0.58, and the correlation between the Transparency International measure and the WGI corruption measure is 0.81. Both correlations are significant at the 1 percent level. For the empirical analysis we create lagged three year averages of the two WGI measures.

4 Estimation and Identification

To obtain an estimable equation, we take logs of equation (2), rewrite average costs $\frac{C(w_1,w_2,q)}{q}$ as c, denote $\frac{\delta}{\alpha+\beta}=\gamma$, $\frac{1-(\alpha+\beta)}{\alpha+\beta}=\phi_1$, $\frac{\alpha}{\alpha+\beta}=\phi_2$, $\frac{\beta}{\alpha+\beta}=\phi_3$, add an error term and fixed effects for work activities, time and region as well as subscripts for work activities, work types, countries and time. We thereby obtain

$$\begin{aligned}\ln c_{apit} =& \gamma A_{it} + \ln\theta + \phi_1 \ln q_{apit} + \phi_2 \ln w_{1apit} + \phi_3 \ln w_{2apit} \\ &+ \kappa_{apit} + \tau_t + \xi_{pt} + \rho_{ap} + \epsilon_{apit} \end{aligned} \tag{3}$$

for work activity $a = 1,\ldots,A$, work type $p = 1,\ldots,P$, country $i = 1,\ldots,N$, and time $t = 1,\ldots,T$, where c is the cost per kilometer and q is a dummy variable that is equal to one if the length of the road is above 50 km; we do not have data on the cost of labor and capital for each construction project. Rather than estimating the technological parameters, our controls are selected to proxy for the determinants of factor prices. The cost of capital is going to be a function of access to markets, so we include the distance to the nearest ice-free coast from Nunn and Puga (2012) as a measure of the price of capital and equipment. For about half of the road work activities we know whether the terrain in which the road works are undertaken is flat, mountainous, hilly or rolling. We include these as dummy variables, and additionally include a measure of country-level ruggedness to account for higher input

[20] A popular source, due to its coverage across countries and time, for perception based data on institutions is the International Crisis Research Group (for example, Alesina and Weder (2002), Fisman and Miguel (2007), Ahmed (2013), Svensson (2005), Wei (2000)). We do not include this measure due to questionable scores as highlighted by Treisman (2007), and the fact that the ICRG measure reflects the *political risk* associated with corruption, rather than a country's level of corruption (Graf Lambsdorff 2005); the ICRG website does not provide information on how the scores are constructed.

costs required on more rugged terrain. Given that unit costs might be higher in countries with high levels of rainfall, we include the three year average of lagged precipitation. We further include the log of GDP per capita to proxy for the price of labor and capital. We decided that contemporaneous GDP would lead to too severe endogeneity problems, and therefore chose to use GDP in 1985. We use our measures of corruption and conflict to proxy for A, and include two dummy variables indicating that a country is above the median level of political instability or corruption of the sample.[21] Appreciating that road work contracts require a substantial amount of time to negotiate, we lag time varying country level controls by one year.

To account for differences in the source of unit costs, procurement, financing body, and contractor type, κ_{apit} is a vector of dummy variables capturing whether the source of costs is estimated or contracted costs with the base category being actual costs, the financing body (World Bank, bilateral donor, government or other donor), and if the work was carried out by an international firm or joint venture. All models include work activity fixed effects to control for systematic differences in costs across work activities, year fixed effects to account for worldwide construction industry trends, interaction terms between work type and 5-year dummies to allow for differences in the evolution of costs for different work types, region fixed effects, and an error term.[22] We have missing values for certain countries for some of the explanatory variables. In this case, we follow a procedure known as modified zero-order regression outlined by (Greene 2003, p.60) in which we include a dummy variable that is equal to one if the variable is missing, and replace the missing observations with zero. We are not interested in the coefficients of the missing dummy variables, so do not report them when discussing the results.[23]

In order to interpret the coefficient estimates on the included variables as causal relationships, we would require that $E(\epsilon_{apit}|X_{apit}) = 0$ where X_{apit} denotes a vector of all included controls. This is a restrictive assumption. It is unlikely that there is reverse causality

[21] We take the median of distinct country-year observations we have in the sample.

[22] Table A.4 in the Appendix shows the coefficients of the work type dummy variables including and excluding country level controls. In the discussion of the results in the next section, we always control for work activity fixed effects, but do not discuss the differences in unit costs across these categories as this is not the main focus of this paper.

[23] Appendix B discusses the robustness of our results to alternative ways of dealing with missing variables.

from unit costs to the control variables, but omitted variables might bias our parameter estimates. Unfortunately, many of the controls are time invariant, and we do not have enough variation over time to include country fixed effects to account for time invariant unobservable characteristics and still precisely estimate the coefficient estimates of time-varying variables. The parameter estimates should therefore be interpreted as statistical associations, which still contain valuable insights. As a robustness check we will also estimate equation (3) with country fixed effects to test whether the road work activity characteristics, which have substantial within country variation, remain significant.

4.1 Selection

Our unit cost sample is selected along two dimensions. First, from inspection of Table A.1 in the Appendix it becomes clear that the distribution of road work activities is not a random sample of contracts per country for each year. Rather, as mentioned in Section 3, the data are clustered around pilot countries, with additional countries being added gradually. Conversations with those responsible for the database suggest that selection into the database out of the population of projects carried out does not follow any specific pattern, so that we regard it as random. To capture time invariant unobservables determining selection as a pilot country, we also include a dummy variable that is equal to one if a country belongs to the first two sets of pilot countries.[24]

Second, we only observe costs for projects that were implemented, so out of the population of potential road work activities we miss projects which have not been started.[25] Considering that the net present value of a project at time=0 is $NPV_0 = -I_0 + (B_1 - C_1)/(1 + r)^1 + \ldots + (B_T - C_T)/(1 + r)^T$, projects which appear in the database must have low enough costs (initial costs I_0 as well as maintenance costs C) or high enough benefits B. We therefore observe a truncation of the response variable (those with high project costs and low benefits). We can examine the bias introduced by such truncation. Assume that the true model is $c = \beta_0 + \beta_1 x + u$ where c are unit costs, β_0 is a constant, β_1 is our coefficient of

[24]These countries are Armenia, Bangladesh, Ghana, Philippines, Thailand, Uganda, Vietnam, India.

[25]For work activities in the sample for which we have estimated or contracted costs, we do not have information whether they were completed.

interest, and u is an error term. Consider a project with the same level of benefits in two countries. Let x be corruption, assume that corruption increases costs so that $\beta_1 > 0$, and that one country has a high level of corruption, while the other country has a low level of corruption. While the project is undertaken in the low corruption country, it might fail to generate a high enough NPV in the high corruption country. We therefore miss projects with high x and high u. Thus, x and u will be negatively correlated in the truncated sample and the OLS estimate of β_1 will be downward biased (towards zero), *underestimating* the effect of corruption on unit costs.[26] Thus, our estimates can be viewed as conservative. If the benefits of a project are a function of the individuals affected by the improved road, and congestion costs are important, we would expect the benefit of transport infrastructure to be higher in densely populated areas, so that projects are more likely to be selected even if costs are higher than in an otherwise equivalent context. Unfortunately, we do not have information on projects which have not been carried out. We are therefore limited to controlling for population density to account for selection on observables.

5 Empirical Results and Discussion

We start by presenting the main results from equation (3) including our measures of conflict, and then turn to corruption. Given the correlation between conflict and corruption, we initially examine these variables separately. We then test the robustness of our results by including country fixed effects, employing alternative functional forms and dependent variables, and different ways of dealing with missing data. As a next step, we discuss sources of omitted variable bias and include variables that proxy for the business environment and government capacity in contracting. Finally, we provide additional evidence for some of the geographical and scale variables from a subset of 941 road work activities which we manually geo-referenced.

[26] Similarly, assume that x is a measure of flatness of the terrain, so that higher values correspond to flatter terrain, and lower values to mountainous terrain. Since it is cheaper to build a road on flat terrain, $\beta_1 < 0$. Consider again a project yielding the same level of benefits in a flat and in a mountainous country. Following the logic above, a project yielding the same benefits is more likely to be in our sample in flat terrain (high x) and we will tend to miss out on projects in mountainous areas, so that x and u will be positively correlated in the truncated sample and the OLS estimate of β_1 will be upward biased, i.e. again towards zero. In this case, we will underestimate the cost-reducing effect of flat terrain.

Table 4 shows that there is a robust and significant relationship between violent conflict and its legacy and unit costs. Countries which are in conflict have about 30% higher unit costs. Although the coefficient on the post-conflict dummy is positive, it is not significantly different from zero. We find evidence for the higher costs in politically unstable countries also when using the political instability measure from the Worldwide Governance Indicators (where we use the continuous measure as well as a dummy variable for whether the measure is above the median of the sample). Countries which are above the median of the sample in terms of political instability, face about 15% higher costs. The size and significance of the coefficients is robust to omitting GDP per capita, or controlling for contemporaneous GDP per capita.[27] The estimated effect appears in line with Benamghar and Iimi (2011), who find that halving security incidents would reduce procurement costs by 10% and cost overruns by 15%.

The ruggedness of the terrain in a country, surface area and population density of a country are significantly and positively associated with unit costs. Building a road in a more rugged terrain is likely to involve higher unit costs of construction and maintenance. Column (1) suggests that a one percent increase in the ruggedness of a country is associated with about 0.07 percent higher unit costs. The surface area and distance to the nearest ice-free coast are highly correlated, so that when we include the surface area we cannot estimate the coefficient on the distance to the nearest ice-free coast precisely. The positive coefficient on the surface area therefore is likely to pick up both the effects of being landlocked, leading to higher transport costs, as well as the fact that perhaps constructing and maintaining roads in larger countries involves higher organizational costs. Population density is also positively and significantly associated with unit costs, indicating that unit costs rise by about ten percent for an increase of 100 people per square kilometer. One possible reason is that, if population density is high then the value of having a road is higher and building a road is more likely to be justified in a cost-benefit analysis. An alternative explanation could be that price levels and wages are higher in cities and this is reflected in the final costs.[28]

[27] Results available upon request.

[28] A further explanation could be that road specifications are higher in urban areas, but this difference

Finally, we turn to the work activity specific control variables. The estimates suggest that there are significant economies of scale. Unit costs are between 10-12% lower when road work activities cover a length of at least 50 km. This is close to an estimate by AFRICON (2008) who find that median unit costs are 15-20% lower for road contracts that are larger than 50 km. There is no evidence that estimated and contracted costs are different from actual costs.[29] Work activities undertaken by a foreign firm or joint venture compared to a local firm are on average 24-28% more costly. This could reflect a lack of competition: in environments where local firms are unable to compete, foreign firms have market power and can charge higher prices.[30] We do not find evidence that work activities which were financed by the World Bank or bilateral donors are more expensive compared to work activities financed by governments themselves.

We now turn to corruption in Table 5. The pattern is consistent for the corruption variables from Transparency International and the Worldwide Governance Indicators. We find that Transparency International's measure of corruption is significantly correlated with unit costs, so that a one point increase in corruption on a ten-point scale is associated with an increase in costs by about 7%. The WGI measure suggests that moving a country from the 75th percentile of corruption to the 25th percentile of corruption is associated with 6.8% lower unit costs. Unit costs in countries with a level of corruption above the median

should be largely absorbed into our work activity fixed effects.

[29]Unfortunately, data on the type of procurement is missing for more than half of the sample. For the unit costs for which we have data, the procurement was done by international competitive bidding in 62% of the cases, national competitive bidding in 36% of the cases, with the remaining work activities procured via single source selection, force account or limited international bidding. We have also tried including a dummy variable that is equal to one if procurement was done via international competitive bidding and zero otherwise, as well as a dummy variable that is equal to one if we miss procurement information. The results suggest that work activities awarded through an international auction have 35-38% higher costs (significant at the 5 percent level) compared to national bidding process, single source selection or force account. Alexeeva et al. (2008) find, when analyzing 109 contracts in 13 Sub-Saharan African countries, that local firms have a cost advantage over international firms, likely due to lower management and overhead costs. However, local firms perform worse in the implementation of the project, including longer delays and higher cost overruns. We do not have data related to the implementation of the project, so we cannot test whether we find the same with our data.

[30]We would have liked to include a variable that measures the thickness of the construction sector in a particular country. Unfortunately, research on the construction industry in developing countries in the past two decades has been largely non-existent (Ofori 2007; Ofori 2011); as a consequence, apart from anecdotal evidence and a few country-level studies little is known with regard to the functioning of construction markets, number of players and the interaction between local and international firms. The general notion is that markets are thin with few large domestic firms which tend to be state-owned and a larger number of smaller firms (Kenny 2007).

as measured by the Worldwide Governance Indicator of corruption have on average 15% higher costs.[31] The effects of the other control variables are stable when comparing their coefficients and standard errors with Table 4.

Table A.5 in the Appendix shows the results without controls for conflict and corruption, and some of the omitted controls which are still of interest. Pilot countries have on average lower costs, but the coefficient is not significantly different from zero. There is substantial regional variation. Unit costs in East Asia and the Pacific, Latin America and the Carribean, the Middle East and North Africa, and South Asia are all significantly lower than in costs in the base category, Sub-Saharan Africa. Looking at column (1), these differences in costs range between 49% in East Asia and the Pacific and 20% in Latin America and the Caribbean.

5.1 Robustness

We now perform a number of robustness checks on our results. First, we introduce country fixed effects in Table 6 in order to control for unobserved time constant country heterogeneity in costs. This is a very limited test because most of our variables are country-specific and so drop out. As Kaufmann et al. (2010) point out, most countries in the Worldwide Governance Indicators have high persistence in these indicators over time, and changes in indicators are both due to changes in measurement as well as in the performance of a country. However, we have within country level variation in the conflict variable due to the different timing of the road work activities and conflicts, and this variable does not suffer from changes in measurement. The coefficients on those variables that can be tested are not significantly affected. The scale effect remains significant, negative, higher in magnitude, and coincides even closer with the results of AFRICON (2008). The coefficient on the conflict variable remains significant and positive but slightly lower in size, suggesting that countries undertaking road works during times of violence face 20% higher costs.

Second, given the significance of population density, we have also estimated a speci-

[31] We also tested whether estimated or contracted costs are significantly lower compared to actual costs in countries which suffer from conflicts, or countries with high levels of corruption, but we do not find any evidence for this.

fication in which population density enters non-parametrically (see Tables A.6 and A.7 in the online Appendix). To test the robustness of our second measure of scale, the length of a work activity, we include the length variable in bins: contracts less than 20 km (base category), compared to work activities between 20 and 50 km, 50 km and 100 km and above 100 km (see Tables A.8 and A.9 in the online Appendix). We find that including population density non-parametrically does not affect our results, and the coefficients on flexibly entered length variable show that costs decrease with the length of the contract as we would expect. We have also estimated the model with costs per square meter instead of costs per km, using different lag structures of the WGI measures, tested whether large countries are driving the conflict results, and tested a range of alternative ways of dealing with missing data. Appendix B discusses these further robustness checks in more detail.

5.2 Public Investment Management and Doing Business

Having established that conflict and corruption are associated with higher costs, our main concern that prevents us from interpreting the coefficient estimates as causal are omitted variables. The fact that the inclusion of per capita GDP does not substantially alter the results is suggestive that conflict and corruption are correlated with unit costs not simply through the level of income. However, conflict and corruption might be correlated with other unobserved variables. For example, conflict states are likely to both have weak government public investment management capacity, as well as an unfriendly business environment. We therefore use information on the Public Investment Management Index and data from the Doing Business Indicators in 2007 to test whether these two dimensions capture part of the higher costs. We use variables which are underlying the Doing Business Indicators: the time it takes to start a business, obtain a construction permit, import and export, register property, and enforce a contract. The Public Investment Management Index is measured on a scale from 1 to 4, with higher values reflecting better public investment management capacity. If our results are not affected by their inclusion, this does not imply a causal relationship, but it weakens the argument that our conflict and corruption variables are simply proxying for a weak business environment and government capacity.

Table 7 summarizes the effect of progressively adding the various controls using the Transparency International measure for corruption and the ACD measure of conflicts;[32] column (3) shows that both, the conflict variable as well as the corruption variable, decrease in size when they are jointly included, suggesting that part of the higher costs of conflict affected countries is because these countries also have higher levels of corruption, and vice versa.

The main significant correlation between costs and the additional variables on the business environment and government investment capacity is with time it takes to enforce a contract. A 10% increase in the number of days it takes to enforce a contract is associated with 2.9% higher unit costs. The inclusion of the Doing Business Indicators reduces the correlation of unit costs and the conflict variable, leaving the coefficient on the corruption variable largely unchanged. The coefficient on the Public Investment Management Index is not significantly different from zero and its inclusion does not affect the size and significance of the coefficients. Overall, column (6) illustrates that part of the higher costs in conflict countries is due to a worse business environment, but this does not explain the whole effect.

5.3 A Closer Look at the Role of Geography and Population Density

As noted above, most of the explanatory variables are measured at the country level, and several are constant over time within countries. The aggregation involved in the construction of such variables clearly implies some loss of variation in the data, which could lead to misleading results. This is more of a concern for variables that vary a lot within countries, e.g. population density and certain geographical characteristics, than for variables for which there is relatively little within country variation, e.g. corruption. To investigate if we can obtain sharper findings regarding the relationship between unit costs and geographical characteristics and population density, we conducted a separate analysis of more disaggregated data obtained for a selected subset of countries. Specifically, for Bangladesh, Ethiopia, Ghana, India, the Philippines, Thailand and Uganda, we geo-referenced a total of

[32] Tables A.10 and A.11 in the online Appendix show the results separately for conflict and corruption.

941 road projects, and matched these data geographically to data on population density, precipitation, ruggedness, distance to the nearest city of more than 100,000 people, and distance to the nearest port.[33][34] Appendix C provides detailed information on how we spatially linked the road work activity data with the additional data. Summary statistics for these variables are shown in Table A.14 and results from estimated unit cost regressions using these disaggregated data are shown in Table 8.

Columns (1) - (2) in Table 8 show results for a specification similar to our baseline models in Tables 4 - 5, the only difference being that disaggregated data on geographical characteristics and population density are used and that estimation is based on a smaller sample of countries. The conflict and corruption results are in fact stronger when we use the disaggregated data on geography and population density to measure these controls. There is thus no evidence that the significant effects on conflict and corruption are an artefact driven by aggregation of these control variables. The population density variable is statistically highly significant and the coefficient estimate is positive, albeit smaller, than in the baseline regressions above. The relationship between the geography variables and unit costs is generally weaker than what was found previously. Rainfall is statistically significant at the 10% level only, in column (2). Ruggedness, distance to large city, and distance to port are all statistically insignificant. In column (3) we add country-time fixed effects, hence the corruption and conflict variables must be excluded from the specification due to collinearity. The results change only marginally as a result, suggesting a weak correlation between country-time level unobservables and the remaining regressors. The inclusion of the fixed effects implies that the estimated coefficient on population density falls to 0.005 and is no longer statistically significant. The geographical variables are mostly insignificant. In all three specifications reported in Table 8, the coefficient on the dummy indicating whether the road is longer than 50 km remains negative, and it is highly statistically significant in column (3). Thus, the evidence of increasing returns to scale in road construction is robust to unobserved heterogeneity in the form of country-time fixed effects. We further

[33] We are very grateful to an anonymous referee for suggesting this approach.

[34] These are the countries with the highest number of work activities for which we have information on the section, maintaining a geographical balance between Africa and Asia.

obtain stronger evidence than previously of systematic cost differences across financing bodies: World Bank and bilateral donor financing is associated with lower unit costs than government financing, and the difference is statistically significant. Finally, we obtain some evidence that estimated costs are higher, on average, than contracted or actual costs, conditional on the explanatory variables in the model. Why this is the case is hard to determine, and, as we have seen above, not a result that holds generally for the full sample.

6 Conclusion

This paper presented a systematic analysis of drivers of unit costs of transport infrastructure across countries. Our analysis yielded four main findings. First, there is a large dispersion in unit costs across low and middle income countries for comparable road work activities. For example, the difference between countries of an asphalt overlay of 40 to 59 mm amounts to a factor of three to four. Second, conditional on environmental drivers of costs such as terrain ruggedness and proximity to markets, residual unit costs are significantly higher in fragile countries. Countries which are in conflict have about 30% higher unit costs. This result is robust across a range of measures of conflict and political instability. Third, costs are higher in countries with higher levels of corruption. Countries with corruption levels as measured by the World Governance Indicators above the median in the sample have about 15% higher costs. Fourth, the premium charged by firms in conflict and corrupt countries remains when we control for the government's public investment capacity and the business environment.

Our results have important implications for development policy in extreme conditions such as South Sudan and Liberia. In South Sudan the road network is skeletal while the population is highly dispersed. In consequence, the population lacks connectivity, which is a pre-condition for development. But connectivity can be increased either by investing in roads, or by encouraging people to relocate into villages and towns. To date, the Government of South Sudan has chosen the former strategy. In Liberia, during the long period of conflict people relocated from rural areas to Monrovia for reasons of security. Since then, official development policy has been to encourage people to return to rural areas, increasing dispersion and so the need for roads. Yet we have found that road infrastructure is substantially more costly to construct in conditions of conflict and corruption, neither of which are readily amenable to policy. According to our estimates, for an average African country in conflict, with corruption levels above our sample median, and a business environment below our sample median, costs are approximately double. In such situations, either donors should accept that their finance for road budgets will need to be exceptionally high, or governments should become more sympathetic to rapid urbanization.

References

AFRICON (2008). Unit costs of infrastructure projects in sub-saharan africa, africa infrastructure country diagnostic. Background Paper No. 11 (Phase I), Africa Infrastructure Country Diagnostic, The World Bank.

Ahmed, F. Z. (2013). Remittances deteriorate governance. *Review of Economics and Statistics 95*(4), 1166–1182.

Alesina, A. and B. Weder (2002). Do corrupt governments receive less foreign aid? *The American Economic Review 92*(4), 1126–1137.

Alexeeva, V., C. Queiroz, and S. Ishihara (2008). Monitoring road works contracts and unit costs for enhanced governance in sub-saharan africa. Transport Paper 21, The World Bank.

Alexeeva, V., C. Queiroz, and S. Ishihara (2011). Monitoring road works contracts and unit costs for enhanced governance in europe and central asia. Transport Paper 33, The World Bank.

Bandiera, O., A. Prat, and T. Valletti (2009). Active and passive waste in government spending: Evidence from a policy experiment. *The American Economic Review 99*(4), 1278–1308.

Banerjee, A., S. Mullainathan, and R. Hanna (2012). Corruption. NBER Working Paper No. 17968.

Benamghar, R. and A. Iimi (2011). Efficiency in public procurement in rural road projects of nepal. World Bank Policy Research Working Paper 5736.

Blattman, C. and E. Miguel (2010). Civil war. *Journal of Economic Literature 48*(1), 3–57.

Board, S. (2011). Relational contracts and the value of loyalty. *American Economic Review 101*(7), 3349.

Burgess, R., R. Jedwab, E. Miguel, A. Morjaria, et al. (2013). The value of democracy: Evidence from road building in kenya. Nber working paper no. 19398, National Bureau of Economic Research.

Cameron, A. C. and P. K. Trivedi (2005). *Microeconometrics: methods and applications*. Cambridge University Press.

Casaburi, L., R. Glennerster, and T. Suri (2013). Rural roads and intermediated trade: Regression discontinuity evidence from sierra leone. mimeo.

Center for International Earth Science Information Network - CIESIN - Columbia University, and Centro Internacional de Agricultura Tropical - CIAT. 2005 (2005). Gridded Population of the World, Version 3 (GPWv3): Population Density Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H4XK8CG2. Accessed September 2012.

Compte, O., A. Lambert-Mogiliansky, and T. Verdier (2005). Corruption and competition in procurement auctions. *Rand Journal of Economics 36*(1), 1–15.

Dabla-Norris, E., J. Brumby, A. Kyobe, Z. Mills, and C. Papageorgiou (2011). Investing in public investment: an index of public investment efficiency. IMF Working Paper WP/11/37.

Dell, M., B. F. Jones, and B. A. Olken (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics 4*(3), 66–95.

DeLorme Publishing Company, Inc. (2014). World Cities. http://www.arcgis.com/home/item.html?id=dfab3b294ab24961899b2a98e9e8cd3d. Accessed January 2014.

Dercon, S., D. O. Gilligan, J. Hoddinott, and T. Woldehanna (2009). The impact of agricultural extension and roads on poverty and consumption growth in fifteen ethiopian villages. *American Journal of Agricultural Economics 91*(4), 1007–1021.

Di Tella, R. and E. Schargrodsky (2003). The role of wages and auditing during a crackdown on corruption in the city of buenos aires. *Journal of Law and Economics 46*(1), 269–292.

Donaldson, D. (2013). Railroads of the raj: Estimating the impact of transportation infrastructure. *American Economic Review*. Forthcoming.

Estache, A. and A. Iimi (2009). Joint bidding, governance and public procurement costs: a case of road projects. *Annals of Public and Cooperative Economics 80*(3), 393–429.

Estache, A. and A. Iimi (2010). Bidder asymmetry in infrastructure procurement: Are there any fringe bidders? *Review of Industrial Organization 36*(2), 163–187.

Faber, B. (2014). Trade integration, market size, and industrialization: Evidence from china's national trunk highway system. *Review of Economic Studies*. Forthcoming.

Fisman, R. and E. Miguel (2007). Corruption, norms, and legal enforcement: Evidence from diplomatic parking tickets. *Journal of Political Economy 115*(6), 1020–1048.

Flyvbjerg, B., M. K. Skamris Holm, and S. L. Buhl (2003). How common and how large are cost overruns in transport infrastructure projects? *Transport Reviews 23*(1), 71–88.

Gertler, P. J., M. Gonzalez-Navarro, T. Gracner, and A. D. Rothenberg (2014). The role of road quality investments on economic activity and welfare: Evidence from indonesia?s highways.

Gleditsch, N., P. Wallensteen, M. Eriksson, M. Sollenberg, and H. Strand (2002). Armed conflict 1946-2001: A new dataset. *Journal of peace research 39*(5), 615–637.

Graf Lambsdorff, J. (2005). Determining trends for perceived levels of corruption. Technical report, Passauer Diskussionspapiere: Volkswirtschaftliche Reihe.

Greene, W. H. (2003). *Econometric analysis*, Volume 5. Prentice hall Upper Saddle River, NJ.

Harris, I., P. Jones, T. Osborn, and D. Lister (2014). Updated high-resolution grids of monthly climatic observations–the cru ts3. 10 dataset. *International Journal of Climatology 34*(3), 623–642.

Huysentruyt, M. (2011). Development aid by contract: Outsourcing and contractor identity. mimeo.

Hyytinen, A., S. Lundberg, and O. Toivanen (2007). Politics and procurement: Evidence from cleaning contracts. Discussion Paper No 233, Helsinki Center of Economic Research.

Jacoby, H. G. and B. Minten (2009). On measuring the benefits of lower transport costs. *Journal of Development Economics 89*(1), 28–38.

Kaufmann, D., A. Kraay, and M. Mastruzzi (2010). The worldwide governance indicators: methodology and analytical issues. World Bank Policy Research Working Paper 5430.

Kenny, C. (2007). Construction, corruption and developing countries. World Bank Policy Research Working Paper 4271.

Kenny, C. (2009). Measuring corruption in infrastructure: Evidence from transition and developing countries. *The Journal of Development Studies 45*(3), 314–332.

Krasnokutskaya, E. and K. Seim (2011). Bid preference programs and participation in highway procurement auctions. *The American Economic Review 101*(6), 2653–2686.

Lewis, G. and P. Bajari (2011). Procurement contracting with time incentives: Theory and evidence. *The Quarterly Journal of Economics 126*(3), 1173–1211.

Lewis-Faupel, S., Y. Neggers, B. A. Olken, and R. Pande (2014). Can electronic procurement improve infrastructure provision? evidence from public works in india and indonesia. Nber working paper no. 20344, National Bureau of Economic Research.

Li, T. and X. Zheng (2009). Entry and competition effects in first-price auctions: Theory and evidence from procurement auctions. *The Review of Economic Studies 76*(4), 1397–1429.

Limao, N. and A. J. Venables (2001). Infrastructure, geographical disadvantage, transport costs, and trade. *The World Bank Economic Review 15*(3), 451–479.

Miguel, E., S. Satyanath, and E. Sergenti (2004). Economic shocks and civil conflict: An instrumental variables approach. *Journal of political Economy 112*(4), 725–753.

Moavenzadeh, F. (1978). Construction industry in developing countries. *World Development 6*(1), 97–116.

Mu, R. and D. van de Walle (2011). Rural roads and local market development in vietnam. *The Journal of Development Studies 47*(5), 709–734.

National Geospatial Intelligence Agency (2015). World Port Index 2015. National Geospatial Intelligence Agency, Springfield, Virginia.

Nunn, N. and D. Puga (2012). Ruggedness: The blessing of bad geography in africa. *Review of Economics and Statistics 94*(1), 20–36.

Ofori, G. (2007). Construction in developing countries. *Construction Management and Economics 25*(1), 1–6.

Ofori, G. (2011). The construction industries in developing countries: strategic review of the book. In *New perspectives on construction in developing countries*. Routledge.

Olken, B. A. (2007). Monitoring corruption: Evidence from a field experiment in indonesia. *Journal of Political Economy 115*(2), 200–249.

Olken, B. A. and R. Pande (2012). Corruption in developing countries. *Annual Review of Economics 4*(1), 479–509.

Pesendorfer, M. (2000). A study of collusion in first-price auctions. *The Review of Economic Studies 67*(3), 381–411.

Rebosio, M. and P. E. Wam (2011). Violent conflict and the road sector: Points of interaction. Technical report, The World Bank.

Shiferaw, A., M. Soederbom, E. Siba, and G. Alemu (2011). Road networks and enterprise performance in ethiopia: Evidence from the road sector development program. IGC Working Paper 12/0696.

Stifel, D., B. Minten, and B. Koro (2012). Economic benefits and returns to rural feeder roads: Evidence from a quasi-experimental setting in ethiopia. ESSP II Working Paper 40.

Svensson, J. (2005). Eight questions about corruption. *The Journal of Economic Perspectives 19*(3), 19–42.

Teravaninthorn, S. and G. Raballand (2009). *Transport Prices and Costs in Africa: A Review of the Main International Corridors*, Volume 772. World Bank Publications.

Themnér, L. and P. Wallensteen (2012). Armed conflicts, 1946–2011. *Journal of Peace Research 49*(4), 565–575.

Thompson, T. and A. Shah (2005). Transparency international's corruption perceptions index: Whose perceptions are they anyway? mimeo.

Tran, A. (2011). Can procurement auctions reduce corruption? evidence from the internal records of a bribe-paying firm.

Transparency International (2011). Bribe payer's index 2011. Technical report, Transparency International.

Treisman, D. (2007). What have we learned about the causes of corruption from ten years of cross-national empirical research? *Annual Review of Political Science 10*, 211–244.

Wei, S.-J. (2000). How taxing is corruption on international investors? *Review of economics and statistics 82*(1), 1–11.

World Bank (2006). Road Costs Knowledge System (ROCKS) Version 2.3 User's Guide. Transport and Urban Development Department, The World Bank.

World Bank (2011a). Curbing fraud, corruption, and collusion in the roads sector. Technical report, Washington, DC: World Bank.

World Bank (2011b). *World development report 2011: Conflict, Security and Development*. Washington, DC: World Bank.

Zitzewitz, E. (2012). Forensic economics. *Journal of Economic Literature 50*(3), 731–69.

7 Figures and Tables

Table 1: Complete ROCKS Database for Low and Middle Income Countries

	N	Percent
Low income	780	23.48
Lower middle income	1,352	40.70
Upper middle income	1,190	35.82
Total	3,322	100

Notes: Income classification based on World Development Indicators 2012.

Table 2: Unit Costs per km of Asphalt Overlays 40 to 59 mm

Country	Cost per km in $1000	Number	Year	Country	Cost per km in $1000	Number	Year
Work activities undertaken between 1996-1998							
Dominican Republic	33.5	1	1997	Argentina	69.7	1	1997
Ghana	42.9	5	1998	Brazil	74.4	1	1998
Lithuania	44.4	1	1996	Argentina	74.9	1	1996
Indonesia	48.5	1	1996	Cameroon	76.8	4	1997
Lithuania	49.7	1	1998	Bangladesh	79.1	26	1998
Mexico	50.7	1	1997	Vietnam	79.6	2	1998
Ghana	52.7	1	1996	Bangladesh	83.6	1	1997
Costa Rica	57.9	1	1996	Panama	84.1	1	1997
Armenia	60.7	1	1997	Nigeria	95.1	1	1997
Brazil	62.5	2	1996	El Salvador	102.2	1	1998
Bolivia	67.4	1	1997	Pakistan	105.0	1	1997
India	68.1	3	1997	Tanzania	111.7	1	1996
Work activities undertaken between 2005-2007							
Paraguay	31.2	1	2005	Botswana	68.0	1	2006
India	35.9	2	2006	Nigeria	73.0	1	2007
Bulgaria	40.7	1	2006	Argentina	76.2	3	2006
Ecuador	41.6	1	2005	Georgia	82.6	1	2006
India	45.6	1	2005	Brazil	82.9	2	2005
Burkina Faso	48.0	1	2007	Georgia	84.9	1	2005
Brazil	55.2	3	2006	Vietnam	85.4	1	2005
Brazil	58.2	1	2007	Macedonia	85.7	1	2007
Thailand	59.5	1	2005	Rwanda	90.6	1	2006
Philippines	60.8	1	2006	Philippines	94.8	1	2005
Bosnia and Herzegovina	61.9	2	2006	Chile	98.9	1	2006
Nepal	63.1	1	2006				

Notes: costs per km of asphalt overlays 40 to 59 mm; all costs are in 2000 US$; number denotes the number of work activities in a given country over which a simple average is taken.

Table 3: Description of Main Data and Sources

Variable	Description	Source
Log of Cost	Log of unit cost of a particular road work activity (1984-2008)	ROCKS dataset, World Bank
Estimate	=1 if estimated costs	ROCKS dataset, World Bank
Contract	=1 if contracted costs	ROCKS dataset, World Bank
Actual	=1 if actual costs	ROCKS dataset, World Bank
Flat	=1 if terrain is flat	ROCKS dataset, World Bank
Hilly	=1 if terrain is hilly	ROCKS dataset, World Bank
Mountainous	=1 if terrain is mountainous	ROCKS dataset, World Bank
Rolling	=1 if terrain is rolling	ROCKS dataset, World Bank
Foreign firm or JV	=1 if the work activity was carried out by a foreign firm or joint venture	ROCKS dataset, World Bank
World Bank	=1 if the work activity was financed by the World Bank	ROCKS dataset, World Bank
Bilateral Donor	=1 if the work activity was financed by a bilateral donor	ROCKS dataset, World Bank
Log of Ruggedness	Log of Terrain Ruggedness Index, representing the average ruggedness of a country measured as hundred of meters of elevation difference for grid points 926 meters apart	Nunn and Puga (2012)
Log of Distance to the nearest ice free coast	Log of average distance to nearest ice-free coast (1000 km)	Nunn and Puga (2012)
Log of Rainfall	Log of yearly precipitation in 100s mm, 2000-2008	Dell et al. (2012)
Population Density	Population Density (100 people per square km), 1960-2012	World Development Indicators
Log of Surface Area	Log of Surface Area (1,000 square kilometers)	World Development Indicators
Log of GDP	Log of GDP per capita (1984-2008), constant 2000 US$	World Development Indicators
ACD Conflict	=1 if country is in a conflict	Armed Conflict Dataset
WGI Instability	Index of political instability and violence from World governance Indicators (1996-2012), redefined to: -1.26 (lowest) to 2.21 (highest)	World Governance Indicators
TI Corruption	Corruption index from Transparency International, survey 2008, rescaled to 0.1 (lowest corruption), 5.6 (highest corruption)	Transparency International
WGI Corruption	Index of corruption from World Governance Indicators (1996-2012), redefined to: -1.45 (lowest corruption) to 1.6 (highest corruption)	World Governance Indicators
PIMI	Public Investment Management Index, 2011, measured on scale from 0 (worst) to 4 (best)	Dabla-Norris et al. (2011)
Log of DB Contract	Number of days it takes to enforce a contract, from Doing Business Indicators 2007	Doing Business Indicators

Table 4: Conflict

	ACD	WGI	WGImed
	(1)	(2)	(3)
ACD Conflict	0.307*** (0.06)		
ACD Post-Conflict	0.057 (0.057)		
WGI Instability		0.106** (0.045)	
WGI Instability > Median			0.15** (0.059)
Log Ruggedness	0.065** (0.027)	0.098*** (0.033)	0.099*** (0.032)
Log of Rainfall	-.107* (0.063)	-.105 (0.068)	-.107 (0.069)
Log dist to coast	-.016 (0.039)	-.040 (0.043)	-.044 (0.042)
Population Density	0.11*** (0.016)	0.088*** (0.016)	0.082*** (0.015)
Log of Surface Area	0.047** (0.019)	0.062*** (0.02)	0.072*** (0.018)
Length > than 50km	-.128*** (0.041)	-.107** (0.044)	-.113*** (0.043)
Estimate	-.011 (0.055)	-.016 (0.058)	-.017 (0.057)
Contract	-.062 (0.074)	-.050 (0.073)	-.064 (0.072)
Log of GDP pc (1985)	-.024 (0.043)	-.027 (0.044)	-.044 (0.042)
Foreign firm or JV	0.242** (0.12)	0.277** (0.122)	0.264** (0.123)
World Bank	0.007 (0.097)	0.028 (0.096)	0.007 (0.093)
Bilateral Donor	0.191 (0.138)	0.196 (0.141)	0.18 (0.138)
Obs.	3322	3322	3322
R^2	0.899	0.898	0.898

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table 5: Corruption

	TI	WGI	WGImed
	(1)	(2)	(3)
TI Corruption	0.072***		
	(0.025)		
WGI Corruption		0.111***	
		(0.043)	
WGI Corruption > Median			0.154***
			(0.051)
Log Ruggedness	0.111***	0.123***	0.125***
	(0.035)	(0.033)	(0.032)
Log of Rainfall	-.093	-.081	-.061
	(0.07)	(0.067)	(0.07)
Log dist to coast	-.057	-.052	-.051
	(0.046)	(0.044)	(0.043)
Population Density	0.077***	0.083***	0.074***
	(0.017)	(0.016)	(0.017)
Log of Surface Area	0.076***	0.081***	0.088***
	(0.02)	(0.02)	(0.02)
Length > than 50km	-.103**	-.107**	-.110**
	(0.042)	(0.043)	(0.043)
Estimate	-.023	-.023	-.011
	(0.058)	(0.058)	(0.057)
Contract	-.060	-.058	-.054
	(0.073)	(0.073)	(0.072)
Log of GDP pc (1985)	-.024	-.025	-.007
	(0.044)	(0.045)	(0.046)
Foreign firm or JV	0.247*	0.282**	0.28**
	(0.135)	(0.122)	(0.124)
World Bank	-.005	0.005	-.017
	(0.09)	(0.092)	(0.093)
Bilateral Donor	0.164	0.185	0.175
	(0.137)	(0.138)	(0.136)
Obs.	3322	3322	3322
R^2	0.898	0.897	0.898

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table 6: Robustness Checks - Fixed Effects

	FE1	FE2
	(1)	(2)
Estimate	0.013	0.013
	(0.059)	(0.058)
Contract	-.035	-.034
	(0.077)	(0.077)
Length > than 50km	-.139***	-.139***
	(0.041)	(0.041)
ACD Conflict		0.195*
		(0.116)
ACD Post-Conflict		0.069
		(0.106)
Foreign firm or JV	0.189*	0.186*
	(0.102)	(0.103)
World Bank	-.108	-.104
	(0.096)	(0.095)
Bilateral Donor	0.081	0.081
	(0.138)	(0.138)
Obs.	3322	3322
R^2	0.909	0.909

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table 7: Incremental Specification

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6
	(1)	(2)	(3)	(4)	(5)	(6)
ACD Conflict	0.294***		0.278***	0.243***	0.288***	0.248***
	(0.056)		(0.053)	(0.049)	(0.055)	(0.051)
TI Corruption		0.072***	0.06***	0.053***	0.066***	0.058***
		(0.025)	(0.021)	(0.02)	(0.022)	(0.021)
Log of DB Start Business				0.048		0.058
				(0.05)		(0.045)
Log of DB Construction Permit				0.013		-.010
				(0.063)		(0.065)
Log of DB Import+Export				-.043		-.034
				(0.083)		(0.08)
Log of DB Register Property				0.032		0.025
				(0.029)		(0.031)
Log of DB Enforce Contract				0.29***		0.319***
				(0.08)		(0.087)
PIMI					0.012	-.002
					(0.058)	(0.066)
Foreign firm or JV		0.247*	0.216*	0.182	0.232*	0.201*
		(0.135)	(0.131)	(0.12)	(0.123)	(0.116)
World Bank	0.007	-.005	-.005	-.017	-.009	-.028
	(0.096)	(0.09)	(0.096)	(0.094)	(0.094)	(0.092)
Bilateral Donor	0.187	0.164	0.175	0.149	0.169	0.134
	(0.137)	(0.137)	(0.137)	(0.132)	(0.137)	(0.131)
Obs.	3322	3322	3322	3322	3322	3322
R^2	0.899	0.898	0.9	0.901	0.9	0.901

Notes: Regression includes all controls (not shown) from the base model in Table 4; dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table 8: Geo-referenced Roads

	EQ1	EQ2	EQ3CF
	(1)	(2)	(3)
ACD Conflict	0.311**		
	(0.131)		
TI Corruption		0.372***	
		(0.072)	
Length > than 50km	-.135	-.140*	-.192**
	(0.087)	(0.084)	(0.08)
Population Density	0.015**	0.012***	0.005
	(0.006)	(0.005)	(0.005)
Log Ruggedness	-.019	0.014	0.019
	(0.027)	(0.019)	(0.025)
Log of Rainfall	0.057	-.212*	0.162
	(0.111)	(0.122)	(0.135)
Log distance to city	-.002	0.00009	-.004
	(0.016)	(0.014)	(0.014)
Log distance to port	0.032	0.015	-.038*
	(0.02)	(0.021)	(0.021)
Estimate	0.292***	0.362***	0.271***
	(0.089)	(0.085)	(0.095)
Contract	0.026	0.063	0.061
	(0.049)	(0.049)	(0.056)
World Bank	-.061	-.260***	-.509***
	(0.097)	(0.097)	(0.131)
Bilateral Donor	-.106	-.275***	-.285***
	(0.101)	(0.096)	(0.108)
Obs.	941	941	941
R^2	0.933	0.935	0.947

Notes: Dependent variable is the log of cost per km; column (1) includes country fixed effects; column (2) includes country-year fixed effects; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at a one degree country level grid; *, **, *** denote significance at 10%, 5% and 1% levels.

APPENDIX - FOR ONLINE PUBLICATION

A Additional Tables

Table A.1: List of Countries

Country	1984-1990	1991-1995	1995-2000	2001-2005	2005-2008	Total
Afghanistan	0	0	0	12	0	12
Albania	0	5	31	20	3	59
Algeria	0	3	3	0	0	6
Angola	0	0	0	8	0	8
Argentina	0	64	17	15	19	115
Armenia	0	3	48	0	0	51
Azerbaijan	0	0	0	2	0	2
Bangladesh	0	49	110	29	0	188
Belize	0	0	0	3	0	3
Benin	0	0	0	2	0	2
Bhutan	0	0	0	4	3	7
Bolivia	2	4	20	11	0	37
Bosnia and Herzegovina	0	0	0	1	7	8
Botswana	0	1	0	0	4	5
Brazil	8	42	33	32	33	148
Bulgaria	0	0	0	0	6	6
Burkina Faso	0	0	0	24	2	26
Burundi	0	0	0	3	2	5
Cambodia	0	0	0	11	4	15
Cameroon	0	4	12	13	0	29
Cape Verde	0	7	0	8	0	15
Chad	0	2	0	3	0	5
Chile	9	12	11	0	7	39
China	1	25	37	61	5	129
Colombia	0	13	0	0	0	13
Comoros	0	0	2	0	0	2
Congo	0	0	0	0	1	1
Costa Rica	0	0	6	0	0	6
Dem. Rep. Congo	0	0	0	16	1	17
Djibouti	0	0	5	6	0	11
Dominican Republic	1	4	36	2	0	43
Ecuador	0	1	0	12	0	13
El Salvador	0	0	4	0	0	4
Ethiopia	0	0	38	33	3	74
Fiji	0	0	1	0	0	1
Georgia	0	0	0	3	3	6
Ghana	2	29	217	38	1	287
Guatemala	0	3	0	0	0	3
Guinea	0	1	0	9	0	10
Haiti	0	0	1	7	0	8
Honduras	0	12	6	0	14	32
India	13	7	84	63	11	178
Indonesia	0	9	8	21	1	39
Iran	0	0	0	0	1	1
Jamaica	0	1	0	0	0	1
Jordan	0	4	4	0	0	8

Continued on next page

Table A.1 – continued from previous page

Country	1984-1990	1991-1995	1995-2000	2001-2005	2005-2008	Total
Kazakhstan	0	0	17	7	0	24
Kenya	0	1	0	34	6	41
Kyrgyz Republic	0	2	5	7	0	14
Lao PDR	3	10	35	46	6	100
Latvia	0	0	6	0	0	6
Lebanon	0	14	9	25	0	48
Lesotho	0	0	4	3	0	7
Lithuania	0	0	5	0	0	5
Macedonia	0	0	2	13	3	18
Madagascar	0	1	1	8	0	10
Malawi	0	3	0	15	0	18
Malaysia	0	1	0	0	0	1
Mali	0	2	3	2	1	8
Mauritania	0	0	0	1	0	1
Mauritius	0	2	0	0	0	2
Mexico	3	8	49	2	0	62
Moldova	0	0	0	0	2	2
Mongolia	0	0	1	7	0	8
Morocco	0	2	0	2	0	4
Mozambique	0	0	0	21	3	24
Namibia	0	0	0	3	0	3
Nepal	0	8	7	7	7	29
Nicaragua	0	8	11	20	0	39
Niger	0	0	3	6	1	10
Nigeria	0	11	22	11	9	53
Pakistan	0	0	22	34	0	56
Panama	0	0	12	33	0	45
Papua New Guinea	0	4	1	29	0	34
Paraguay	0	5	5	13	0	23
Peru	0	14	8	5	0	27
Philippines	5	26	61	52	10	154
Romania	0	0	1	3	0	4
Russia	0	44	17	0	0	61
Rwanda	0	0	0	1	5	6
Samoa	0	0	1	0	0	1
Senegal	0	0	3	14	0	17
Serbia	0	1	0	0	0	1
Sierra Leone	0	6	0	7	0	13
South Africa	0	0	0	3	0	3
Sri Lanka	0	0	4	0	0	4
Swaziland	0	0	0	1	0	1
Tanzania	0	2	25	8	1	36
Thailand	0	29	116	25	0	170
Tunisia	0	6	2	4	0	12
Turkey	0	0	2	24	0	26
Uganda	0	11	173	18	0	202
Uruguay	0	11	61	0	0	72
Venezuela	0	1	47	1	0	49

Continued on next page

Table A.1 – continued from previous page

Country	1984-1990	1991-1995	1995-2000	2001-2005	2005-2008	Total
Vietnam	0	3	14	18	7	42
West Bank and Gaza	0	0	3	0	0	3
Yemen	1	4	3	2	0	10
Zambia	0	16	0	15	0	31
Zimbabwe	0	4	0	0	0	4
Total	48	565	1,495	1,022	192	3,322

Table A.2: Cost per km for Different Work Types, by Work Category

Development	N	mean	p50	sd	min	max
New 6L Expressway	1	5,571,488	5,571,488	.	5,571,488	5,571,488
New 4L Expressway	65	2,838,562	2,495,592	1,474,420	937,499	7,810,495
New 4L Highway	11	2,195,810	2,213,333	1,159,299	660,242	4,561,035
New 6L Highway	2	1,990,155	1,990,155	991,449	1,289,094	2,691,215
Widening and Reconstruction	108	874,209	776,071	752,950	178,494	6,532,523
Widening	138	842,697	776,071	742,325	8,751	5,785,612
New 2L Highway	68	750,396	696,537	399,828	22,403	1,985,876
Partial Widening and Reconstruct	117	261,380	252,202	129,635	8,219	682,508
Upgrading	360	250,472	218,863	171,322	3,551	940,837
Partial Widening	12	137,773	148,321	29,027	67,299	168,278
New 1L Road	7	91,788	81,244	36,153	58,151	167,702
Total	889	678,283	358,293	930,798	3,551	7,810,495

Preservation	N	mean	p50	sd	min	max
Concrete Pavement Restoration	4	539,348	650,623	321,650	68,558	787,587
Reconstruction	745	220,287	169,668	209,577	1,973	2,615,657
Strengthening	422	139,371	120,799	75,097	27,473	553,857
Asphalt Mix Resurfacing	458	64,551	60,356	29,538	12,350	211,000
Surface Treatment Resurfacing	230	25,090	18,767	23,520	3,409	176,682
Gravel Resurfacing	275	18,169	13,198	15,765	1,872	112,950
Bituminous Pavement Preventive Treatment	47	7,355	5,534	6,190	1,147	30,653
Unsealed Preventive Treatment	101	4,347	4,385	1,319	2,009	8,402
Routine Maintenance	119	2,144	1,897	1,383	277	8,685
Grading	23	515	151	771	51	2,542
Total	2,424	109,930	67,561	149,738	51	2,615,657

Table A.3: Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Road activity controls					
Cost per km (2000 US$)	261741.12	558093.15	50.57	7810495.02	3322
Estimate	0.44	0.5	0	1	3322
Contract	0.27	0.44	0	1	3322
Actual	0.28	0.45	0	1	3322
World Bank	0.6	0.49	0	1	3090
Bilateral Donor	0.22	0.41	0	1	3090
Funded by government	0.11	0.31	0	1	3090
Funded by other donor	0.08	0.26	0	1	3090
Missing: funding source	0.07	0.25	0	1	3322
Local	0.84	0.37	0	1	708
Foreign firm or JV	0.16	0.37	0	1	708
Missing: Contractor	0.79	0.41	0	1	3322
Length > than 50 km	0.37	0.48	0	1	2452
Missing: Length	0.26	0.44	0	1	3322
Flat	0.38	0.49	0	1	1587
Hilly	0.09	0.29	0	1	1587
Mountainous	0.27	0.44	0	1	1587
Rolling	0.26	0.44	0	1	1587
Missing: Terrain	0.52	0.5	0	1	3322
Geographic controls					
Log Ruggedness	4.46	0.92	2.44	6.51	3322
Log of Rainfall	2.43	0.5	0.36	3.62	3319
Missing: Rainfall	0	0.03	0	1	3322
Log dist to coast	-1.45	1.21	-5.85	0.79	3322
Log of Surface Area	6.17	1.65	0.62	9.75	3322
Population Density	1.43	2	0.02	9.76	3322
Log of GDP per capita	6.72	1.14	4.53	9.07	3310
Missing: Log of GPD per capita	0	0.06	0	1	3322
Log of GDP pc (1985)	6.39	1.17	4.76	8.72	2985
Missing: Log of GPD pc (1985)	0.1	0.3	0	1	3322
East Asia & Pacific	0.21	0.41	0	1	3322
Europe & Central Asia	0.09	0.28	0	1	3322
Latin America & Caribbean	0.24	0.42	0	1	3322
Middle East & North Africa	0.03	0.17	0	1	3322
South Asia	0.14	0.35	0	1	3322
Sub-Saharan Africa	0.29	0.46	0	1	3322
Conflict and corruption controls					
ACD Conflict	0.25	0.43	0	1	3322
ACD Post-Conflict	0.12	0.32	0	1	3322
WGI Instability	0.56	0.63	-1.26	2.21	3322
TI Corruption	3.91	1	0.1	5.60	3318
Missing: TI Corruption	0	0.03	0	1	3322
WGI Corruption	0.48	0.46	-1.45	1.6	3322

Continued on next page

Table A.3 – continued from previous page

Variable	Mean	Std. Dev.	Min.	Max.	N
WGI Corruption > Median	0.51	0.5	0	1	3322
Public investment management and DB controls					
Public Investment Management Index	1.92	0.6	0.27	3.53	2113
Missing: Public Investment Management Index	0.36	0.48	0	1	3322
Log of DB Start Business	3.64	0.62	1.79	5.31	3322
Log of DB Construction Permit	5.32	0.44	4.44	6.51	3314
Missing: DB Construction Permit	0	0.05	0	1	3322
Log of DB Register Property	3.98	1.16	0.69	6.53	3322
Log of DB Import+Export	4.08	0.42	2.89	5.19	3322
Log of DB Enforce Contract	6.28	0.28	5.35	6.89	2852
Missing: DB Enforce Contract	0.14	0.35	0	1	3322

Table A.4: Differences in Unit Costs across different Work Types

	eq1	eq2
	(1)	(2)
Preservation Works		
Routine Maintenance	-4.289***	-4.279***
	(0.143)	(0.169)
Grading	-6.396***	-6.333***
	(0.352)	(0.378)
Gravel Resurfacing	-2.275***	-2.236***
	(0.117)	(0.168)
Bituminous Pavement Preventive Treatment	-3.076***	-2.991***
	(0.134)	(0.179)
Unsealed Preventive Treatment	-3.375***	-3.361***
	(0.179)	(0.207)
Surface Treatment Resurfacing	-1.981***	-1.946***
	(0.135)	(0.186)
Asphalt Mix Resurfacing	-.848***	-.904***
	(0.092)	(0.153)
Strengthening	-.117	-.210
	(0.085)	(0.162)
Concrete Pavement Restoration	1.000	1.071**
	(0.629)	(0.522)
Reconstruction	0.073	-.002
	(0.102)	(0.164)
Development Works		
Partial Widening and Reconstruction	0.258	0.343**
	(0.224)	(0.156)
Widening	1.410***	1.360***
	(0.171)	(0.233)
Widening and Reconstruction	1.539***	1.479***
	(0.142)	(0.177)
Upgrading	0.271**	0.201
	(0.118)	(0.166)
New 1L Road	-.349**	-.036
	(0.148)	(0.203)
New 2L Highway	1.529***	1.404***
	(0.199)	(0.257)
New 2L Highway	1.529***	1.404***
	(0.199)	(0.257)
New 4L Highway	2.542***	2.487***
	(0.297)	(0.326)
New 6L Highway	2.464***	2.374***
	(0.097)	(0.191)
New 4L Expressway	2.824***	2.762***
	(0.072)	(0.163)
New 6L Expressway	3.682***	3.403***
	(0.127)	(0.234)
Obs.	3322	3322
R^2	0.83	0.842

Notes: Omitted category is partial widening; column (1) includes year dummies and contract characteristics included in all models; column (2) also includes country characteristics; standard errors brackets, clustered at the country level; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.5: Baseline Results

	BASEI	BASEII	BASEIII
	(1)	(2)	(3)
Log Ruggedness	0.132***	0.124***	0.129***
	(0.032)	(0.036)	(0.035)
Log of Rainfall	-.040	-.058	-.054
	(0.071)	(0.071)	(0.073)
Log dist to coast	-.029	-.051	-.034
	(0.048)	(0.051)	(0.048)
Population Density	0.093***	0.089***	0.092***
	(0.016)	(0.017)	(0.017)
Log of Surface Area	0.075***	0.087***	0.078***
	(0.02)	(0.022)	(0.02)
Length > than 50km	-.104**	-.120***	-.110***
	(0.042)	(0.041)	(0.042)
Estimate	-.021	-.019	-.015
	(0.059)	(0.058)	(0.058)
Contract	-.057	-.060	-.058
	(0.073)	(0.075)	(0.074)
Log of GDP per capita		-.083**	
		(0.038)	
Log of GDP pc (1985)			-.030
			(0.046)
Pilot Country	-.054	-.054	-.062
	(0.081)	(0.087)	(0.083)
Foreign firm or JV	0.284**	0.263**	0.283**
	(0.124)	(0.127)	(0.125)
World Bank	0.0009	0.002	0.009
	(0.09)	(0.091)	(0.089)
Bilateral Donor	0.163	0.192	0.179
	(0.131)	(0.14)	(0.136)
East Asia & Pacific	-.496***	-.435***	-.481***
	(0.089)	(0.104)	(0.096)
Europe & Central Asia	-.131	-.016	-.045
	(0.089)	(0.104)	(0.102)
Latin America & Caribbean	-.204**	-.044	-.152
	(0.089)	(0.109)	(0.125)
Middle East & North Africa	-.479***	-.337***	-.394***
	(0.112)	(0.128)	(0.11)
South Asia	-.468***	-.457***	-.474***
	(0.116)	(0.125)	(0.117)
Obs.	3322	3322	3322
R^2	0.897	0.897	0.897

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.6: Semiparametric specification: Conflict

	ACD	WGI	WGImed
	(1)	(2)	(3)
ACD Conflict	0.244***		
	(0.058)		
ACD Post-Conflict	0.023		
	(0.065)		
WGI Instability		0.103***	
		(0.038)	
WGI Instability > Median			0.123**
			(0.057)
Log Ruggedness	0.095***	0.114***	0.113***
	(0.036)	(0.04)	(0.041)
Log of Rainfall	-.097	-.100	-.088
	(0.071)	(0.071)	(0.072)
Log dist to coast	-.0006	-.019	-.018
	(0.04)	(0.04)	(0.041)
Log of Surface Area	0.041**	0.047**	0.06***
	(0.017)	(0.019)	(0.016)
Length > than 50km	-.117***	-.098**	-.103**
	(0.042)	(0.045)	(0.044)
Estimate	-.006	-.011	-.013
	(0.057)	(0.059)	(0.059)
Contract	-.055	-.042	-.050
	(0.075)	(0.073)	(0.073)
Log of GDP pc (1985)	-.015	-.020	-.034
	(0.045)	(0.045)	(0.043)
Obs.	3322	3322	3322
R^2	0.887	0.886	0.886

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.7: Semiparametric specification: Corruption

	TI	WGI	WGImed
	(1)	(2)	(3)
TI Corruption	0.053** (0.023)		
WGI Corruption		0.081** (0.04)	
WGI Corruption > Median			0.129* (0.066)
Log Ruggedness	0.119*** (0.041)	0.132*** (0.04)	0.125*** (0.04)
Log of Rainfall	-.089 (0.077)	-.074 (0.072)	-.062 (0.071)
Log dist to coast	-.028 (0.044)	-.018 (0.042)	-.021 (0.041)
Log of Surface Area	0.062*** (0.018)	0.065*** (0.017)	0.07*** (0.017)
Length > than 50km	-.095** (0.044)	-.097** (0.044)	-.101** (0.044)
Estimate	-.021 (0.06)	-.020 (0.061)	-.016 (0.061)
Contract	-.046 (0.073)	-.048 (0.073)	-.047 (0.073)
Log of GDP pc (1985)	-.019 (0.044)	-.019 (0.045)	0.0001 (0.047)
Obs.	3322	3322	3322
R^2	0.886	0.886	0.886

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.8: Flexible length specification: Conflict

	ACD	WGI	WGImed
	(1)	(2)	(3)
ACD Conflict	0.31***		
	(0.06)		
ACD Post-Conflict	0.056		
	(0.058)		
WGI Instability		0.107**	
		(0.045)	
WGI Instability > Median			0.155***
			(0.059)
Log Ruggedness	0.066**	0.099***	0.099***
	(0.028)	(0.033)	(0.032)
Log of Rainfall	-.110*	-.107	-.110
	(0.065)	(0.07)	(0.07)
Log dist to coast	-.017	-.041	-.045
	(0.039)	(0.044)	(0.043)
Population Density	0.116***	0.093***	0.087***
	(0.016)	(0.016)	(0.016)
Log of Surface Area	0.052***	0.066***	0.077***
	(0.02)	(0.022)	(0.019)
20km < length < 50km	-.099*	-.102*	-.109*
	(0.059)	(0.058)	(0.058)
50km < length < 100km	-.147**	-.137**	-.149**
	(0.064)	(0.067)	(0.066)
Length > 100km	-.227***	-.199***	-.206***
	(0.07)	(0.075)	(0.074)
Estimate	-.008	-.014	-.016
	(0.056)	(0.059)	(0.059)
Contract	-.068	-.055	-.068
	(0.076)	(0.076)	(0.076)
Log of GDP pc (1985)	-.029	-.032	-.049
	(0.044)	(0.045)	(0.043)
Foreign firm or JV	0.262**	0.299**	0.288**
	(0.114)	(0.117)	(0.119)
World Bank	0.012	0.034	0.012
	(0.095)	(0.094)	(0.091)
Bilateral Donor	0.192	0.199	0.182
	(0.133)	(0.136)	(0.132)
Obs.	3322	3322	3322
R^2	0.899	0.898	0.898

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.9: Flexible length specification: Corruption

	TI	WGI	WGImed
	(1)	(2)	(3)
TI Corruption	0.071***		
	(0.025)		
WGI Corruption		0.11**	
		(0.044)	
WGI Corruption > Median			0.156***
			(0.052)
Log Ruggedness	0.112***	0.124***	0.126***
	(0.035)	(0.034)	(0.033)
Log of Rainfall	-.094	-.082	-.063
	(0.071)	(0.069)	(0.071)
Log dist to coast	-.058	-.053	-.052
	(0.046)	(0.045)	(0.043)
Population Density	0.081***	0.088***	0.079***
	(0.016)	(0.016)	(0.017)
Log of Surface Area	0.08***	0.085***	0.093***
	(0.021)	(0.021)	(0.021)
20km < length < 50km	-.101*	-.098*	-.103*
	(0.058)	(0.058)	(0.058)
50km < length < 100km	-.137**	-.135**	-.143**
	(0.066)	(0.067)	(0.067)
Length > 100km	-.188**	-.194***	-.199***
	(0.074)	(0.075)	(0.074)
Estimate	-.021	-.021	-.009
	(0.059)	(0.06)	(0.059)
Contract	-.064	-.062	-.058
	(0.076)	(0.076)	(0.075)
Log of GDP pc (1985)	-.028	-.030	-.011
	(0.045)	(0.046)	(0.047)
Foreign firm or JV	0.269**	0.303***	0.303**
	(0.13)	(0.118)	(0.119)
World Bank	-.0006	0.01	-.013
	(0.088)	(0.09)	(0.091)
Bilateral Donor	0.166	0.187	0.177
	(0.132)	(0.133)	(0.13)
Obs.	3322	3322	3322
R^2	0.898	0.898	0.898

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.10: Omitted Variables: conflict

	ACD	WGI	WGImed
	(1)	(2)	(3)
ACD Conflict	0.311***		
	(0.064)		
ACD Post-Conflict	0.055		
	(0.061)		
WGI Instability		0.114**	
		(0.047)	
WGI Instability > Median			0.164**
			(0.067)
Public Investment Management Index	-.013	0.01	0.019
	(0.059)	(0.064)	(0.067)
Foreign firm or JV	0.248**	0.287**	0.275**
	(0.113)	(0.113)	(0.114)
World Bank	0.006	0.028	0.004
	(0.096)	(0.096)	(0.092)
Bilateral Donor	0.188	0.195	0.177
	(0.139)	(0.143)	(0.138)
Obs.	3322	3322	3322
R^2	0.899	0.898	0.898
ACD Conflict	0.259***		
	(0.055)		
ACD Post-Conflict	0.06		
	(0.058)		
WGI Instability		0.096***	
		(0.035)	
WGI Instability > Median			0.13**
			(0.051)
Log of DB Enforce Contract	0.305***	0.382***	0.378***
	(0.082)	(0.088)	(0.09)
Foreign firm or JV	0.229*	0.253**	0.244**
	(0.119)	(0.12)	(0.121)
World Bank	-.011	0.002	-.016
	(0.091)	(0.09)	(0.087)
Bilateral Donor	0.165	0.163	0.149
	(0.13)	(0.131)	(0.128)
Obs.	3322	3322	3322
R^2	0.9	0.899	0.899

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

Table A.11: Omitted Variables: corruption

	TI	WGI	WGImed
	(1)	(2)	(3)
TI Corruption	0.066***		
	(0.022)		
WGI Corruption		0.081**	
		(0.041)	
WGI Corruption > Median			0.142***
			(0.049)
ACD Conflict	0.288***	0.288***	0.288***
	(0.055)	(0.058)	(0.057)
ACD Post-Conflict			
Public Investment Management Index	0.012	0.004	0.033
	(0.058)	(0.056)	(0.057)
Foreign firm or JV	0.232*	0.258**	0.262**
	(0.123)	(0.111)	(0.112)
World Bank	-.009	0.003	-.020
	(0.094)	(0.097)	(0.096)
Bilateral Donor	0.169	0.189	0.18
	(0.137)	(0.139)	(0.136)
Obs.	3322	3322	3322
R^2	0.9	0.899	0.9
TI Corruption	0.067***		
	(0.02)		
WGI Corruption		0.117***	
		(0.042)	
WGI Corruption > Median			0.161***
			(0.049)
ACD Conflict			
Log of DB Enforce Contract	0.384***	0.407***	0.406***
	(0.093)	(0.098)	(0.101)
Foreign firm or JV	0.225*	0.257**	0.254**
	(0.134)	(0.119)	(0.121)
World Bank	-.029	-.020	-.044
	(0.085)	(0.086)	(0.087)
Bilateral Donor	0.133	0.152	0.142
	(0.128)	(0.128)	(0.126)
Obs.	3322	3322	3322
R^2	0.899	0.899	0.899

Notes: Dependent variable is the log of cost per km; all models control for work activity fixed effects, year fixed effects, an interaction between work type and 5-year period fixed effects and region fixed effects; base categories are actual costs; robust standard errors in parentheses, clustered at the country; *, **, *** denote significance at 10%, 5% and 1% levels.

B Additional Robustness Tests

We undertook a number of further robustness tests. First, we also estimate the models with costs per square meter instead of costs per km and find that the results are substantively the same. We prefer to use costs per km as we loose 500 observations when using the cost per square meter. Second, instead of the three-year lagged average of the WGI measures, we also use the variable in the year before the road work activity, as well as taking 5-year averages; the results are not affected. Third, one concern with the ACD conflict measure is that it has a cut-off of at least 25 battle-related deaths so that we might be picking up conflicts in remote areas in large countries which do not actually affect the whole country. To test whether this is driving the results, we interact the conflict and the post conflict dummy variables with the size of the country. We perform a joint significance test on these two interaction terms and find that we fail to reject the null hypothesis that they are jointly equal to zero, suggesting that this is not driving the results.

Fourth, we test whether our results are robust to alternative ways of dealing with missing data. In the analysis so far we employed three different types of controls: (i) geographic controls and GDP; (ii) project specific controls; and (iii) measures of conflict and corruption. We discuss missing values in turn for these four categories. Geographic controls and GDP data[35] are from various other data sets and with some exceptions completely available for all countries. The main reason for GDP in 1985 being missing for 17 countries is that many of them did not exist in 1985, such as Bosnia and Herzegovina, Kazakhstan, Kyrgyz Republic and Russia. The project specific controls[36] with the largest number of missing values are terrain and the length of the road work activity. Our coverage of the conflict and corruption[37] indicators is extensive in terms of countries covered. Our main approach

[35]Ruggedness, population, land area, distance to the nearest ice-free coast and region are available for all countries and years; precipitation is available for all countries except the West Bank and Gaza from 2000-2008; road projects before this date are assigned the 2000 value; GDP is available for all countries except Afghanistan; GDP in 1985 is not available for 17 countries or 337 road projects.

[36]The type of costs (estimate, contract or actual) and work type is available for all road work activities; work activity (one classification below work activity) is available for 2,926 work activities; terrain is available for 1,587 work activities; length of the project is available for 2,452 work activities.

[37]The ACD conflict and post-conflict variables cover all countries and time periods; WGI indicators for political instability and corruption are available for all countries; the Transparency International measure of corruption is missing only for Fiji (1 road work activity) and the West Bank and Gaza (3 road work activities)

to missing data has been modified zero-order regression, which is equivalent to replacing missing variables with means of the available observations. An alternative approach is to use 'listwise deletion', where we only use variables for which we have complete data (Cameron and Trivedi 2005). We therefore dropped any missing values in GDP, length of the road, Transparency International's measure for corruption, terrain and rainfall, and re-estimated the equations; our results are substantively the same. Due to the overlapping nature of the missing data the listwise deletion approach leads to a drop in the number of observations from 3,322 to 1,042. As a second alternative, we use the modified zero-order regression for the base controls (geographic controls and project-specific controls), and then use pair-wise deletion by dropping observations in which the corruption measure is missing, for equations in which there are missing values in the corruption measure. Third, we individually drop observations with missing data one by one and re-estimate our model each time, and our results are robust. Given that the specific terrain is recorded for less than half of the sample, we also estimated the model without the work activity associated terrain fixed effect and only include the country level ruggedness variable. The results are consistent across these various specifications.

C Geo-referencing Roads

To geo-reference roads, we used the information on the variable "section", and geo-coded by hand the start and end point of each road segment.[38] Table A.12 shows the distribution of work activities across countries.

Table A.12: Countries with Geo-referenced Roads

	Freq.	Percent	Cum.
Bangladesh	158	16.79	16.79
Ethiopia	61	6.48	23.27
Ghana	237	25.19	48.46
India	77	8.18	56.64
Philippines	96	10.2	66.84
Thailand	139	14.77	81.62
Uganda	173	18.38	100
Total	941	100	

Across these seven countries, we were able to geo-locate 941 road work activities; in 84% of these cases we could locate both the start and end point of the road project, in 12% of the cases only the start point (some of the projects are bypasses so only one location is provided), and in 3% of cases we only located the end point. We then computed the average population density, precipitation, ruggedness, distance to the nearest city of more than 100,000 people, and distance to the nearest port as defined in Table A.13.

To extract average population density, ruggedness and precipitation, we connected the start and end location of a road segment with a straight line and drew a 30km buffer around the line segment. For the road work activities for which we only had one point, we drew a 30km buffer around the location. We resampled the precipitation data at a cell size of 0.05 x 0.05 degrees as the original 0.5 degree resolution was too coarse for our polygon size to compute average cell level statistics. We also computed the shortest geodesic distance of any point on the straight line road segment to the nearest city of more than 100,000 people and to the nearest port. Similar to before, if we only had the start or end location, we compute the distance between the start or end location and the nearest city of more than 100,000 people and the nearest port.[39] Table A.14 provides the summary statistics.

[38] If there was ambiguity about the location, we further used the length variable to narrow choices.

[39] Alternatively, we used the 30km buffer to compute the distances to the nearest city and the nearest port.

Table A.13: Description of Additional Data and Sources

Variable	Description	Source
Log of Ruggedness	Log of Terrain Ruggedness Index, representing the average ruggedness for the road buffer measured as meters of elevation difference for grid points 926 meters apart	Nunn and Puga (2012)
Log of Rainfall	Log of yearly precipitation in mm, averaged monthly data from Jan 1984-Dec 2008	Harris et al. (2014)
Population Density	Population Density (100 people per square km), 2000	Gridded Population of the World version 3, Center for International Earth Science Information Network - CIESIN - Columbia University, and Centro Internacional de Agricultura Tropical - CIAT. 2005 (2005)
Log of Distance to city (>100,000 ppl)	Log of average distance to nearest city of more than 100,000 people	Esri; DeLorme Publishing Company, Inc. (2014)
Log of Distance to port	Log of average distance to nearest port	World Port Index, National Geospatial Intelligence Agency (2015)

Table A.14: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Estimate	0.25	0.43	0	1	941
Contract	0.48	0.5	0	1	941
Actual	0.26	0.44	0	1	941
World Bank	0.41	0.49	0	1	866
Government	0.25	0.43	0	1	866
Bilateral Donor	0.22	0.42	0	1	866
Length > than 50 km	0.3	0.46	0	1	940
Missing: Length	0	0.03	0	1	941
East Asia & Pacific	0.25	0.43	0	1	941
South Asia	0.25	0.43	0	1	941
Sub-Saharan Africa	0.5	0.5	0	1	941
Population Density	4.46	6.18	0.11	47.61	941
Log Ruggedness	3.45	1.29	-1.25	6.48	941
Log of Rainfall	4.74	0.33	3.81	5.64	941
Log distance to city	3.68	1.69	-3.28	6.12	941
Log distance to port	5.17	1.52	-0.77	7.12	941

As many roads have a city of more than 100,000 people in the neighborhood of 30km, this variable would be zero for these observations. The results are not substantively different, but to use all the information possible we prefer to use the continuous measure of distance.