RENEGOTIATIONS AND CORRUPTION IN INFRASTRUCTURE: THE ODEBRECHT CASE

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Abstract

In 2016, Brazilian construction firm Odebrecht was fined $2.6 billion by the US Department of Justice (DOJ). According to the plea agreement, between 2001 and 2016 Odebrecht paid $786 million in bribes in 10 Latin American and two African countries in around 150 large projects. The DOJ estimated that bribe payments increased Odebrecht's profits by $3.2 billion.

Judicial documents and press reports on the Odebrecht case reveal detailed information on the workings of corruption in the infrastructure sector. Based on these sources we establish five facts. First, renegotiations amounted to 71.3 percent of investment estimated when contracts were awarded, compared with 6.5 percent for projects where Odebrecht paid no bribes. Second, Odebrecht's bribes were of the order of one percent of a project's final investment. Third, Odebrecht's profits were small, both in projects where it paid bribes (less than two percent of final investment) and in its overall operation. Fourth, following the creation of an internal unit to centralize bribe payments and substitute electronic payments into off shore accounts for cash, Odebrecht's sales increased close to ten-fold while its profits remained small. Last, net profits from bribing were Odebrecht's main source of profits during the period.

We build a model where firms compete for a project, anticipating a bilateral renegotiation at which their bargaining power is larger if they pay a bribe. Conditional on paying a bribe and cost dispersion among firms being small, in equilibrium firms' profits are small, while lowballing and renegotiated amounts are large. Small bribes are necessary to produce large renegotiations. When one firm unilaterally innovates by reducing the cost of paying bribes, its market share increases substantially while profits, which are proportional to both the cost advantage and the magnitude of bribes, remain small. A parametrization with the DOJ's data suggests that Odebrecht enjoyed a substantial cost advantage in bribing, of the order of 70 percent.

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1 Introduction

It is commonly believed that corruption in infrastructure is widespread and costly, and that the bribes that firms pay to public officials and politicians are large. Yet the evidence on which these beliefs are based is limited. Indeed, there are many open questions on how corruption works, how much firms pay to politicians and public officials, and what firms receive in exchange for these payments.[2] In this paper we present novel evidence on how corruption works in the infrastructure sector, report reliable data on the amounts of bribes paid, and build a model consistent with our findings.

Our window into the workings of corruption is the Odebrecht case. In 2016 the Brazilian construction firm Odebrecht was fined $2.6 billion by the US Department of Justice (DOJ). Between 2001 and 2016, Odebrecht paid $788 million in bribes to politicians and public officials in ten Latin American and two African countries in around 150 contracts for major infrastructure projects. The DOJ estimated that by paying bribes, Odebrecht increased its profits by $3.2 billion, the highest amount among cases prosecuted under the Foreign Corruption Practices Act passed in 1977. The data revealed by the DOJ on bribe payments, the legal statements of close to 100 Odebrecht executives who planned, designed and managed the corruption scheme, and a host of media reports reveal several novel facts about corruption in infrastructure.

One of the striking facts emerging from the Odebrecht case is the size of contract renegotiations is much larger for projects where bribes were paid. We analyze all projects won by Odebrecht in eight countries during the period considered in the plea agreement with the DOJ. We find that in the 63 projects where Odebrecht paid bribes, renegotiations increased investments by 71.3 percent, more than ten times as much as in the 27 projects were it did not pay bribes (6.5 percent). Second, despite the fact that renegotiated amounts were large, the bribes that Odebrecht paid were small relative to total investment in the project: of the order of 1 percent of initial investments.

Similarly, over the entire period of the plea agreement, Odebrecht made small profits, of the order of one percent of sales, both in projects where it paid bribes and in the rest of its operations. Indeed, it seems that all profits Odebrecht made during this period (around US$2.5 billion) can be ascribed to bribing.[3] The last fact is that Odebrecht became an innovator in bribing in 2006, by creating the Division of Structured Operations (DSO), a stand-alone department in charge of vetting bribes and substituting transfers to offshore accounts for cash payments.[4] The creation of the DSO was followed by major increases in both sales and bribe payments.

Some of the facts described above tightly constrain the assumptions in the model we propose. In particular, the observation that profits are small and renegotiations are large when bribes are paid, compel us to assume that firms compete in an auction anticipating that they will earn significant rents in a

[2] For recent surveys see Svensson (2005), Zitzewitz (2012), Banerjee et al. (2012), Olken and Pande (2012) and Burguet et al. (2016)

[3] As shown in Appendix B, for an industry that is a byword for corruption, engineering and construction has low rates of profits on sales worldwide. The average return on assets is also low. This indicates fairly competitive markets for infrastructure, at least among the groups of countries considered in the appendix.

[4] "Odebrecht, Latin America's biggest construction firm, had an upper hand over competitors by developing a secretive system to hide its bribes to foreign officials, politicians and political parties. It set up a special office, called the Division of Structured Operations, that funneled illicit money never reported on the company's balance sheet, according to the settlement." Wall Street Journal, December 22, 2016. *Odebrecht Bribery Scandal Shakes Up Latin America.*

renegotiation—Williamson's 'fundamental transformation.'[5]

We begin by analyzing analyzing our model in the case where firms draw their cost parameter from the same distribution and are equally efficient in bribing. This describes the equilibrium prior to the creation of the DSO. In the first stage of the game, firms compete in an auction for the contract; in the second stage the contract is renegotiated. In equilibrium, firms anticipate that, conditional on winning, they will renegotiate the contract. Because renegotiations are not competitive, firms obtain ex post rents, but competition in the auction forces each firm to bid below cost and dissipate rents. Our model shows that when firms pay bribes, in equilibrium lowballing increases and renegotiated amounts are larger than when they do not pay bribes.

Our model has additional implications that go beyond the observed correlation between bribes and renegotiations, and which are driven by competition in the auction. First, cost overruns are not unexpected, but result from the anticipation of renegotiations. Moreover, we provide content to the belief that large cost overruns suggest corruption. Essentially, bribes stimulate cost overruns because they increase renegotiation rents, thereby leading to lowballing in the auction. Second, small bribes are necessary for cost overruns to be large. If bribes were large, there would be a small surplus remaining to be renegotiated, so firms would have to bid close to their costs (i.e., little or no lowballing) in the auction and renegotiations would be small. Third, we show that when all firms are equally efficient in paying bribes, their profits do not depend on the size of the bribes they pay, nor on the probability of renegotiation nor the size of renegotiation rents. Thus there is no relation between bribes and firm profits. The reason is that when firms are symmetric in willingness to bribe and renegotiation ability, they compete away the rents created through renegotiation by lowballing in the auction. Because of this, the auction is decided only by cost differences and the most efficient firm wins. Bribes come at the expense of social surplus and the public purse and have no effect on firms' profits. Thus, from the point of view of the outcome of the auction, corruption and bribes do not distort firm selection. At the same time, because firms that pay bribes expect to earn more in renegotiations, they can bid more aggressively. Thus, firms that do not pay bribes are excluded from the auction—competition does not "protect" them.

Next we analyze the equilibrium when one firm enjoys a cost advantage in bribing, which represents the situation of Odebrecht after the creation of the DSO. We asume that bribes are relatively small. When competition in the auction is intense, an advantage in bribing buys a large increase in the probability of winning, but only a modest increase in profits. Moreover, the increase in profits is proportional and of the same order as the size of the bribes—exactly what we see in the data. This is reminiscent of Bertrand competition with homogeneous products: a small cost advantage generates a large change in market share but no commensurate increase in profits. Note that now the allocation in the auction may be inefficient since there is a probability (which depends on the relative efficiency of the DSO) that the most efficient firm is not selected in the auction. Nevertheless, if the cost advantage is small, the size of the inefficiency is also small.

The magnitude of the cost advantage enjoyed by Odebrecht following the creation of the DSO is necessary to explain the observed increase in its market participation without a significant increase in its

[5]Firms have good estimates of the various sources that may affect their costs, see Bajari et al. (2014).

profits. Indeed, our model implies that observed bribes and profits from bribing can be used to compute a lower bound of the cost advantage in bribing. When we estimate the lower bound with the DOJ data, we find that Odebrecht enjoyed a cost advantage of at least 70 percent in bribing—that is, Odebrecht had to spend only $3 to achieve the same as a competitor paying a $10 bribe. We are also able to gauge the social costs of corruption, both before and after the innovation in bribing, and find that both are small when compared with the magnitude of investments: approximately 3 and 2 percent, respectively. The decrease in the cost of corruption following Odebrecht's innovation by approximately one-third stems from a reduction in bribe payments. By contrast, the fact that Odebrecht wins projects even when it is not the most efficient firm has a small effect by comparison.

The remainder of the paper is organized as follows. Section 2 discusses this paper's relation to the literature. Section 3 describes the facts on corruption in infrastructure revealed by the Odebtrecht case. Section 4 builds a model aimed at explaining these fact in a coherent framework. Section 5 uses the evidence of Section 3 to gauge the size of the model's parameters. Section 6 concludes and is followed by several appendices.

2 Relation to the literature

Our paper contributes to the measurement of corruption. As Rose-Ackerman (1975, p. 187) notes, one essential aspect of corruption is bribing—an illegal transfer of money made to induce a public official in a position of power to act against the interest of the government.[6] This definition is a clear prescription for measurement, but its use is limited because bribes and the quid pro quo are seldom observed.[7] For this reason, in the case of infrastructure researchers have estimated the magnitude of theft instead. For example, Golden and Picci (2005) measured the difference between the cumulative disbursements made by the government when building the existing infrastructure and separate estimates of the physical quantity of existing public infrastructure in each Italian province. Olken (2007) measured the difference between what an Indonesian village government spent on a road, and a cost estimate by expert engineers. He estimated that missing expenditures averaged approximately one fourth of the total cost of the road.[8] Other researchers have developed proxy indicators for corruption—an outcome variable likely to be correlated with bribes. For example, Fazekas and Toth (2018) argue that the percentage of single-bidder contracts awarded in the European Union measures the degree of unfair restriction of competition in the procurement of transport projects and signals corruption. Collier et al. (2016) showed that unit cost of roads is 15

[6] Similarly, the World Bank (2004) defines a "corrupt practice" as "[...] the offering, giving, receiving, or soliciting, directly or indirectly, of anything of value to influence the action of a public official in the procurement process or in contract execution."

[7] Exceptions are McMillan and Zoido (2004) (Montecinos in Peru); Olken and Barron (2009) (bribes paid by truckers in Indonesia); and Sequeira and Djankov (2010) (ports in Africa). Gorodnichenko and Peter (2007) estimated bribes paid to public officials in the Ukraine comparing government aggregate salary payments with the household expenditures of public employees reported in consumption household surveys.

[8] Several studies estimate theft by public officials in different activities. See, for example, Reinikka and Svensson (2004) (schools in Uganda), Fisman and Wei (2004) (custom's inspections between, Hong-Kong and China), Hsieh and Moretti (2006) (Food for Energy humanitarian program, Irak), Olken (2006, 2007) (income redistribution through a food program and public works -respectively, Indonesia), Ferraz and Finan (2008, 2011) (electoral accountability, Brasil), and Niehaus and Sukhtankar (2010) (welfare programs, India).

percent higher in countries with corruption, as measured by the World Governance Indicators, above the median.[9]

In the case considered in this paper, however, the DOJ measured bribes and the profits they generated directly. Odebrecht's executives described the quid pro quos, confessed to whom they paid bribes, and explained how they paid them. When this information is combined with the amounts invested and renegotiated in each project, and profit and sales information from Odebrecht's financial statements, a fairly accurate estimate of the relative size of bribes and profits emerges.

It is fair to say that the generalized perception is that in major infrastructure projects firms pay large bribes and obtain large economic rents generated by overpriced contracts.[10] According to this perception, bribed public officials use their discretionary authority to restrict entry, raise prices and steal vast amounts from the public purse. Nevertheless, our evidence suggests that –at least for most of the countries in which Odebrecht operated– firms do not receive large economic rents, and that public officials do not obtain huge bribes, at least relative to the size of the projects they oversee and influence. Thus, as Olken (2009) warns, studies that estimate the intensity of corruption by surveying perceptions should be viewed with caution.[11]

Our paper is also related to the literature on the industrial organization of corruption. A basic insight, due to Shleifer and Vishny (1993), is that a corrupt public official with power to exclude firms from a market can extract bribes by restricting quantity, thus increasing the value of a bribe, in the same way that a monopolist creates a market power rent by restricting output.[12] When several corrupt public officials have power to exclude, bribes are stacked, and quantity falls even more than with just one corrupt public official.[13]

Nevertheless, the confessions indicate that Odebrecht bought influence from politicians and public officials, but did not restrict quantity—that is, the number of projects—to raise price in any meaningful way. Moreover, relatively small bribes and profits indicate that a different mechanism was at work—Williamson's fundamental transformation. As Williamson (1979, 1985) argued, when a contract is put to tender, there is ex ante competition when bidding for the contract, but a bilateral monopoly ex post.

[9] In the data base, Collier et al. (2016) use unit costs per kilometer or per square meter measured for 3,322 work activities in ninety-nine low- and middle-income countries.

[10] For example, Kenny (2009b) claims that in infrastructure between 5 and 20 percent of construction costs are lost to bribe payments. Mauro (1997) argues that the cost of a large infrastructure project is difficult to monitor. Rose-Ackerman and Palifka (2016) argue that large infrastructure projects are complex and, moreover, even a small fraction of the investment value creates large corruption rents. Golden and Picci (2005) and Kenny (2009a) argue that in large projects information is asymmetric, which makes it hard to detect inflated prices, inferior quality, or sluggish delivery. Also, in 2004 the American Society of Civil Engineers claimed that corruption accounts for an estimated $340 billion of worldwide construction costs each year, around 10 percent of the global construction market value added of $3.2 trillion.

[11] Olken (2009) compared the measure of theft he developed in Olken (2007) with perceptions by villagers. He found that perceptions tend to be biased and that the individual characteristics of the survey respondent (e.g., educational level) predict perceived corruption more accurately than actual corruption.

[12] Firms often pay bribes in order to use an input or to obtain a permit which allows the firm to execute an activity. Because of this, the demand for bribes is derived from the demand for the final good and resulting bribes tend to be a significant percentage of the final good's price.

[13] This is the well-known problem of Cournot complements. In 1838, Augustin Cournot demonstrated that when two upstream monopolists both post their prices to a downstream producer independently of one another, they charge higher prices and sell less than if they collude and choose a single, profit-maximizing price for both inputs. The implication is that two monopolies are worse than one. See Olken and Barron (2009) for a test of this theory with data from a field experiment, in which surveyors accompanied Indonesian truck drivers along a route and registered the bribes demanded by police, soldiers, and weigh station attendants.

We add to this insight by providing evidence that ex ante competition can dissipate rents and profits through lowballing, even when bribes buy influence and increase the firm's ex post bargaining power. Moreover, we show that when bribes buy influence and increase the firm's bargaining power, a clear relation between bribes and renegotiated amounts emerges. Last, and somewhat surprisingly, we show that if the fundamental transformation is at work, large lowballing and renegotiated amounts indicate that bribes are relatively small, not that they are large.

When modeling the interaction between the fundamental transformation, bribes and renegotiations in infrastructure, we borrow from—and also contribute to—three strands of the corruption literature. One strand studies the relation between competition among firms and the intensity of bribing. Rose-Ackerman (1975, p. 188) observed long ago that a competitive auction for a contract may eliminate bribes. Indeed, as shown by Ades and di Tella (1999), when competition dissipates rents firms have little left to pay bribes. The fact that Odebrecht made relatively small profits and paid relatively small bribes, therefore, suggests that competition in the tendering stage worked as the literature indicates. Of course, as Bliss and Di Tella (1997) show, public officials with power and discretion to restrict access can endogenously create the surplus to extract bribes.[14] Nevertheless, small bribes relative to investment suggest that public officials could not restrict access. More generally, the confessions of Odebrecht's executives confirm that public officials in charge of the tenders did not have enough discretion to sell access to projects, and were subjected to controls that limited their discretion. This is an important insight, because many papers show that competitive auctions can be vulnerable to bribes and corruption.[15] Yet the evidence of the Odebrecht case suggests that in several Latin American countries the institutions ensuring competitive auctions worked to a significant extent, despite rampant and widespread bribe payments.

A second strand of the literature notes that public officials that provide similar services may compete, thus reducing the size of the equilibrium bribe. This is the so-called supply side competition for bribes.[16] The level of bribes is exogenous in our model. Nevertheless, the fact that observed bribes are small relative to the size of the projects, and that Odebrecht developed a large network of bribed public officials suggests that public officials compete, or that the amount of discretion they have is limited.

A third strand of the literature studies corruption in bilateral relationships, the appropriate setting to study renegotiations of infrastructure contracts. Rose-Ackerman (1975) argued that bribing was attractive when waiting was costly for the firm. Essentially, by bribing, the firm induces the public officials to reach an agreement faster.[17] The literature, however, typically assumes that bargaining is about the size of the bribe. In contrast, in our model the firm bribes to increase its bargaining power in a legitimate renegotiation, and this yields novel results. First, our theoretical analysis shows that ex post bargaining generates adverse selection—firms that are unwilling to bribe cannot compete for contracts.[18] Second, we show that

[14] See also Amir and Burr (2015).

[15] For example, bribes may buy favoritism in the auction: see Arozamena and Weinschelbaum (2009), Burguet and Perry (2007), Koc and Neilson (2008); or buy favoritism ex-post—the favored bidder can change her bid to match a better bid—: see Burguet and Che (2004), Compte et al. (2005), Lengwiler and Wolfstetter (2010), Menezes and Monteiro (2006).

[16] See Rose-Ackerman (1975, ch. 7), Klitgaard (1988) and Shleifer and Vishny (1993). For recent empirical studies see Drugov (2010), Burgess et al. (2012) and Kiselev (2012).

[17] On bargaining and bribes see also Fisman and Gatti (2011). Svensson (2003) studies how the level of an outside option affects the bribe that firms negotiate with corrupt public officials.

[18] Boas, Hidalgo and Richardson (2014) show that in Brazil, campaign donors win more public works contracts when their

there is a direct link between (relatively) small bribes and large renegotiated amounts, a prediction of the model which appears in the data. Third, small profits even after large renegotiated amounts suggest that Odebrecht seemed confident it would be able to secure large increases in contracted amounts, despite paying small bribes. Lastly, the data suggests that Odebrecht accurately anticipated how much it would renegotiate in each project. Thus Odebrecht renegotiated small amounts when it did not pay bribes and large amounts when it paid bribes, but it did not incur losses in either case, on average.

Large renegotiations suggest that the governance of the post-tender stage is considerably weaker than the governance that oversees the tendering stage. This is consistent with Piga's (2011) observation that post-tender corruption is monitored less effectively by judges, authorities and the media. He argues that post-tendering monitoring is expensive and time consuming, more difficult, and requires more expertise than overseeing auctions.[19] In any case, corruption in the post tender stage has attracted less research than corruption during auctions. An exception is Iossa and Martimort (2016). In their model a firm bribes a public official to induce him to misreport the realization of a shock. As in Iossa and Martimort (2016), in our model there is no bargaining over the bribe, and the bribe is paid in order to receive more favorable treatment We contribute to this (still small) literature by endogenizing the link between post tender renegotiations and the auction for the contract.

Our application of the fundamental transformation also sheds light on the mechanism underlying large cost overruns, which routinely emerge in large infrastructure projects.[20] The endogeneity of overruns and its relation with renegotiations has been pointed out by Dewatripont and Legros (2005) and Engel et al. (2019a). We contribute to this literature by linking theoretically and empirically cost overruns, the anticipation of renegotiations, and bribing. Indeed, by establishing a systematic link between bribes paid and cost overruns, we provide some grounds to the conjecture in the literature that cost overruns signal corruption.[21]

Finally, our paper is also related to the literature on renegotiations of public-private partnerships (PPP) infrastructure contracts.[22] The first comprehensive empirical study of renegotiations of PPPs is Guasch (2004), who analyzed more than 1.000 concession contracts in Latin America and established a number of stylized facts, prominent among them that renegotiations are pervasive and that a large fraction occur during the construction stage. Several theoretical and empirical papers followed. Guasch et al. (2006) and Guasch and Straub (2006) developed a theory of the determinants of renegotiations. Guasch et al. (2007) and later Bitrán et al. (2013) applied the theory empirically to quantify the determinants of government-led renegotiations in Latin America. Guasch et al. (2008) empirically studied renegotiations in transport and water in Latin America.[23] Nevertheless, only Guasch and Straub (2009) studied the correlation between the frequency of renegotiations in transportation and water concessions in Latin America and a corruption in-

supported candidate is elected. The adverse selection effect is consistent with this finding.

[19] See aldo Soreide (2002) who explains corrupt practices that emerge during contract execution.

[20] The classic book is Flyvbjerg, Bruzelius and Rothengatter (2002).

[21] See, for example, Locatelli et al. (2017).

[22] In our database, 21 of the 90 projects are PPPs, while the remainder are public works.

[23] Guasch and Straub (2006), Andrés and Guasch (2008) and Andrés et al. (2008a, 2008b) are useful overviews of this line of research.

dicator.[24] They found that in countries with worse corruption indicators, firm-led renegotiations occurred more often but government-led renegotiations were less frequent. Our study is the first that documents the explicit link between renegotiations and bribes.

3 Facts

Table 1 shows information about corruption, culled from the DOJ Statements of Marcelo Odebrecht, the company's CEO. The first two columns are derived directly from Odebrecht's plea agreement. The first column reports bribes paid by Odebrecht in each country. The second column reports, as stated in the Statement of Facts in the agreement, "any profit earned on a particular project for which a profit was generated as the result of a bribe payment."

Table 1: Profits and bribes according to the Department of Justice

Country	Bribes US$MM*	Gross Profits US$MM**	Bribes/Profits (%)	Investment (US$MM)***	Period	Projects
Argentina	35	278	12.6	12.515	2007-2014	8
Brazil	349	1900	18.4		2004-2016	
Colombia	11	50	22.0	1.828	2009-2014	4
Dominican Republic	92	163	56,4	3.959	2001 -2014	16
Ecuador	33,5	116	28.9	3.465	2007-2016	10
Guatemala	18	34	52.9	384	2013-2015	1
Mexico	10,5	39	26.9	2.158	2010-2014	6
Panama	59	175	33.7	8.843	2010-2014	21
Peru	29	143	20.3	12.868	2005-2014	24
Venezuela	98				2006-2015	
Angola	50	262	19.1		2006-2013	
Mozambique	0,9				2011-2014	
Total	**785.9**	**3159,9**	**24.9**	**46.620**	**2001 - 2016**	**90**

*The information comes from the Plea Agreement between Odebrecht S,A. and the Department of Justice (DOJ) United States of America, **The term benefit as used in the Statement of Facts relates to any profit earned on a particular project for which a profit was generated as the result of a bribe payment. As stated in the agreement, for projects that resulted in profits to Odebrecht that were less than the amount of the associated bribe payment, the amount of the bribe payment was used to calculate the benefit, ***Investment: authors' calculations based upon legal and media sources, as described in Appendix A.

So far we have been able to determine the amount invested, both before and after renegotiations, as well as whether bribes were paid or not, for all Odebrecht projects in eight countries during the period considered in the agreement.[25] These cover all countries in Latin America included in the plea bargain, with the exception of Venezuela (because of data limitations) and Brazil (which we plan to include in future versions). This amounts to 90 projects procured either as a public work (69 projects) or a public-private partnership (21 projects).

With the data from these 90 projects we establish the following facts. First, renegotiations were much larger when bribes were paid. Second, bribes and profits are "modest" relative to investments. Third,

[24]The corruption indicator is the annual country-level index from Political Risk Service, International Country Risk Guide.

[25]The countries are Argentina, Colombia, Dominican Republic, Ecuador, Guatemala, Mexico, Panama and Peru. See Appendix A for how we determined whether bribes were paid by Odebrecht for each of the projects considered.

Odebrecht made important innovations in bribing. Fourth, Odebrecht increased its volume more than three-fold following this innovation. Fifth, auctions for infrastructure contracts were competitive both before and after the innovation.

3.1 Bribes and the size of renegotiations

Contract renegotiations of infrastructure projects, especially in the case of public-private partnerships, have long been suspected of being associated with corruption,[26] yet we are not aware of any previous direct evidence. The Odebrecht case confirms that there is a large and positive association between bribe payments and the size of contract renegotiations.

Table 2: Increase of investments after renegotiations

		Evidence on bribes	
		Legal	Legal or Media
No bribes	Number of projects:	50	27
	Simple avge.:	27.6%	18.4%
	Weighted avge:	11.8%	6.5%
Bribes	Number of projects:	40	63
	Simple avge.	67.9%	57.1%
	Weighted avge.	80.9%	71.3%

Authors' calculations using data from DOJ, media and investments as reported by government agencies..

Table 2 shows the number of projects with bribes and the increase in project investments after renegotiations. The column labeled 'Legal' considers evidence on bribes from documents issued by courts and prosecutors. The column 'Legal or Media' also considers evidence on bribes from the investigative media.[27] The fraction of projects with evidence of bribe payment is 44 percent under the first definition and 70 percent under the second definition. The second and third rows in each set show the increase in investment in the project after renegotiation, both weighted by initial project investments, and unweighted. It is clear that renegotiations after a bribe are far more generous to Odebrecht than in cases when no bribe has been paid.[28] For example, if we consider evidence from legal documents and media sources, total investment in the 63 projects where Odebrecht paid bribes grew by 71.3 percent after renegotiations, compared with 6.5 percent for projects with no bribes.[29,30]

[26] See Guasch and Straub (2009).

[27] In Appendix A we explain the distinction.

[28] In Appendix C we show that this difference is statistically significant.

[29] Bajari et al. (2014) examined 819 highway procurement contracts in California and found that the final price was, on average, 5.8% higher.

[30] The fact that the difference between renegotiations with and without bribes is larger when considering weighted averages, suggests that the correlation between bribe payments and renegotiations increases with the size of the project.

3.2 Bribes and profits are small relative to investments

Table 3 shows bribes and profits that can be attributed to bribe payments, as a fraction of investment. We consider both initial investments, I_0, and investments including renegotiations, I_1. Bribes as a fraction of initial investments are small: less than 1 percent if we consider all projects, around 1.5 percent if we only consider projects with bribes.[31] When we normalize by total investments, the fractions are obviously smaller.[32] Profits generated by bribes are somewhat larger but still small. The largest value of 3.7 percent is obtained when considering projects with bribes (legal documents) and normalizing by investments before renegotiations.

Table 3: Bribes and associated profits relative to investment

	Number	Bribes/I_0	Bribes/I_1	Profits/I_0	Profits/I_1
Projects with bribes (legal sources):	40	1.52%	0.84%	3.74%	2.07%
Projects with bribes (legal or media sources):	63	1.19%	0.69%	2.93%	1.71%
All projects:	90	0.59%	0.42%	1.45%	1.04%

Authors' calculations. Projects with bribes determined from legal and media sources.
Investment data obtained from government agencies. See Appendix A for details.

3.3 The Division of Structured Operations[33]

In its 2016 plea agreement with the DOJ, Odebrecht admitted engaging in a massive bribery scheme beginning in 2001, in order to win business in many countries. A major development in this scheme occurred in 2006, when Odebrecht created the Division of Structured Operations (DSO) to manage bribe payments and illegal campaign contributions and make them more efficient. According to the DOJ, the DSO effectively functioned as a stand-alone bribe department within Odebrecht. The creation of the DSO was followed by strong growth both in sales and in bribe payments.[34] We argue next that the DSO provided Odebrecht with a competitive advantage in bribing that explains its rapid growth in market share.

Three Odebrecht executives and four secretaries worked at the DSO and were in charge of paying bribes into foreign accounts.[35] As mentioned by the DOJ, "to conceal its activities, the Division of Structured Operations utilized an entirely separate and off-book communications system [...] to communicate

[31] For Colombia, Ecuador and Peru the National Attorney has presented evidence suggesting that higher bribes than those mentioned in the DOJ-Odebrecht plea agreement were paid. Nonetheless, these percentages continue being small if these additional bribes are included.

[32] Kaufmann (2005) and IMF (2016) estimate worldwide bribe payments at roughly 2 percent of GDP. The numbers we present here suggest that, at least in the infrastructure sector, bribe payments are less than one half of this estimate.

[33] This subsection is based on "Odebrecht and Braskem Plead Guilty and Agree to Pay at Least $3.5 Billion in Global Penalties to Resolve Largest Foreign Bribery Case in History." US Department of Justice. Office of Public Affairs. December 21, 2016, and other sources.

[34] In his confession, Mascarenhas da Silva, the executive who headed the DSO, told the DAs that after the division was created in 2006, the amounts paid in bribes grew from an annual average of BR$ 60-70 MM (no period mentioned) before the creation of the DSO to BR$ 420MM in 2010 and BR$ 720 MM in 2012. During the period 2005-2012, the exchange rate was approximately 1US$=2BR$. Source: https://idl-reporteros.pe/asi-perdio-el-juego-odebrecht/.

[35] According to Marcelo Odebrecht's plea bargain with the DOJ, the DSO combined three compensation options: legal contributions to political campaigns, illegal contributions to political campaigns, and bribes paid to public officials and politicians.

with one another and with outside financial operators [...] via secure emails and instant messages, using codenames and passwords." The DSO also used a bespoke information management system (MyWebDay) for bookkeeping and to track information flow.

Bribe payments followed a clear organizational flow. Until 2009, the head of the DSO reported to the highest executives of Odebrecht to obtain approval of bribe payments. Thereafter, a contract manager would deal with potential bribe recipients—public officials and politicians—and reported to the country manager. The country manager decided and paid small bribes with local funds, while larger bribes had to be approved in Brazil by a business leader who reported directly to the company CEO, Marcelo Odebrecht, who made the final decision.

Once a bribe was authorized, the DSO registered, managed, and made the payment through a complex network of shell companies, off-book transactions and off-shore bank accounts, that included the Antigua subsidiary of Austria's Meinl Bank, acquired for this purpose by Odebrecht. An independently funded parallel cash trove (Caixa 2) was used to pay bribes and campaign contributions. In this way, the DSO reduced transaction costs for bribe recipients and helped establish long-term relationships between the company and corrupt officials.

Thanks to the DSO, the center knew how much was being paid in bribes and to whom, which minimized 'leakage', an important inefficiency associated with bribe payments, as suggested by a major corruption case uncovered recently in Argentina.[36] In addition, paying bribes electronically is cheaper than carrying and laundering cash. And providing a sophisticated network to help conceal bribe receipts is also valuable for the corrupt officials involved and fosters long term relationships between bribe payer and bribe recipient.

3.4 Profitability and sales: Before and after the creation of the DSO

In this section we show that the creation of the DSO led to a rapid increase in Odebrecht's revenues, without a corresponding growth in profits. While there were years of high profits, on average profits represented a small fraction of sales.[37]

Using data obtained from Odebrecht's annual reports, there is a large increase in sales in 2007, the year after introducing the improvement in their corruption technology. Sales increased by 57 percent that year, and until the Lava Jato case in 2014, the rate of increase in sales was 20 percent per year. However, the profitability on these sales remained limited and on average was close to 1 percent. This can be seen in Figure 1 which shows both sales and profits for the years 2004-2014.[38,39]

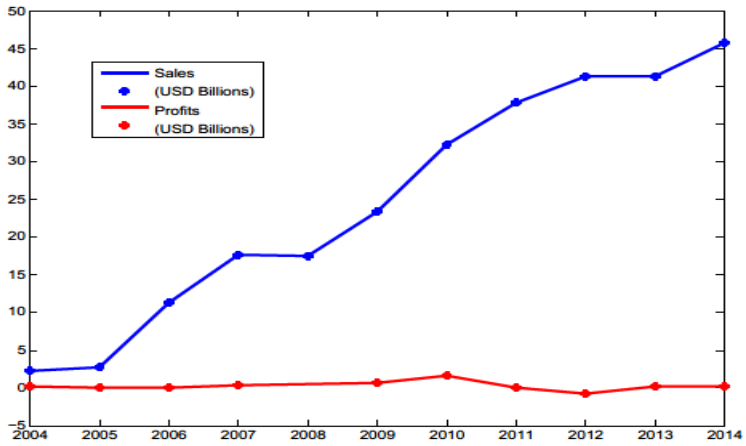
[36]This is the Bribery Notebooks scandal, also involving infrastructure projects. A driver transferred bagfuls of US Dollars between locations in Buenos Aires, including the house of then President Kirchner. In an interview with a newspaper, the official in charge of making the payments claimed that the cost of paying bribes in cash, which probably includes leakages, is about half the amount paid.

[37]In Appendix B we present evidence suggesting that on average construction firms worldwide have a low ratio of profits to revenue. Moreover, their return on assets is low and the average return on equity of the firms we examined is below the average for all sectors in the US (see `http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/roe.html`). Indeed, Bajari et al. (2014) report that the profit margins of the publicly traded firms in their sample of contractors that bid for highway construction contracts in California is 3 percent.

[38]There is no publicly available data for Odebrecht's profits in 2008.

[39]The relatively low profits depicted in the figure are consistent with an independent source of information: during the last

Figure 1: Total revenues and profit/revenue ratio of Odebrecht



While Odebrecht's profits as a percentage of sales were fairly low—slightly above one percent—, paying bribes was profitable. To see this, note that according to its financial statements over the period covered by the plea agreement, Odebrecht made around US$2.4 billion in profits. This is a reasonable 11.3 percent rate of return on equity in the period ending in 2014,[40] albeit only a 1 percent return on assets. Moreover, recall that the DOJ estimated that by paying US$788 MM in bribes, Odebrecht made about US$3.3BN in gross profits, that is, around US$2.5 billion net (which, not coincidentally, happens to be close to the fine that the DOJ ultimately imposed, and close to the aggregate profits for the period). Therefore, it seems that most of the profits Odebrecht made during the period were due to bribes.

In summary, the effect of improving the corruption technology was to increase sales, without affecting the low ratio of profit over sales. At the same time, bribing helped Odebrecht's profits, which nonetheless were low by various measures.

3.5 Competitive auctions with bribes

Elsewhere we provide detailed case studies on how corruption took place in a representative sample of projects with evidence of bribe payments.[41] These studies show that, despite the payment of bribes, in many countries the environment where projects were auctioned was fairly competitive, as suggested by the low returns we described in Section 3.4.

For example, the auction of Metro Line 1 in Lima, Peru, was allocated based on a weighted average of a technical score and an economic offer. The technical score included subjective elements, and Odebrecht bribed some of the officials that were involved in assigning this score. On the other hand, the economic offer was objective: a number that could be compared to the economic offers of other firms. As it turned out, Odebrecht would have won even without bribes, as its economic offer was 18 percent lower than that of its closest competitor.

decade, according to Forbes, the net worth of the Odebrecht family remained in the US$4-6 billion range.

[40] Though lower than the 15.8 percent average for our sample of Brazilian construction companies, see Appendix A.

[41] See Campos et al. (2019).

Odebrecht's modest profits, moreover, and the fact that they stem mainly from bribing, confirm that auctions were competitive and dissipated whatever rents Odebrecht made in renegotiations.

4 Model

Our aim is to explain four facts within a unified framework. First, when bribes are paid, the model should lead to substantial lowballing and large renegotiations. Second, when no bribes are paid, the model should yield small lowballing and small renegotiations. Third, even when paying bribes, firms should make small profits in equilibrium. Lastly, a firm enjoying a cost advantage in bribing should see a major increase in market share without a significant increase in profits.

Two assumptions, which are consistent with the facts presented in Section 3, are central in our model. First, when the firm pays a bribe it obtains a larger share of the surplus at the renegotiation stage than when it does not pay a bribe. Second, we assume that auctions are competitive and firms know that they play a dynamic game. It follows that the project is awarded to the lowest bid and that firms incorporate into their bids expected rents from renegotiations.

4.1 Basic set up

Consider a project with gross value W. This value may reflect social welfare or, as in Rose-Ackerman (1975), the willingness to pay for the project, perhaps determined by the available budget that can be spent on it. There are many ex ante identical construction firms who can build the project. The cost of each firm is an i.i.d. draw from a normal distribution with mean $\bar{\theta}$ and variance σ^2, and is private information. Hence, firms have asymmetric private information about the costs of production. We also assume that $W > \theta$,[42] and that the project is in charge of a public official, who may be corrupt or not corrupt; only a corrupt official asks for bribes.

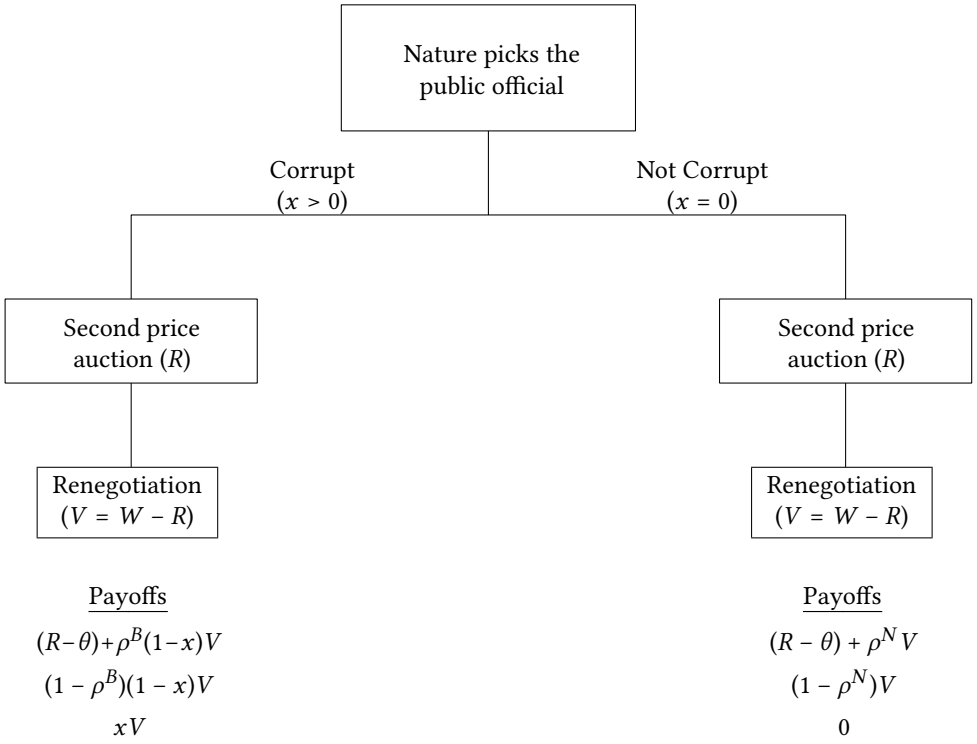
The time line of the game is shown in Figure 2. At the beginning of the game, nature decides whether the public official in charge of the project is corrupt or not corrupt. Knowing the type of the public official, firms compete in a sealed-bid, second-price auction with bidding variable equal to the amount they ask for building the project. Nevertheless, in the second stage of the game, the winner of the auction and the public official renegotiate the contract. When renegotiating the contract the surplus "up for grabs" is $V = W - R$, the difference between the social welfare (or willingness to pay) and the second lowest bid R.

Note that the game models Williamson's (1979, 1985) fundamental transformation: construction firms compete in the auction, but the firm and the government are bilateral monopolies when they bargain at the renegotiation stage. We assume that if the public official is not corrupt, the firm receives a fraction $\rho^N \in (0, 1)$ of the surplus up for grabs, and the country retains the rest. In this case, the firm's total payoff increases from $R - \theta$ to $(R - \theta) + \rho^N V$, and the country's payoff is $(1 - \rho^N)V$.

By contrast, if the public official is corrupt, he will ask for a bribe equal to a fraction $x \in (0, 1)$ of the surplus, but in exchange the firm will increase its bargaining power to $\rho^B > \rho^N$, where superscripts

[42] Strictly speaking, we assume σ much smaller than $\bar{\theta}$ so that the probability that $W < \theta$ is negligible.

Figure 2: Timeline of the game



denote the case with bribes (B) and with no bribes (N).[43] Thus, with a corrupt official the firm's total payoff increases from $R - \theta$ to $(R - \theta) + \rho^B(1 - x)V$, and the country's payoff is $(1 - x)(1 - \rho^B)V$. As discussed in Section 3.1, the assumption that the firm increases its bargaining power by bribing follows from the depositions of Odebrecht's executives (see Table 2.

We can now solve the game by backwards induction. Before proceeding, however, note that we are assuming that construction firms have perfect foresight—they know whether the official is corrupt and they know that the contract will be renegotiated. Perfect foresight regarding contract renegotiation can be naïvely interpreted as the firms knowing the parameters of the actual second-stage bargaining game. Nevertheless, as argued by Bajari et al. (2014), by assuming that firms are risk neutral, one can rationalize the more compelling assumption that firms have symmetric uncertainty about the ex post bargaining game. Independent of how one interprets rational expectations, this assumption is consistent with the empirical finding in Bajari et al. (2014), that construction firms correctly anticipate the post tender renegotiation game and contract modifications on average when bidding in the auction. As we will see next, the assumption of rational expectation is necessary to rationalize the facts of the Odebrecht case, in particular, Odebrecht's overall modest profit

[43] We assume ρ^N and ρ^B are constant for a given project. Since firms are risk neutral, all results presented in this section extend to the case where ρ^B and ρ^N are the expected value of the random variable that describes the firm's bargaining power when the official is corrupt and not corrupt, respectively.

4.2 Competitive auction and renegotiation

Next we solve the auction. We consider the case where the firm pays a bribe and, for ease of notation, we write ρ instead of ρ^B. Also note that, by setting $\rho = \rho^N$ and $x = 0$, the results that follow also apply to the case where the firm does not pay a bribe.

If the firm wins and the second lowest bid is $\tilde{R}$, its profits are

$$\Pi(\tilde{R}) \equiv \tilde{R} - \theta + \rho(1 - x)(W - \tilde{R}), \tag{1}$$

where $\tilde{R} - \theta$ represents profits if no renegotiation takes place and $\rho(1 - x)(W - \tilde{R})$ corresponds to expected profits from renegotiation. These benefits are higher if the firm's bargaining power is higher (larger ρ). They also grow with the amount up for grabs at a renegotiation, $W - \tilde{R}$.

Because firms compete in a second price auction it is a dominant strategy to make a zero-profit bid. Hence, bids can be derived from the firm's zero profit condition:

$$R - \theta + \rho(1 - x)(W - R) = 0.$$

This yields

$$R = \theta - \frac{\rho(1 - x)}{1 - \rho(1 - x)}(W - \theta). \tag{2}$$

Expression (2) implies that firms bid below their costs, that is, they anticipate that, conditional on winning, they will renegotiate the contract. Because renegotiations are not competitive, firms obtain a rent when they renegotiate. Competition in the auction then forces each firm to bid below cost to dissipate the renegotiation rent. Thus, the assumption of competition in the auction rationalizes the observation that firms obtain low profits even though renegotiations are large. Otherwise the firms would make rents when renegotiating in scenarios when their bargaining power is positive—i.e., when dealing with corrupt officials—and these profits would show up in the financial statements.

It follows from (2) that the firm lowballs by

$$\mathcal{L} \equiv \theta - R = \frac{\rho(1 - x)}{1 - \rho(1 - x)}(W - \theta) > 0. \tag{3}$$

This amount is increasing in ρ and $W - \theta$. By contrast, a higher bribe (larger x) reduces the amount up for grabs during renegotiation of the contract and therefore reduces the amount of lowballing $\mathcal{L}$. We also have that the combination of a large value of ρ and small x leads to substantial lowballing. The following results follow directly and describe the relations between bribes and large renegotiations that we observe in the data.

Result 1 *A combination of large ρ, small x, and large $W - \theta$, yields substantial lowballing and large renegotiations.*

Result 2 *Assume $(\rho^B - \rho^N)/\rho^B > x$.*[44] *Then bids are lower and there is more lowballing when bribes are paid.*

[44] This condition provides a lower bound on the increase in bargaining power that justifies paying a bribe.

Results 1 and 2 explain the first two facts described in Section 3. Conditional on bribing, the firm obtains a larger fraction of any surplus that can be appropriated in a renegotiation. In equilibrium, lowballing increases and renegotiated amounts are larger. The relation between bribes and renegotiated amounts thus suggests that firms bribe to obtain better terms in the renegotiation. However, competition in the auction dissipates the rents thus acquired.

Renegotiations are often attributed to unexpected cost overruns. Nevertheless, Results 1 and 2 suggest that cost "overruns" are endogenous and a result of the expectation of a renegotiation. Moreover, the fact that construction firms make small profits even though renegotiated amounts are large, suggests that overruns are anticipated.

The following result reveals a surprising relation between the size of the bribes and the magnitude of renegotiations (and lowballing).

Result 3 *When the public official demands a high fraction of the surplus in renegotiations (a large x), there are low levels of lowballing and small amounts renegotiated. However, total bribes increase.*

The mechanics of Result 3 is straightforward.[45] Intuitively, if x is large and close to 1, there is little net surplus left for the firm in a renegotiation. In this case, when firms compete in the auction their bids tend to be close to cost and renegotiations are small. Result 3 suggests, therefore, that large renegotiations indicate that small bribes are being paid.

The last implication is that bribes, renegotiations and competitive auctions may exclude firms that do not pay bribes.[46,47]

Result 4 *Assume $\rho^B(1-x) > \rho^N$. Then, a firm that decides not to bribe, when others are willing to bribe, faces a competitive disadvantage.*

Consider the firm's decision of whether to bribe or not in a project where bribes buy a larger value of ρ so that $\rho^B(1-x) > \rho^N$. The logic of Result 4 can then be appreciated by noting that using (2),

$$R^B = \theta - \frac{\rho^B(1-x)}{1-\rho^B(1-x)}(W-\theta) < \theta - \frac{\rho^N}{1-\rho^N}(W-\theta) = R^N,$$

where R^B and R^N denote the firm's bid with and without bribes. That is, when $(\rho^B - \rho^N)/\rho^B > x$, firms that pay bribes expect to earn more in renegotiations and bid more aggressively, thereby leaving at a competitive disadvantage identical firms unwilling (or unable) to pay bribes. Even though the auction is competitive, firms that do not pay bribes cannot compete because they cannot lowball enough.

[45] To see that total bribes increase with x, note that bribe payments satisfy $B = xV = x(W-R) = x(W-\theta)/(1-\rho(1-x))$, where we used (2). Then $dB/dx = 1-\rho > 0$.

[46] The result that follows considers an extension of our model where firms may decide whether to pay a bribe or not when a corrupt official is in charge of the renegotiation

[47] This result may explain why US firms rarely participate in the Latin American market for big infrastructure projects. The Foreign Corrupt Practices Act makes it less attractive for US firms to pay bribes than for local firms (or firms from other advanced economies), thereby deterring their participation.

4.3 Pre-innovation equilibrium

We analyze the equilibrium prior to Odebrecht's innovation in the bribing technology in 2006. We consider a competitive auction with two identical firms.[48] The project-specific values of θ for both firms are independent draws from a normal distribution with mean $\bar{\theta}$ and variance σ^2.[49] The two firms have the same expected renegotiation parameter, ρ.[50]

Denoting by θ_i and R_i the draw of θ and the bid of firm i, $i = 1, 2$, it follows from (2) that

$$R_i = \theta_i - \frac{\rho(1-x)}{1-\rho(1-x)}(W - \theta_i), \quad i = 1, 2.$$

Firm 1 wins if and only if $R_1 \leq R_2$ which is equivalent to $\theta_1 \leq \theta_2$, which happens with probability 1/2. It follows from (1) that when it wins, firm 1's profits are given by

$$\Pi_1(R_2) = R_2 - \theta_1 + \rho(1-x)(W - R_2) = \theta_2 - \theta_1. \tag{4}$$

It follows that firms' profits do not depend on the size of bribes nor on the renegotiation parameter. The intuition is that because firms are symmetric, they all lowball by the same amount and the auction is decided only by cost heterogeneity.

The public official expects to collect bribes in the amount of

$$B = x(W - R_2) = \frac{x}{1-\rho(1-x)}(W - \theta_2), \tag{5}$$

so that bribe payments are increasing in x, ρ and W and decreasing in the cost of the less efficient firm. Social surplus (the country's payoff we referred to above) is given by

$$S = \frac{(1-\rho)(1-x)}{1-\rho(1-x)}(W - \theta_2). \tag{6}$$

It follows that total surplus, that is, the sum of Π_1, B and S, is equal to $W - \theta_2$. And since firms' profits depend only on productivity differences and not on the fraction of the surplus dedicated to bribes, we conclude that bribes are paid at the expense of social surplus. Also note that all projects that are socially valuable (or valuable to the politician) get built.

We end this section with an explicit expression for expected profits.

Proposition 1 (Pre-innovation equilibrium) *Consider projects where bribes are paid and two firms with the same parameter ρ. Assume the values of θ for both firms are i.i.d. draws from a normal distribution with mean $\bar{\theta}$ and variance σ^2.*

Then, firm 1 wins if $\theta_1 < \theta_2$, which happens with probability 1/2. In this case profits and bribe payments are given by (4) *and* (5)*, respectively. Bribes have do not lead to allocative inefficiencies—only projects with*

[48] The extension from two to n firms, with $n \geq 3$ given, is straightforward.

[49] We will see below that the data suggest that σ is small. It follows that the fact that a normal distribution can take negative values is irrelevant in what follows as long as $W - \bar{\theta}$ is sufficiently larger than σ, say at least three times as large.

[50] As mentioned above, we consider two firms that bribe, so that $\rho = \rho^B$ and $x > 0$. Nonetheless, the results also apply in the case with no bribes, albeit with $\rho = \rho^N$ and $x = 0$.

positive value get built— and expected profits for firm 1 (as well as firm 2) are given by:[51]

$$\mathrm{E}[\Pi_1] = \frac{\sigma}{\sqrt{\pi}}. \tag{7}$$

Proof See Appendix B. ∎

Observe that when σ is small, construction firms have similar costs and compete intensely in the auction. Consequently, profits are small, despite the fact that renegotiations are large. On the other hand, if cost dispersion is large, competition is less intense and profits are larger.

Also, from Proposition 1 it follows that expected profits do not depend on the bribing parameter x, nor on the renegotiation parameter ρ, that is, there is no relation between resources destined to bribes and firm profits.[52] Technically this occurs because the lowballing expression vanishes from the firm's profit. The economics is that when firms are symmetric in terms of bribing and renegotiation, each pays the same bribe, and all bids are scaled down by the same amount. Thus, the auction is decided only by cost heterogeneity. An additional implication is that bribes do not affect firms' profits, because they are factored dollar-by-dollar into each firm?s bid. Thus, because firms compete, bribes are fully paid by taxpayers

4.4 Post-innovation equilibrium

We show next that heterogeneity in bribing is key to explain Odebrecht's increase in market share. Starting at the equilibrium described above we assume that firm 1 (Odebrecht) innovates in the bribing business and only needs to pay a fraction $(1-\gamma)x$ of the renegotiated amount to the corrupt official, instead of x. The parameter $\gamma \in (0, 1]$ measures the size of the innovation, combining the reduction in leakage for the bribing firm and the decrease in transaction costs for the corrupt official that resulted from the creation of the DSO (see Section 3.3). Otherwise the assumptions are the same as in Section 4.3.

With the same rationale that led to (2), and denoting $x_1 = (1-\gamma)x$ and $x_2 = x$, we obtain that the i-th firm's bid will be:

$$R_i = \theta_i - \mathcal{L}_i,$$

with

$$\mathcal{L}_i = \frac{\rho(1-x_i)}{1-\rho(1-x_i)}(W-\theta_i).$$

As before, the amount by which a firm lowballs in the auction increases with ρ. Note however, that the firm with the advantage in bribing technology will lowball by more than its competitor. Facing a reduced bribe payment increases the net surplus to be divided in the renegotiation, which in turn leads to a more aggressive bid.

[51] The expression that follows include the possibility that firm 1 does not win the auction. Expected profits conditional on firm 1 winning the auction are twice as large.

[52] Thus, in particular, (7) also is valid for projects where no bribes are paid, as long as the renegotiation parameter, ρ^N, also takes the same value for both firms in this case.

Firm 1 wins if $R_1 < R_2$, that is if

$$\theta_1 < \theta_2 + \frac{\rho\gamma x}{1-\rho(1-x)}(W-\theta_2). \tag{8}$$

It follows that firm 1 may win even when it is less efficient than firm 2, a scenario that is impossible when firms have identical bribing technologies. This introduces an allocative inefficiency in the post-innovation equilibrium that was not present in the symmetric case.

The expression for R in (2) in the symmetric case generalizes to

$$R_i = \theta_i - \frac{\rho(1-x_i)}{1-\rho(1-x_i)}(W-\theta_i), \quad i=1,2, \tag{9}$$

and therefore

$$W-\theta_i = [1-\rho(1-x_i)](W-R_i), \quad i=1,2. \tag{10}$$

It follows from (1) and (9) that when firm 1 wins, its profit are equal to

$$\Pi_1(R_2) = R_2 - \theta_1 + \rho(1-x_1)(W-R_2) = (\theta_2-\theta_1) + \frac{\rho\gamma x}{1-\rho(1-x)}(W-\theta_2). \tag{11}$$

The competitive advantage in bribing increases the firm's profits through two channels. First, the firm obtains higher profits in projects it would have won anyway (the intensive margin). Compared with the symmetric case where the firm's profits are $\theta_2 - \theta_1$, for these projects the firm obtains an extra profit ('bribing rent') equal to the last term on the r.h.s. of (11). These rents are increasing both in the parameter that determines the importance of renegotiations (ρ) and in the parameters that characterize the magnitude of the bribe advantage (γ and x).

The second channel for additional profits (the extensive margin) comes from projects firm 1 wins thanks to the bribe advantage, that is, projects where its costs are higher ($\theta_1 > \theta_2$) and for which (8) holds. For these projects, extra profits are smaller than the third term on the r.h.s. of (11). That is, the firm obtains additional, less profitable projects.

As discussed in Sections 3.2 and 3.4, the rents Odebrecht obtained from bribes are approximately equal to its overall profits during the period considered in its plea bargain with the DOJ. This implies that the contribution to profits of the first term on the r.h.s. of (11), $(\theta_2-\theta_1)$ is small compared with the contribution of the second term, $\rho\gamma x(W-\theta_2)/[1-\rho(1-x)]$. Since the first term is proportional to σ and the second term is (approximately) proportional to x,[53] this suggests that the contribution to Odebrecht's rents from bribing was mainly through the extensive margin, that is, through the extra projects Odebrecht won thanks to the DSO.

A small value of σ also implies that firm 1's market share following a bribing innovation will have a large increase. Firm 1 will win most projects (because σ is small) but rents from its bribing advantage will

[53] This approximation assumes that ρ is not close to one.

be small (because x is small as well).[54] The parallel of the above digression with Bertrand competition is evident. As is well known, the profits made by a firm that has a small cost advantage and competes Bertrand are equal to volume times the cost advantage. Thus our model suggests that Odebrecht's profits came mainly from its ability to create more "value" per dollar of bribe paid.

We formalize the insight discussed above in the following proposition:

Proposition 2 (Post-innovation equilibrium) *Consider the same assumptions as in Proposition 1, but allow for firm-specific values of the bribe parameter x: $x_1 = (1-\gamma)x$ and $x_2 = x$ with $0 < \gamma \leq 1$. Define*

$$C = \frac{\rho\gamma x}{1-\rho(1-x)}. \tag{12}$$

Then, firm 1 wins if and only if

$$\theta_1 < \theta_2 + C(W - \theta_2),$$

and the firm's profits, conditional on winning, are equal to

$$[\Pi_1 | wins] = \theta_2 - \theta_1 + C(W - \theta_2). \tag{13}$$

Define

$$\mu = C(W - \bar{\theta}), \quad \tau^2 = [(1-C)^2 + 1]\sigma^2.$$

Then the probability that firm 1 wins and its unconditional expected profits are given by:

$$\Pr(\textit{Firm 1 wins}) = \Phi(\mu/\tau), \tag{14}$$

$$\mathrm{E}[\Pi_1] = \mu\Phi(\mu/\tau) + \tau\phi(\mu/\tau), \tag{15}$$

where Φ and ϕ denote the cumulative distribution function and probability density function for a standard normal random variable.

Proof See Appendix D. ∎

We may use (14) and (15) to understand the effects of the creation of the DSO by Odebrecht. The parameter μ, which was zero before the DSO, became positive. As a result, Odebrecht's market share increased dramatically if μ/τ is large, that is, if σ is small or ρ is close to one. With respect to profits, the comparative statics implied by (15) are non-monotone in most parameters, yet the following upper bound,

[54] Note that social surplus (or the politician's surplus), when firm 1 wins is given by:

$$S = W - (\Pi_1 + \theta_1) - (1-\gamma)x(W - R_2) = \frac{(1-\rho)[1-(1-\gamma)x]}{1-\rho(1-x)}(W - \theta_2).$$

We have that $\partial S/\partial x = -(1-\rho)[1-\gamma(1-\rho)]/[1-\rho(1-x)]^2 < 0$ and $\partial S/\partial\rho = -x\rho[1-(1-\gamma)x](W-\theta_2)/[1-\rho(1-x)]^2 < 0$. Also, it is straightforward to see that $\partial S/\partial\gamma > 0$. It follows that the surplus is decreasing in the bribe parameter x and in the renegotiation parameter, ρ, and increasing in the bribing efficiency parameter γ.

that requires small x, provides valuable insights:

$$\mathrm{E}[\Pi_1] \leq \frac{\rho\gamma x}{1-\rho}(W-\bar{\theta}) + \frac{\sigma}{\sqrt{\pi}}.$$

The first term on the r.h.s. bounds profits that result from the innovation in bribing. If x is small and ρ is not too close to one, these bribing rents will be small. The second term is the one we already had in the symmetric case.

The general lesson from Proposition 2 is that when there is intense competition in the auction (small σ) and bribes are small (small x), an advantage in bribing buys a large increase in the probability of winning, i.e., in the market share, but only a modest increase in profits. A competitive advantage in bribing implies a positive value of μ, thus μ/τ can be arbitrarily large when competition is intense and it follows from (14) that the probability that firm 1 wins will take values close to one. By contrast, it follows from (15) that expected profits will increase by little, since the first term on the r.h.s. is proportional to x and the second term is proportional to σ. This is reminiscent of price competition with almost homogeneous products: a small cost advantage generates a large change in market share but no major increase in profits.

5 Gauging the size of parameter values

Odebrecht's plea bargain with the DOJ includes assessments of both bribes paid by Odebrecht and the rents Odebrecht obtained from paying these bribes. Next we show how this information and the data we collected on contract renegotiations can be used to gauge the magnitude of the parameters in our model.[55] We then use the bounds on parameter values to illustrate the main insights from the preceding section and to obtain a rough estimate for the welfare costs from corruption.

5.1 Bribing efficiency parameter γ

It follows from (11) that Odebrecht's rents from bribing are given by:

$$\text{Rents} = \begin{cases} \frac{\rho\gamma x}{1-\rho(1-x)}(W-\theta_2) - (\theta_1-\theta_2), & \text{if } \theta_1 > \theta_2, \\ \\ \frac{\rho\gamma x}{1-\rho(1-x)}(W-\theta_2), & \text{otherwise.} \end{cases}$$

Therefore

$$\text{Rents} \leq \frac{\rho\gamma x}{1-\rho(1-x)}(W-\theta_2), \tag{16}$$

with equality when $\sigma = 0$.

We also have that

$$\text{Bribes} = (1-\gamma)x(W-R_2) = \frac{(1-\gamma)x}{1-\rho(1-x)}(W-\theta_2), \tag{17}$$

[55] Throughout this section we ignore that projects are adjudicated in first-price auctions and not in second-price auctions as assumed in our model. This is justified because, as established in Sections 3 and 4, both x and σ are small.

where we used (9) in the second equality. Combining (16) and (17) yields

$$\frac{\text{Rents}}{\text{Bribes}} \leq \frac{\rho\gamma}{1-\gamma}, \tag{18}$$

and therefore

$$\frac{\text{Rents}}{\text{Rents} + \text{Bribes}} = \frac{1}{1 + \text{Bribes/Rents}} \leq \frac{1}{1 + \frac{1-\gamma}{\rho\gamma}} = \frac{\rho\gamma}{\rho\gamma + 1 - \gamma}. \tag{19}$$

Since the right hand side of this expression is increasing in ρ, it will be bounded from above by the value it takes when $\rho = 1$, that is, by γ. This yields the following lower bound for γ:

$$\gamma \geq \frac{\text{Rents}}{\text{Rents} + \text{Bribes}}. \tag{20}$$

This bound increases with the ratio of rents to bribes, from zero in the case with no rents, approaching one as the ratio becomes large. We also note that the bound in (20) becomes an identity when $\rho = 1$ and $\sigma = 0$. In this case rents obtained by Odebrecht equal $\gamma x(W - R_2)$ and bribe payments equal $(1 - \gamma)x(W - R_2)$. Because of its technological advantage in bribe payments, Odebrecht pays $(1-\gamma)x(W-R_2)$ in bribes instead of $x(W - R_2)$. Odebrecht's rents are equal to its savings in bribe payments because it obtains all rents left after bribe payments ($\rho = 1$) and because Odebrecht never wins projects where its costs are higher than those of its competitors ($\sigma = 0$).

Using the numbers reported by Odebrecht in its plea bargain with the DOJ (see Table 1), we obtain a lower bound for γ of 0.75. If we compute rents and bribes for the 90 projects in Tables 2 and 3, we conclude that $\gamma \geq 0.71$. We conclude that the reduction in leakage (for Odebrecht) and transaction costs (for the bribe recipient) added up to a significant competitive advantage in the infrastructure business for Odebrecht.

The above bound implies that even though bribe payments were relatively small, Odebrecht's competitive advantage in bribe payments was large. For example, if a competitor needed to pay \$10 million to bribe a public official, Odebrecht required only (approximately) \$3 million. Extrapolating from the anecdotal evidence presented in Section 3.3, we have that five of the seven million dollars saved by Odebrecht are explained by the elimination of leakage. Arguably, the remaining two million correspond to the corrupt official's valuation of receiving bribes in a manner that seemed impossible to detect.

5.2 Bribe payment parameter, x

We have that the Odebrecht's investment following the renegotiation, ΔI, satisfies

$$\Delta I = \rho[1 - (1 - \gamma)x](W - R_2). \tag{21}$$

Combining this expression with (17) implies

$$\frac{\text{Bribes}}{\Delta I} = \frac{(1 - \gamma)x}{\rho[1 - (1 - \gamma)x]}. \tag{22}$$

Since σ is small, (18) holds (approximately) with equality. Combining this expression with (22) yields

$$\frac{\text{Rents}}{\Delta I} \simeq \frac{\gamma x}{1-(1-\gamma)x}. \tag{23}$$

And using (22) and (23) we have that

$$x = \gamma x + (1-\gamma)x \simeq [1-(1-\gamma)x]\left\{\rho\frac{\text{Bribes}}{\Delta I} + \frac{\text{Rents}}{\Delta I}\right\}$$

and therefore

$$x \simeq \frac{\rho\frac{\text{Bribes}}{\Delta I} + \frac{\text{Rents}}{\Delta I}}{1+\rho(1-\gamma)\frac{\text{Bribes}}{\Delta I} + (1-\gamma)\frac{\text{Rents}}{\Delta I}}. \tag{24}$$

Since rents and bribes in our dataset are much smaller then the investments that resulted from renegotiations, we obtain the following approximate expression for x:

$$x \simeq \rho\frac{\text{Bribes}}{\Delta I} + \frac{\text{Rents}}{\Delta I}.$$

Finally, since ρ takes values between 0 and 1, the above expression yields the following approximate bounds for x:

$$\frac{\text{Rents}}{\Delta I} \leq x \leq \frac{\text{Rents} + \text{Bribes}}{\Delta I}. \tag{25}$$

Table 4 presents the bounds for x obtained from (25). Total bribe and rents are those reported by Odebrecht for the eight countries for which we have data on renegotiations. To compute ΔI we consider only projects where bribes were paid. For projects with either legal or media evidence of bribe payments, we obtain a lower and upper bound of 0.041 and 0.058. The bounds are slightly larger if we only consider projects with legal evidence of bribe payments.

Table 4: Bounds on the parameter x

	Number	Bribes (MM US$)	Rents (MM US$)	ΔI (MM US$)	Bounds for x Lower	Upper
Only legal sources:	40	288	710	15,371	0.046	0.065
Legal or media sources:	63	288	710	17,307	0.041	0.058

Authors' calculations. Projects with bribes determined from legal and media sources.
Investment data obtained from government agencies. See Appendix A for details.

In Section 3 we established that bribes, as a fraction of initial and final investment, were small (see Table 3). Table 4 shows that bribes are also small when viewed through the lense of our model. Bribes, as a fraction of rents up for grabs at renegotiations, are somewhere between 4.1 and 6.5%.

5.3 Renegotiation parameters ρ^N and ρ^B

Combining (21) and (10) and ignoring terms of order x leads to

$$\Delta I \simeq \frac{\rho}{1-\rho}(W - \theta_2).$$

Since σ is small, we may replace θ_2 by θ_1. Dividing both sides by θ_1 and rearranging terms then yields

$$\frac{\rho}{1-\rho} \simeq \frac{\Delta I/\theta_1}{(W-\theta_1)/\theta_1}. \tag{26}$$

Solving for ρ we obtain

$$\rho \simeq \frac{K}{1+K}, \tag{27}$$

with

$$K = \frac{\Delta I/\theta_1}{(W-\theta_1)/\theta_1}. \tag{28}$$

The expression for ρ in (27) depends on the two ratios that define K in (28). The first ratio, $(W - \theta_1)/\theta_1$, may be interpreted as the social return on the investment.[56] Even though estimates for returns on infrastructure projects vary considerably, estimates based on more than 1,000 World Bank transport sector projects suggest average returns between 14 percent (rail) to 26 percent (highways). Also, returns for highway projects in the US between 1950 and 1980 are close to 30 percent.[57] Thus, since World Bank projects are likely to have higher returns on average than other projects, below we consider values for this ratio between 10 and 30 percent.

The second ratio that determines K, and therefore ρ, is $\Delta I/\theta_1$, that is, renegotiations as a fraction of total investment. Table 2, that reports renegotiations as a fraction of initial investments, can be used to calculate this ratio, leading to estimates that are much larger for projects with bribes than for projects without bribes.

Table 5: Range of values for ρ^N and ρ^B

Source for bribes	$\Delta I^N/\theta_1$	$\Delta I^B/\theta_1$	Return on projects	ρ^N	ρ^B
Only legal sources:	0.105	0.447	10%	0.51	0.82
			20%	0.35	0.69
			30%	0.26	0.60
Legal or media sources:	0.061	0.416	10%	0.38	0.81
			20%	0.23	0.68
			30%	0.17	0.58

Authors' calculations, based on (27) and (28) and numbers reported in Table 2 for the case with weighted averages.

[56] This interpretation considers realized returns, not ex ante expected returns, which would lead to $(W - R)/R$. One advantage of the interpretation of returns we choose is that it does not depend on the bias introduced by renegotiations in the calculation of social returns.

[57] For both sets of estimates of returns see FHWA (2016).

The expressions obtained in (27) and (28) are valid both for ρ^N and ρ^B, as long as we note that, as discussed above, the ratios that enter K, especially $\Delta I/\theta_1$, are different for projects with and without bribes.[58] Table 5 reports values for ρ^N and ρ^B obtained from these expressions, using the weighted estimates for renegotiations from Table 2. For example, when the return on projects is 20 percent and both media and legal sources are considered to determine whether bribes were paid, $\rho^B = 0.68$ while $\rho^N = 0.23$.[59]

5.4 Returns and participation before and after the DSO: An example

We end this section by illustrating the main insights from Section 4 using the parameter values we derived above. We assume $\rho^B = 0.68$, consistent with the value in Table 5 when returns to projects are 20 percent and both legal and media sources are used to determine projects with bribes. It then follows from (24) and (19) that $x = 0.048$ and $\gamma = 0.78$.

For interpretation purposes it is convenient to rewrite the expressions we derived in Proposition 2 in terms of the coefficient of variation of θ, CV $\equiv \sigma/\bar{\theta}$. To do this we recall that $C = \rho\gamma x/[1-\rho(1-x)]$ and define

$$\tilde{\mu} = \mu/\bar{\theta} = C\frac{(W-\bar{\theta})}{\bar{\theta}}, \qquad \tilde{\tau}^2 = \tau^2/\bar{\theta}^2 = [(1-C)^2+1]\text{CV}^2.$$

The probability that firm 1 wins and its unconditional expected profits may then be written as:

$$\Pr(\text{Firm 1 wins}) = \Phi(\tilde{\mu}/\tilde{\tau}), \tag{29}$$

$$\frac{\text{E}[\Pi_1]}{\bar{\theta}} = \tilde{\mu}\Phi(\tilde{\mu}/\tilde{\tau}) + \tilde{\tau}\phi(\tilde{\mu}/\tilde{\tau}), \tag{30}$$

Figure 3 shows the probability of winning as a function of the coefficient of variation of θ, CV, both before (lower, green line) and after (upper, blue line) the creation of the DSO, that is, both in the symmetric equilibrium of Proposition 1 and in the post-bribe-innovation equilibrium of Proposition 2. In the pre-innovation equilibrium, the probability of winning does not depend on the CV and is always 0.5. By contrast, in the post-innovation equilibrium the probability of winning jumps to 1 when the CV is close to zero and decreases as the CV grows, reaching 0.6 when CV = 0.042 and 0.55 when CV = .084.

Figure 4 shows how profits, normalized by total investment, vary with CV, both before (lower, green line) and after (upper, blue line) the creation of the DSO. When CV=0, profits in the symmetric equilibrium

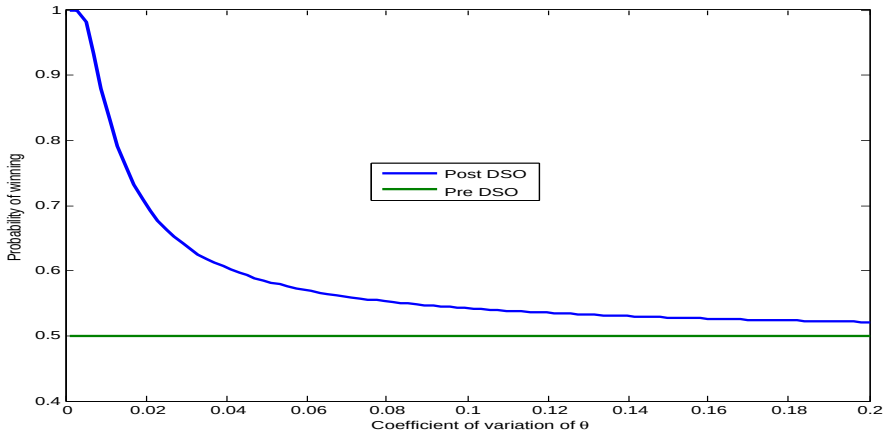
[58] As a first approximation we may assume no systematic difference in the returns to projects with and without bribes.

[59] The ratios between the value of renegotiations associated to the parameters ρ^B and ρ^N in Table 5 are smaller than the ratios between renegotiations. For example, with the broader definition for bribe payments, the ratios for the latter are 11 when normalizing by initial investment (see Table 2) and 6.8 when normalizing by total investment (see Table 5), which are both much larger than the corresponding value of ρ^B/ρ^N, which is approximately 3 when the social return to projects is 20%. To see why this is the case, we note that using (26) for ρ^B and ρ^N, dividing the first expression by the second one and assuming that returns to projects are, on average, the same for projects with and without bribes, leads to:

$$\frac{\rho^B/(1-\rho^B)}{\rho^N/(1-\rho^N)} \simeq \frac{\Delta I^B/\theta_1}{\Delta I^N/\theta_1},$$

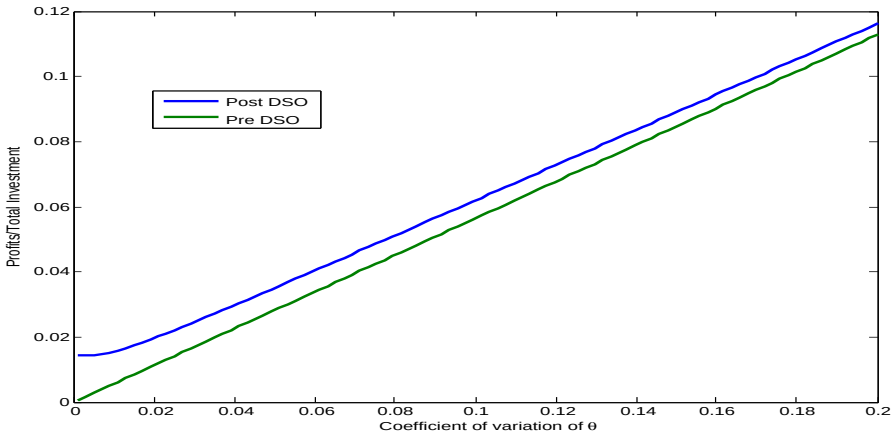
where $\Delta I^B/\theta_1$ and $\Delta I^N/\theta_1$ denote the ratios of renegotiations to total investment for projects with and without bribes. It follows that the *odds ratio* of the renegotiation ρ^B and ρ^N is equal to the ratio of renegotiations with and without bribes, not the ratio of renegotiation parameters. Furthermore, if there is no systematic relation between returns to projects with and without bribes, this odds ratio does not depend on actual returns to the projects.

Figure 3: Market participation: Before and after the creation of the DSO



are equal to zero. while in the post-bribe-innovation equilibrium they are equal to $\tilde{\mu} = 0.2C = 1.44$ percent. As CV grows, the difference between pre- and post-innovation profits decreases systematically.

Figure 4: Profits as a fraction of total investment: Before and after the creation of the DSO



The data in Table 3 suggest a value of 1.71 percent for profits relative to total investment. Figure 3 implies a coefficient of variation of 1.5 percent for this level of post-innovation profits while Figure 4 implies a probability of winning of 76 percent. The corresponding pre-innovation profits are 0.85% of investments. Thus, in our simple model, the creation of the DSO increased Odebrecht's market share by approximately 50 percent while its profits doubled. Since initial profits, relative to investment were less than one percent, profits after the innovation continued being small.

Summing up, our admittedly stylized competitive model with bribe payments can be taken to the data quite easily, obtaining relatively tight bounds for its parameters. These parameter values are reasonable and imply that profits and market shares reacted to an innovation in the bribing technology as predicted by our model: Odebrecht's market participation increased significantly while its profits remained modest.

5.5 Welfare costs

We end this section with an analysis of the welfare costs of corruption, as implied by our model. We consider first the symmetric equilibrium, that is, the equilibrium prior to the creation of the DSO.[60] It follows from (6) that in the symmetric equilibrium the social surplus as a function of the bribe parameter, $S(x)$, is given by:

$$S(x) = \frac{(1-\rho)(1-x)}{1-\rho(1-x)}(W-\theta'), \tag{31}$$

where θ' denotes the loosing firm's cost. It follows that the welfare cost of corruption, as a fraction of surplus, is given by

$$\frac{\text{Welfare Loss}}{S(0)} = \frac{S(0)-S(x)}{S(0)} = \frac{x}{1-\rho(1-x)}. \tag{32}$$

With the parameter values from Section 5.4, this leads to a 13.6% reduction in welfare due to corruption.

An alternative measure for the welfare costs of corruption is obtained normalizing the welfare difference by the investments at stake. It follows from (31) that this measure is given by

$$\frac{\text{Welfare Loss}}{\theta} = \frac{S(0)-S(x)}{\theta} = \frac{S(0)-S(x)}{S(0)} \times \frac{S(0)}{\theta} = \frac{x}{1-\rho(1-x)} \times \frac{W-\theta'}{\theta} \simeq \frac{x}{1-\rho(1-x)}\text{SR}, \tag{33}$$

where $\text{SR} \equiv (W-\theta)/\theta$ denotes the social return of the project, θ the cost of the winning firm, and in the final step we used that θ and θ' are similar because the coefficient of variation of θ is small. Since SR is 20 percent, we conclude that the welfare cost, as a fraction of total investment is approximately 2.7 percent.

Thus, corruption leads to a significant reduction in welfare of 13.6 percent in the symmetric pre-innovation equilibrium, yet this loss amounts to only 2.7 percent of investments and therefore, at least by this measure, is small.

Following the creation of the DSO, there are three mechanisms that can lead to a change in the welfare costs of corruption. Bribe payments are lower which reduces the welfare cost of corruption. Pointing in the opposite direction we have that Odebrecht will appropriate a rent for its bribing advantage and that, in contrast with the symmetric equilibrium, now we may have the less efficient firm building the project. Note that the welfare calculation also needs to consider what happens to the less efficient firm. Even though it continues paying the same amounts in bribes, the rents it obtains when its cost draw is lower are reduced by Odebrecht's competitive advantage in bribing.

Denoting by $S_i(x)$ the surplus when firm i wins, $i = 1, 2$, we have:[61]

$$\begin{aligned} S_1(x) &= \frac{(1-\rho)[1-(1-\gamma)x]}{1-\rho(1-x)}(W-\theta_2), \\ S_2(x) &= \frac{(1-\rho)(1-x)}{1-\rho[1-(1-\gamma)x]}(W-\theta_1). \end{aligned}$$

[60] Since we estimated parameter values with data from the asymmetric equilibrium, here we use our admittedly very simple "structural model" to make inferences in counterfactual scenarios.

[61] The expression for $S_1(x)$ follows from footntoe 54, the expression for $S_2(x)$ from an analogous calculation.

Using the same logic with which we derived (32) and (33) then yields

$$\frac{\text{Welfare Loss}}{\text{Welfare with no bribes}} = \begin{cases} \frac{(1-\rho)[1-(1-\gamma)x]}{1-\rho(1-x)} & \text{if firm 1 wins,} \\ \\ \frac{(1-\rho)[1-x)}{1-\rho[1-(1-\gamma)x]} & \text{if firm 2 wins,} \end{cases} \tag{34}$$

and

$$\frac{\text{Welfare Loss}}{\theta} \simeq \begin{cases} \frac{(1-\rho)[1-(1-\gamma)x]}{1-\rho(1-x)}\text{SR} & \text{if firm 1 wins,} \\ \\ \frac{(1-\rho)[1-x)}{1-\rho[1-(1-\gamma)x]}\text{SR} & \text{if firm 2 wins.} \end{cases} \tag{35}$$

Using the parameter values from Section 5.4, (34) leads to reduction in welfare of 10.2 percent when firm 1 wins, as compared with 13.6 percent in the symmetric equilibrium. The intuition is the following: When Odebrecht wins after the creation of the DSO, bribe payments are lower, yet an important part of this reduction accrues to Odebrecht as a rent. Furthermore, Odebrecht increases its market participation from 50 to 76 percent and all the extra projects are projects where Odebrecht is less efficient than its competitor. This explains why the welfare loss decreases by only 25 percent even though bribe payments by Odebrecht are 78 percent lower.

Equation (34) also implies that the welfare cost of corruption when firm 2 wins is 6.9 percent. This firm continues paying the same bribes as before, yet its rents are lower because of Odebrecht's competitive advantage. Finally, since Odebrecht wins 76 percent of the projects, the overall welfare cost of corruption, as a fraction of the surplus without bribes, is of 9.4 percent.

As in the symmetric case, the above numbers are much smaller if we normalize by investments. For example, the overall cost of corruption is only 1.9 percent of investment.

Our model assumes that the distribution of costs and the renegotiation parameter is the same for both firms. The cost of corruption may be considerably larger if we relax these assumptions. If firms that are better at renegotiating are less efficient in building, we may have a *selection effect* that excludes firms that are more efficient at building projects but less effective in renegotiating.[62] In this case, the welfare costs from corruption may be large, even when compared with investments.

6 Conclusion

We began this paper by documenting a striking positive correlation between bribes and the amounts renegotiated. We also found that, even though corruption in the procurement of large infrastructure projects was widespread, Odebrecht paid modest bribes and made small profits, at least when compared with the magnitude of investments. Our formal analysis then showed that these outcomes stem from a subtle interaction between competitive auctions and bilateral renegotiations—a mechanism that Oliver Williamson called the 'fundamental transformation.' To conclude, we discuss the open questions that emerge from this

[62] For a model formalizing this intuition see Engel et al. (2019b). The effect is similar, but potentially much larger, than the one described in Result 4 above. Also note that this effect corresponds to the selection channel from the misallocation literature, see e.g. Restuccia and Rogerson (2017).

research.

The literature teaches that the aim of many corrupt transactions is to steal money from the public purse. When the aim of corruption is to steal, bribes are used to divide the proceeds between the corrupt official and the firm. The level of surplus extraction is the endogenous outcome of bargaining between the bribe payer and the public official. In the Odebrecht case, however, the main aim of bribing was not stealing, but to buy influence and bargaining power in renegotiations. That is, bribes are akin to the price of a service, and not the means for splitting the spoils. Moreover, we showed that when firms compete in the auction, small bribes are necessary to rationalize the large renegotiations observed in the data. Because our aim in this paper was to understand the link between bribing and large renegotiations, we assumed that bribes were exogenous and small. But one would like to explain why small bribes emerge endogenously in equilibrium. Moreover, there are countries where the aim of corruption in large infrastructure projects is to steal. What determines whether one country ends in one or the other equilibrium is an open question.[63]

The idea that firms bribe to buy influence has received comparatively less attention in the corruption literature, perhaps because influence is thought to be the outcome of mainly lobbying and campaign financing. Indeed, our model combines an illegal act (bribing) with an outcome that is not necessarily illegal—influencing the outcome of a renegotiation. One paper that studies the interaction of influence and corruption (or, in their terminology, legal and illegal corruption) is Kaufmann and Vicente (2011). They model corruption at the macro level, and ask when one or the other form of corruption will prevail in a given country.[64] By contrast, the Odebrecht case suggests that some influence is bought with bribes and that construction firms use both legal and illegal means of influence. Modeling the joint determination of both means of influence, as part of a portfolio decision, seems a fruitful line of research.

In our analysis we have barely touched on the relation between bribes, corruption and efficiency. Our model has rather conflicting implications. On the one hand, if competition in the auction is intense, then inefficiencies due to corruption are small. On the other hand, bribe payments may induce a self-selection effect—bribes exclude firms that do not pay them, because they cannot compete in the auction. The latter effect can be large if the renegotiating ability of firms is negatively correlated with technical efficiency (see Engel et al., 2019b for a formal model). Finding evidence to estimate the magnitude of this effect, however, remains an open question. Furthermore, understanding other channels that may affect the efficiency cost caused by corruption seems important as well. For example, a important question is whether corruption creates the incentives for poor project design and inadequate management that lead to large renegotiations; or rather that corrupt public officials take advantage of poor design and management to make their influence valuable in renegotiations.

The last observation is about the policy implications of our analysis. One is that, somewhat surpris-

[63] One hypothesis is that the combination of competitive auctions with increased transparency of contracts and renegotiations limits the discretion of public officials. Similarly, improved disclosure of financial information for firms that operate in international bond markets limits the ability to generate funds available for bribes.

[64] For example, as empirical proxies of legal corruption they use influence of well-connected firms in procurement, influence of legal contributions to political parties, independence of the judiciary from influence, and influence on laws and regulations. As proxies for illegal corruption they use illegal donations to political parties, diversion of public funds due to corruption, frequency of bribes in procurement, frequency of bribes in influencing laws and policies, and frequency of bribes in influencing judicial decisions.

ingly, the Odebrecht case suggests that in many countries, even when affected by corruption, auctions of large infrastructure projects work fairly well—they are competitive.[65] Moreover, public officials seem to be unable to create rents by "selling" access to projects via large bribes. At the same time, the post tender stage seems to be working very poorly. A first and simple policy is to require that all the information on contract renegotiations of infrastructure projects be easily available to the public. A more ambitious, yet very simple reform follows from our analysis as well. As we have shown in Engel et al. (2019a), lowballing can be eliminated by increasing the government's bargaining power in the post tender stage. Thus, as argued in Engel et al. (2014, ch. 8), one should subject renegotiations to independent review and approval by an expert panel, and award all additional post tender works in open auctions.[66] Then influence will have little value and there will be no lowballing.

[65]The prevalence of competitive tendering is not a coincidence, but the result of decades of insistence that projects must be tendered in open and transparent auctions by development banks and other institutions. For example, at least since the 1990's, the World Bank has promoted competitive bidding for the projects it finances. More generally, competitive bidding and at least some degree of transparency in public auctions for infrastructure have become fairly common in many developing countries, especially in Latin America. As Knack et al. (2017) find in a sample of 88 countries, more transparency in the procurement process foster firm participation in the bidding process because firms pay smaller bribes or kickbacks and less frequently.

[66]The 2010 reform of Chile's PPP legislation created such a panel.

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Appendix

A Database

The main empirical fact emerging from the Odebrecht case is the systematic correlation between bribes and the size of a renegotiation. As we show in Table 3, on average, and conditional on having paid bribes, renegotiated amounts are about ten times larger in projects where Odebrecht paid a bribe. To establish this correlation, one needs to know, for each public project undertaken by Odebrecht, whether Odebrecht paid bribes, the estimated investment at the time of tendering (initial investment), and total investment after completion of the project (final investment). Nevertheless, the plea agreement only reports, country by country, the total amounts that Odebrecht paid in bribes, and the total profits it made by bribing. It neither reports investment by project nor lists the specific projects in which Odebrect paid bribes.[67]In this appendix we explain how we obtained information about each project.

To capture the data we proceeded in three steps. First, from Odebrecht's annual reports and the websites of Odebrecht's subsidiaries in several countries, we obtained the list of public infrastructure projects awarded each year to Odebrecht in each country. When selecting projects, we only considered years covered by the DOJ's investigation, which vary across countries.

Second, two research assistants conducted systematic on-line searches to find the amounts invested (initial and final) by each project in the list, and evidence of bribe payments associated with each project. To do so, they downloaded all official documents issued by government and judicial bodies which mentioned a project in the list—e.g. contracts, minutes of the bidding process, supplementary contracts. In addition, they downloaded from JOTA.Info all documents issued by public prosecutors that mentioned a project in the list, and the depositions of Odebrecht executives.[68] Last, they downloaded press reports that mentioned a project in the list.

Third, the number of downloaded pages is in the thousands. We therefore deposited the documents and press reports in a bespoke platform where they can be electronically searched by key words.[69] We used key words to select documents that mentioned each project, and then two research assistants read them looking for the amounts invested and evidence of bribe payments.

So far we obtained the amounts invested and renegotiated for 90 public infrastructure projects in eight Latin American countries—Argentina, Colombia, Dominican Republic, Ecuador, Guatemala, Mexico, Panama and Peru.[70] This list comprises all projects that were awarded to Odebrecht during the years

[67]Odebrecht's plea agreement states: "During the relevant time period, Odebrecht, together with its co-conspirators, paid approximately $788 million in bribes in association with more than 100 projects in twelve countries, including Angola, Argentina, Brazil, Colombia, Dominican Republic, Ecuador, Guatemala, Mexico, Mozambique, Panama, Peru and Venezuela".

[68]JOTA.Info is a repository of the legal documents generated by the hundreds of processes that comprise Operation Lava Jato, of which Odebrecht's case is part. Operation Lava Jato is an ongoing criminal investigation of the Federal Police of Brazil, which began as money laundering investigation, but was expanded to cover allegations of corruption in the state-owned oil company Petrobras. Odebrecht's case is part of the Lava Jato investigation.

[69]The platform can be found at `http://searchbench.unholster.com`.

[70]When two sources provided different data for the same project, priority was given to information on contracts and official documents issued by the government. When this information was not available, the information provided by judicial bodies, investigative media and civil society organizations was used.

covered by the DOJ's investigation. We are still working on Brazil, and excluded Venezuela, Mozambique and Angola for lack of reliable information about project-specific bribe payments and investments.

In addition, for each of the 90 projects we looked for evidence of bribe payments. We concluded that a bribe was paid in a given project if an official document or a press report mentions at least one bribe payment. We call this *legal and media corruption.* Under this criterion, the number of projects with bribe payments is 63 (70 percent). To check the robustness of the association between bribe payments and renegotiated amounts we also built an indicator that concludes that a bribe was paid only if at least one official document mentions that a bribe was paid. This criterion is stricter and yields that the number of projects with bribe payments is 40 (44 percent).

B Profit rates in the construction industry

On of the striking features of the construction industry worldwide is that profitability, as a fraction of sales, is low. This may seem at odds with the notion that there is corruption in the industry, and that corruption would lead to large profits (and margins) for the corrupting firms. To examine this issue we have divided the world into groups of countries according to a somewhat idiosyncratic division into: Spanish Latin America, Europe without Scandinavia, Scandinavia, Japan, Korea, Australia, China, Brazil and the US.

Table 6: Average Profit Margin (profit/sales) by group of countries, in percent

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
Sp. Latin America	7,70	11,77	6,03	8,08	8,90	7,59	6,90	6,65	4,92	5,31	8,05	7,45
Australia	4,58	5,50	6,67	5,11	5,10	3,59	3,07	2,83	2,50	1,75	2,86	3,96
Brazil	8,90	7,91	6,58	7,49	4,70	6,28	-3,39	2,20	-1,43	-7,70	-22,23	0,85
China	2,16	2,66	2,28	2,54	2,08	2,48	2,50	2,45	2,54	2,71	2,83	2,48
South Korea					4,81	4,42	2,58	-2,50	-0,03	5,15	-0,02	2,06
United States	3,03	3,11	1,90	3,46	3,78	3,89	2,25	3,35	3,35	-0,48	0,06	2,52
Scandinavian	3,59	3,55	3,00	3,23	2,94	3,28	2,37	2,49	3,20	3,13	2,98	3,07
Europe	2,38	2,10	1,36	1,47	1,52	1,74	0,85	1,26	1,18	1,39	2,27	1,59
Japan	1,76	1,93	1,57	0,04	-0,32	1,05	0,30	1,00	1,56	2,01	4,34	1,39

Source: Authors, from balance sheets and annual statements of the selected firms.

This division provides gives a fairly broad view of the industry, considering groups of countries with different levels of corruption according to the standard indicators (Transparency International's CPI and the World Bank Control of Corruption indicator). In each country group we have looked at the 5 largest firms that have (usually) audited financial information for recent years.[71] The average rate of profits on sales is very low, with Spanish LA firms having the highest rates, as shown in table 6. Even then it is a fairly low number, and seems consistent with the higher risks of the industry in Spanish LA. Thus, the low profitability of Odebrecht does not seem to be an outlier.

While the return on sales is highest for Spanish LA countries, the return on equity in LA for the

[71]The firms are diverse, and often have divisions that are unrelated to construction. For example, Spanish firms hace divisions that have operating PPPs, which are very profitable, but are unrelated to the construction of infrastructure. Some firms include mining services, another unrelated business. Unfortunately, the profitability of the Engineering and construction division –closest to our interest– in terms of assets and equity, or even of sales is usually unavailable.

Table 7: Average return on equity by group of countries, in percent

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
Sp. Latin America	19.75	20.39	12.18	14.80	19.27	16.38	13.44	10.91	8.46	8.45	9.71	**13.98**
Australia	27.48	24.96	32.76	21.50	20.21	14.43	15.79	14.45	11.59	6.30	9.63	**18.10**
Brazil	36.15	30.10	32.15	35.89	17.20	16.71	-16.71	9.81	-6.28	3.10		**15.81**
China	23.84	18.38	5.05	9.20	7.92	8.41	8.45	8.62	8.02	9.42	9.33	**10.60**
South Korea					12.32	9.94	6.31	-8.29	0.58	6.53	-4.50	**3.27**
United States	21.05	17.93	11.16	17.46	13.80	16.89	11.27	16.65	18.69	-2.69	-0.58	**12.87**
Scandinavian	28.77	29.08	25.00	21.85	16.06	20.80	16.33	15.98	21.22	19.35	18.62	**21.19**
Europe	34.33	6.70	5.58	5.96	5.83	7.60	3.48	4.82	4.69	5.50	8.64	**8.47**
Japan	7.34	7.92	7.87	-0.57	-0.58	4.55	1.10	3.93	5.53	6.68	13.13	**5.17**

Source: Authors.

period is 13.98%, which is smaller than the 18.10% return in Australia and the 21.19% return on equity in Scandinavia, see table 7. Scandinavia has low profits on sales, but the stability of the market means that firms require less capital in order to operate, leading to the highest RoE among the groups of countries analyzed. Thus the higher margin in Spanish LA may reflect a market in which higher margins on sales are needed to obtain a reasonable return. This is corroborated when considering the variation in the return on assets, as measured by the standard deviation of annual returns on assets, which ranges from 6.39% in Spanish LA to a 1.26% in Japan, see Table 8. Thus we conclude that this is an industry that is fairly competitive, without large margins on sales, but is reasonably profitable in terms of ROE. Observe that from the point of view of welfare, having low profits on sales means that the cost of a projects does not involve large rents for the construction company. The low margins on sales and standard profitability is important for our theoretical analysis.

Table 8: Average return on assets by group of countries, in percent

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Average
Latin America	8.31	10.02	5.20	7.02	8.83	7.05	6.12	5.60	3.87	3.57	4.70	6.39
Australia	9.74	9.01	10.11	8.55	7.67	5.79	5.44	4.90	4.09	2.70	3.78	6.53
Brazil	17.48	13.61	15.14	11.66	3.59	5.14	-3.99	2.03	-2.38	1.00		6.33
China	2.17	2.43	1.99	2.59	2.31	2.25	2.08	1.81	1.90	1.89	1.95	2.13
South Korea					4.32	3.73	2.49	-1.88	0.08	2.56	-0.34	1.57
United States	6.81	6.13	5.37	6.96	5.57	6.62	3.94	5.93	5.61	0.07	0.39	4.86
Scandinavian	6.35	7.09	5.53	5.32	4.62	5.17	3.71	4.04	5.43	4.80	4.78	5.17
Europe	4.02	2.68	1.70	1.92	1.81	2.30	1.09	1.48	1.44	1.70	2.72	2.08
Japan	1.49	1.66	1.49	0.05	-0.35	0.88	0.27	0.91	1.44	2.02	4.04	1.26

Source: Authors.

C Statistical tests

Table 9 in the main text shows a large and positive correlation between bribe payments and the magnitude of renegotiations. In this appendix we provide a description of the data underlying this table and perform various statistical tests to establish that this difference is not only economically but also statistically

significant.

Table 9: Descriptive Statistics

	Statistic	Projects considered				
		All	No bribe		Bribe	
			Legal	Legal/Media	Legal	Legal/Media
	No. of projects:	90	50	27	40	63
Initial investment, I_0	Average:	545.6	601.9	919.6	475.2	385.3
(MM USD)	Median:	203.4	174.3	172.4	220.4	220.8
	St.dev.:	1096.8	1345.7	1770.2	678.7	570.6
Total investment, I_1	Average:	755.9	673.1	979.7	859.5	660.0
(MM USD)	Median:	293.5	227.9	206.7	417.3	298.8
	St.dev.:	1552.6	1350.7	1774.8	1785.8	1452.0
Renegotiation,	Reneg > 0 (%):	71.1	64.0	55.6	80.0	77.8
Reneg $\equiv (I_1 - I_0)/I_0$	Simple avge.:	45.5	27.6	18.4	67.9	57.1
(% of initial investment)	Weighted avge.:	38.5	11.8	6.5	80.9	71.3
	St.dev.:	58.3	39.3	25.1	69.9	64.4
	Weighted st.dev.:	64.4	28.3	16.3	80.7	77.4

Authors' calculations using data sources described in Appendix A.

Table 9 provides descriptive statistics for initial investments, I_0, final investment, I_1, and the increase of the latter when compared with the former, $(I_1 - I_0)/I_0$. The first column considers the 90 projects in our database, the remaining columns consider either the subset of projects where bribes were paid or the subset where no bribes were paid. We present statistics with both criteria for bribe payments (see Appendix A). For initial and total investment we report the average and median values as well as the standard deviation. For the amount renegotiated, as a percentage of the initial investment, we report the simple average and the weighted average, with weights proportional to initial investment. The latter equals the ratio of total final investment to total initial investment and therefore provides a natural estimate for the aggregate importance of renegotiations.

A comparison of means and medians, both for initial investment and for total investment, suggest distributions that are skewed right. By contrast, if we consider the same statistics for the logarithm of both initial and total investment, the distributions are approximately symmetric. the mean and median of log-initial investment for the entire dataset are almost identical (5.312 vs. 5.313) and the mean and median of log-total investment are similar as well (5.625 vs. 5.682).

The lower third of the table provides statistics for renegotiations as a percentage of initial investment. The first two rows show that differences between projects with and without bribes are larger when we consider weighted averages than when working with simple averages, for both bribe criteria, which suggests a positive correlation between project size and the increase in project renegotiation due to bribes.

Table 10 reports p-values for six tests comparing the means of the magnitude of renegotiations of

Table 10: Formal tests: p-values

			Bribe criterion	
Variances	Method	Average	Legal	Legal/Media
Equal	t-distribution	Simple	0.0008	0.0034
Unequal	t-dist. (Welch approx)	Simple	0.0019	0.0001
Unequal	Bootstrap	Simple	0.0014	0.0004
Unequal	Bootstrap	Weighted	0.0187	0.0091
Unequal	Permutation	Simple	0.0014	0.0004
Unequal	Permutation	Weighted	0.0040	0.0007

This table reports p-values for tests comparing the means of renegotiations of projects with and without bribes, both in percentages. Both definitions for projects with bribes are considered. The test statistic in all cases is the two sample t-statistic. The first columna indicates whether variances are pooled (Equal) or not (Unequal). the second column indicates how the p-value is calculated. The first row uses the exact t-distribution (standard two-sample t test). The second row uses a t-distribution approximation (Welch test). The third and fourth rows use the bootstrap and the fifth and sixth rows use random permutation (Fisher's exact p-value test). The number of replications when using the bootstrap and permutations is 1,000,000. The third column indicates whether simple or weighted (by initial investment) averages are used.

projects with and without bribes. Both definitions for evidence-of-bribes are considered. The first test is a standard two-sample t test. The second test is the Welch test, that also assumes normal distributions but allows for unequal variances. Both these tests lead to small p-values, less than 0.002 in all cases. The remaining four tests consider non-parametric tests and therefore do not require the normality assumption. They use the bootstrap and permutations to calculate p-values. Even though the p-values with weighted averages are somewhat larger, all p-values are less than 0.02 and their average is less than 0.005.

The evidence presented in table 2 in the main text suggested an economically significant difference in the magnitudes of renegotiations of projects with and without bribe payments. Table 10 shows that this difference is also statistically significant.

D Proofs

Lemma 1 *Assume X is a normal random variable, with mean μ and variance τ^2 and define*

$$Y = \begin{cases} X & \text{if } X > 0, \\ 0 & \text{otherwise.} \end{cases}$$

Then:

$$\mathrm{E}[Y] = \mu\Phi(\mu/\tau) + \tau\phi(\mu/\tau), \tag{36}$$

where Φ and ϕ denote the cumulative distribution function and probability density function of a standard normal distribution respectively.

Proof We have:

$$\begin{aligned}
\mathrm{E}[Y] &= \frac{1}{\tau}\int_0^\infty y\phi((y-\mu)/\tau)\,\mathrm{d}y \\
&= \mu\int_{-\mu/\tau}^\infty \phi(z)\,\mathrm{d}z + \tau\int_{-\mu/\tau}^\infty z\phi(z)\,\mathrm{d}z \\
&= \mu[1-\Phi(-\mu/\tau)] - \tau\int_{-\mu/\tau}^\infty \phi'(z)\,\mathrm{d}z \\
&= \mu\Phi(\mu/\tau) + \tau\phi(\mu/\tau),
\end{aligned}$$

where we used that the p.d.f. of Y is $\phi((y-\mu)/\tau)/\tau$ and the Law of the Unconscious Statistician in the first step, the change of variable $y = \mu + \tau z$ in the second step, $\phi'(x) = -x\phi(x)$ in the third step, and $\Phi(x) = 1 - \Phi(-x)$ and $\phi(x) = \phi(-x)$ in the final step.

Proof of Proposition 1

Denote firm 1's profits by Π_1. From (4) we have that

$$\Pi_1 = \begin{cases} \theta_2 - \theta_1 & \text{if } \theta_2 > \theta_1, \\ \\ 0 & \text{otherwise.} \end{cases}$$

The expression for E[Π] then follows from Lemma 1 with $\theta_2 - \theta_1$ in the place of X, so that $\mu = 0$ and $\tau = \sqrt{2}\sigma$. ∎

Proof of Proposition 2

It follows fron (8) and (11) that

$$\Pi_1 = \begin{cases} \theta_2 - \theta_1 + C(W-\theta_2) & \text{if } \theta_2 > \theta_1 + C(W-\theta_2), \\ \\ 0 & \text{otherwise.} \end{cases}$$

The expression for expected profits then follow from Lemma 1, with $\theta_2 - \theta_1 + C(W-\theta_2)$ in the role of X, that is, with $\mu = C(W-\bar{\theta})$ and $\tau^2 = [1+(1-C)^2]\sigma^2$. ∎