Elections and Productivity in Procurement Auctions of Pavement Contracts in Mexico

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Abstract

When allocating contracts, governments decide between exercising hiring discretion or allowing a higher level of competition without firm selection. Ex-ante, it is not clear which allocation mechanism will lead to better outcomes. The trade-off depends in part on the government's ability to select the best firms when restricting competition and on the probability that this practice will lead to corruption. In this paper, I study the allocation of street pavement contracts in Mexico and combine auction methods with an analysis of the firms' productivity to test whether local governments select the most cost-efficient firms when restricting competition. Furthermore, I study the firms' behavior under different auction formats. I find that firms selected to settings with less competition are more experienced and have lower costs in complex pavement projects, but have higher costs in simple ones. When comparing auction formats, firms are more aggressive under auctions by invitation than in public auctions in complex projects, but bid similarly under both auction formats in simple projects. Contrary to the current practice, the results suggest that the government would benefit from opening up simple projects to public auctions. The use of auctions by invitation for complex projects seems warranted, but mixed results on the influence of political factors raise concerns of misuse of a greater hiring discretion on the part of the government.

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1 Introduction

When governments allocate a contract, they choose between allowing a large set of firms to compete for it, or to exercise a greater hiring discretion to select the winning firm. Ex-ante, it is not clear which option leads to better outcomes. Allocation mechanisms that hamper competition may result in overpriced projects or corruption, and yet, as suggested by Spagnolo (2012), a greater discretion to select the winning firms could lead to improvements in non-pecuniary characteristics of a project. The trade-off between these two allocation formats depends in part on the government's ability to select the best firms when avoiding competition. Nevertheless, for developing countries specially, we know little about both which firms are selected by the government when it exercises a greater hiring discretion, and about how the different contract allocation mechanisms compare profit-wise. In a developing context, Mexico provides a right setting to study the government's ability to select the most cost-efficient firms when choosing allocation mechanisms with less competition, and to compare different auction formats with varying degrees of hiring discretion on the part of the government.

In Mexico, by law, the government should allocate public infrastructure projects through public procurement auctions (public auctions), but exceptions to the law allow the government to bypass this procedure and to either choose a firm of its preference (direct allocation) or conduct an auction by invitation to three or more firms (I3P). I leverage the variability in the different allocation mechanisms used for similar projects, to study both the government's firm selection when restricting competition, and to study how firms behave under different auction formats.

In this paper, I focus on the allocation of street pavement contracts with hydraulic concrete from 2011 to 2018. I first test whether the local governments chooses the most cost-efficient firms when bypassing a public procurement auction, and compare which auction format is profit-maximizing from the point of view of the government. Second, given the importance of corruption in the trade-off between greater hiring discretion and more competition, I study whether the choice of allocation mechanisms and the number of contracts follow an electoral cycle.

I find that firms selected to settings with less competition are more experienced and have lower costs for complex pavement contracts (projects with sewage work). Nevertheless, for smaller and simpler projects, they have higher costs than firms that only participate in public auctions. A possible explanation is that the experienced firms are more competitive in complex projects due to economies of scope, where they leverage cost complementarites of the different services they provide (sewage and pavement work). Alternatively, smaller and less experienced firms, consistent with product differentiation, may specialize in simpler projects where larger firms do not have a cost advantage when providing a single service. Regarding the comparison between auction mechanisms, firms bid lower under auctions by invitation than in public auctions in more complex projects. Nevertheless, when the project is small and simple, firms bid similarly under both auction formats. A potential explanation is that firms invited to an auction for a complex contract, know they are facing other experienced firms, which leads them to bid more aggressively than in a setting with no selection on their competitors, as in public auctions. Overall, these results suggest that, for relatively small and simple projects, local governments would gain from increasing the use of public auctions. These results are specially important, since 76 percent of pavement contracts allocated through auctions by invitation are small and simple[1]. On the other hand, for complex projects, the use of auctions by invitation seems warranted, provided the number of invited firms does not differ greatly of the number of participating firms in public auctions, and provided proper monitoring to avoid corruption.

When studying the influence of political factors on contract allocations, I find mixed results on the contracts' electoral cycle. On the one hand, local governments prefer allocation mechanism with greater hiring discretion during the year before municipal elections, where I document a 6 percent increase on the probability that the government will avoid public auctions. Nevertheless, I do not find evidence of an electoral cycle on the number of contracts allocated. As for the influence of political factors on the firms' efficiency, during the year before elections, the firms' average cost-inefficiency increases by 9.4 to 13.8 percent when participating in public auctions (compared to other public auction contracts in non-electoral times)[2]. For firms participating in auctions by invitation, this increase in the average inefficiency during the year before elections is of 12.5 percent. Finally, when the political party of the municipality's mayor and state's governor are aligned, the firm's average cost-efficiency increases by 9.8 to 16.6 percent in public auctions, and by 12.9 percent in auctions by invitation. These increases in efficiency may be due to a better coordination between local and state governments, when the parties are aligned.

The above results come from the estimation of the firms' cost efficiency, paired with information on the timing of contracts and elections. To approximate the firm's efficiency, I follow a two-step procedure. First, I use the fact that most firms receiving contracts by direct allocation or auctions by invitation, also participate in public procurement auctions. Therefore, I use a structural procurement auction model to analyze the public auction data and recover the firm's cost distribution. I model a first-price sealed bid auction under the independent value framework (IPV), where I control for asymmetric bidders. The source of asymmetry between firms depends on whether a firm has received a project by direct allocation or I3P, or if it has only participated in public auc-

[1]Projects allocated through auctions by invitation are on average half the size of projects allocated though public auctions, and 76 percent of them do not include sewage work, compared to 62 percent in public auctions.

[2]Where cost-inefficiency is defined as the proportion by which the firm overuses all inputs, given a fixed level of output and input prices.

tions[3]. On a second step, I augment the estimation of the pseudo costs with input data for street paving. Such data allow the use of stochastic frontier analysis (SFA) to estimate a cost function and an inefficiency term at the level of the firm, measured as the distance of the firm's efficiency to the estimated cost frontier. To the best of my knowledge, this is the first paper that combines a structural auction model with SFA, where the firms' costs estimated from the auction model are used in the SFA. The potential of synergies between these two literatures is large. The auction methods allow the estimation of the often hard to get or estimate firms' costs, a key variable in SFA. Whereas SFA can complement auction methods by providing more structure in analyzing efficiency differences between firms.

To test whether the government selects the most efficient firms, I compare the estimates of the cost distributions and of the efficiency index at the level of the firm, of both the selected firms and those that only participate in public auctions. In developing countries, this indirect approach to compare the firms' efficiency is useful, as it allows us to circumvent the lack of publicly available information on the firms' reputation and competitiveness. To gather the auction bids and project characteristics, I construct a novel data set from the transcription and homogenization of close to 3000 public pavement contracts. To compare the auction mechanisms, I re-estimate the above using the auctions by invitation, where I use a symmetric first-price procurement auction, again conduct an SFA, and compare the results with the public auction estimates. Finally, to study the influence of political factors on the firms' efficiency and the contracts' allocation electoral cycle, I use the firms' efficiency profiles, along with the timing of the pavement contracts and electoral data.

The rest of the paper proceeds as follows. I first discuss the related literature in the remainder of the introduction. Section 2 discusses the allocation procedure of street pavement contracts, along with a description of the bid data. Section 3 describes the procurement auction model and the SFA, followed by a discussion of the results in Section 4. Section 5 provides an analysis of the contracts' allocation electoral cycle, and section 6 concludes.

[3]To recognize this source of asymmetry between firms is important. For example, if a firm's ability to win contracts is determined not by its cost-efficiency but by its ability to participate in settings with less competition, inefficient firms that would not have survived otherwise, may prevail in this market. On the other hand, if reputation matters, an efficient firm with a proven record may be more likely to receive a project by direct allocation or to participate in auctions by invitation. In time, the experience gap would widen and generate efficiency differences between the selected firms and firms that only participate in public auctions.

Related Literature

The present paper is related to several strands of literature. First, it is related to auction models with asymmetric bidders[4]. A difficulty in estimating these types of models is the lack of closed-form solutions, and hence, early papers rely on numerical methods as proposed by Bajari (2001). Nevertheless, recent developments in non-parametric identification have made more accessible the estimation of these models[5]. The majority of applications of asymmetric auctions rise from the extension of Guerre, Perrigne, and Vuong (2000) to various settings. For example, Flambard and Perrigne (2006) propose a nonparametric procedure in the framework of independent private value (IPV) with a binding reserve price, whereas Marion (2007) estimates a model under a preference policy that favors smaller firms. Other extensions include the consideration of unobserved heterogeneity by Krasnokutskaya (2011) and Hu, McAdams, and Shum (2013), endogenous entry by Krasnokutskaya and Seim (2011), unobserved bidder's identity by Lamy (2012) and sequential auctions by Jofre-Bonet and Pesendorfer (2003). Under the framework of affiliated private value (APV), Campo, Perrigne, and Vuong (2003) and Zhang and Guler (2005) also provide nonparametric estimators. This paper contributes to this literature in two ways. First, by considering a new source of asymmetry between firms: the difference in experience and resources due to the government's selection of certain firms to settings with less competition. Second, by combining auction methods with a stochastic frontier analysis to further study cost efficiency differences among firms.

A second related literature compares project allocation mechanisms. The comparison of public auctions to other mechanisms has grown since early work by Bulow and Klemperer (1996, 2009), which stresses the benefits of competition in a simultaneous auction, relative to any other mechanisms with less competition. Nevertheless, recent research has shown that an auction might not be the preferred allocation procedure for every setting. For example, Roberts and Sweeting (2013) show that when comparing a simultaneous auction with a sequential negotiation, if the entry to the negotiation is costly and selective, buyers with higher values are more likely to participate in the negotiation. Thus, the revenue performance between the two mechanisms depends on whether the threat of potential future competition in a negotiation is more valuable to the seller than the actual competition of an auction. Other authors, as Bajari and Tadelis (2001), Bajari, McMillan, and Tadelis (2009), Baldi, Bottasso, Conti, and Piccardo (2016), and Herweg and Schmidt (2017) note that a negotiation procedure might be preferred over an auction if the good is complex, or as in Bajari, Houghton, and Tadelis (2014), if the contractual design is incomplete. The key insight of this literature is that negotiations might be preferred when there are gains from the early ex-

[4]See Maskin and Riley (2000a, 2000b) for theoretical results.

[5]See Hickman, Hubbard, and Sağlam (2012) and Perrigne and Vuong (2019) for surveys on the econometrics of first-price bid auction models.

change of information when allocating a contract, so that the probability of ex-post adaptations is minimized. Relatedly, when negotiations are not possible, Spagnolo (2012) argues that it might be optimal to allow more discretion to the seller to select who can participate in an auction. Although the probability of corruption increases and competition is hampered, the firm's selection may improve non-contractable aspects of the work, such as quality. In this case, the reputation of the firms can be a good discriminatory variable, as shown by Banerjee and Duflo (2000). This paper contributes to this literature by providing an empirical test on whether the government selects the most cost-effective firms when opting for mechanisms with more discretion in the selection of the competing firms. Additionally, it compares the firms' behavior under auctions by invitation and public auctions.

The third strand of literature this paper is related, is the stochastic frontier analysis literature (SFA), which uses econometric models to estimate the cost frontier. A measurement of the firms' relative efficiency is, then, the extent to which the firms fail to reach the frontier. The study of SFA has a long history. For recent surveys see Greene (2008), Behr (2015), Kumbhakar, Wang, and Horncastle (2015) and Sickles and Zelenyuk (2019). As noted above, a contribution of this paper is the combination of auction methods and SFA. The recent developments in structural econometric methods for the study of auctions in the last two decades, allows the estimation of the firms' cost distribution. The use of the estimated or pseudo cost can be greatly beneficial to SFA, since we often do not observe the firms' production costs, a key variable in SFA.

Finally, this paper relates to the literature on distributive politics. See Golden and Min (2013) for an exhaustive survey. As this literature stresses, politicians are motivated to remain in public office, hence, they may allocate public funds while considering how this allocation may affect their probability to remain in office. In Mexico, Costa-I-Font, Rodriguez-Oreggia, and Lunapla (2003), Livert, Gainza, and Acuña (2019) and others, show that the government incurs in pork-barrel politics, which consists of strategically allocating funds in specific regions to prevent the loss of support for a political party[6]. Kerevel (2015) finds that this practice is present even when the officers face no reelection, or when a formula governing the distribution of resources should prevent the deviation of funds, as shown by Timmons and Broid (2013)[7]. Furthermore, Abbott, Cabral, and Jones (2017) and Corvalan, Cox, and Osorio (2018) show that a strategic fund's allocation seems to be more frequent in times of elections, especially when the electoral race is tight. For the specific case of political bias in road construction in Mexico, Selod and Soumahoro (2019) find a partisan allocation of federally-funded highways to municipalities that voted for the president's party in

[6] Other tactics include constraining the resources of unaligned mayors, as shown by Brollo and Nannicini (2012) for the case of Brazil.

[7] Of the three major political parties until 2018, PRI, PAN and PRD, the PRI seems to be the party with the highest level of systematic deviation of funds.

legislative races. This paper contributes to this literature by studying the electoral allocation cycle of both the number of allocated contracts and choice of allocation mechanism, and second, by studying the cost profile of the firms that receive contracts closer to an election.

2 Public Construction Contracts in Mexico

In this section I describe the data on public construction contracts for street pavement with hydraulic concrete. I first explain the allocation procedure to allocate a pavement contract, followed by a description of the bid data for the period of 2011 to 2018.

2.1 Context on the Procurement Auction Procedure

To control for the efficient use of public funds, by law, the government should use a public procurement auction when allocating infrastructure contracts. Nevertheless, when the construction project is relatively small, the law provides exceptions that enable the government to bypass the public auction by either assigning a project directly to a preferred firm or by inviting three or more firms to an auction. I denote this last procedure as I3P. The exceptions that allow the government to bypass a public procurement auction are detailed in the Law of Public Works and Related Services (LPWRS). Some exceptions are vague and broad, and allow for an undue degree of discretion in assigning public works contracts.

The procurement auction takes place through an online system called CompraNet, which is the government's electronic public information system on acquisitions and leases as well as for the allocation of public works and related services. This system is overseen by the Secretariat of the Public Function, through the Public Procurement Policy Unit (UPCP). Through CompraNet, the procedures and data from previous contracts are publicly available. Moreover, CompraNet is not only an entity that centralizes the information of governmental contracts, but it is also the system through which the government conducts all its auctions and procurements.

According to the "Law of Public Works and Related Services", the government should chose the allocation procedure that minimizes construction costs. It suggest that the government should opt first for a public auction and then pursue an auction by invitation or a direct allocation. The exceptions that allow the government to bypass a public auction can be found in the third chapter of the law, article 41. Pertaining public construction projects, the most important exceptions are the following.

- There are circumstances that could cause significant losses or additional costs, duly justified.

- Due to major forces, it is not possible to execute the work by means of the public tender procedure in the time required to attend to the eventuality in question.
- The respective contract has been rescinded for reasons imputable to the contractor. In this case, the second best offer wins the contract.
- If no one went to the public auction.
- If the service required is of maintenance, restoration, reparation, or demolition.
- If it requires rural labor, or if the project is in a marginalized urban area.

Under the legal umbrella of these exceptions, state and federal governments can choose contractors without a public procurement auction. The first two exceptions are of special concern because of their vague terms. In the current study, I am assuming that the choice of a direct contract procedure or I3P is mainly due to the first two exceptions. Hence, I am avoiding all contracts of maintenance, restoration, reparation, or demolition, and I have found little evidence of the third and fourth exceptions, which are directly observable from the data. If none of these exceptions is used, the procedure of the procurement auction is a first-price sealed bid auction.

2.2 Bid Data: Public Procurement Auctions

From 2011 to 2018, I observe 609 street pavement public procurement auctions. The government does not disclose the project characteristics in 205 of them, so I am left with a sample of 404 procurement auctions with 2,784 observed bids. Table 1 provides the summary statistics of the bids. The average bid per cubic meter is 9.01 thousand Mexican pesos per cubic meter of concrete at 2018 prices, and the standard deviation is large, around 7.57. Surprisingly, the average winning bid is close but above the average price. Part of this difference is explained by the fact that many low bids are rejected because they were not presented with the required format or the contract had missing information ($\sim 23\%$). But even when accounting for these factors, a small gap remains.

The average number of bidders in a public auction is close to 7. In each public auction, approximately 2 bidders received at some point a pavement contract by direct allocation or have been invited to participate in an auction of three or more firms (I3P). Likewise, on average, there are close to 5 bidders per auction that have only participated in public auctions. As for the project characteristics, the average contract used 730.8 cubic meters of concrete and lasted around 3.44 months[8]. As observed by the standard deviation of both of these variables, although I am considering only contracts for small streets (as opposed to avenues and highways), I still observe a

[8]The average project paves 8 to 9 blocks of 50 meters of longitude each.

large variability in the size of the streets paved. The observed project heterogeneity, as well as the competition between firms, might be driving forces behind the bid heterogeneity.

Table 1: Summary statistics, first-price sealed bid auctions

	Mean	Median	S.D.	Min	Max	Obs
Bids/m^3 concrete (thousands per m^3)	9.01	7.13	7.57	0.87	92.6	2784
Winning bid/m^3 concrete	9.40	7.45	7.49	1.31	62.1	404
Number of bidders: total	6.89	5	6.22	1	35	404
Num. bidders: at some point Direct/I3P	2.03	2	2.15	0	15	404
Num. bidders: only Public Auction	4.86	3	5.24	0	35	404
M^3 concrete	730.8	588.4	574.9	23.5	4072.9	404
Dummy = 1 if proj. includes sewage work	0.38	0	0.49	0	1	404
Duration of project (months)	3.44	3	3.91	0	49	404
Dummy = 1 if municipal project	0.84	1	0.36	0	1	404

Note: public auction data.

I next study the evidence of asymmetry between firms that have been approached by the government to participate in a format with less competition (i.e., have received a project direct allocation or been invited to an auction), compared to firms that only participated in public auctions. I first observe that for public auctions with the same proportion of these two types of firms, the firms that have been approached by the government won 56 percent of the time, although this is not significantly different from 50 percent. When looking at the experience of these two types of firms, we see important contrasts. For example, again for the auctions with the same proportion of the types of bidders, the firms approached by the government represented 70 percent of the firms with an overlapping project. Furthermore, during the studied period, they had competed in 4.5 different public auctions on average, compared to only 3.39 for the firms that were never approached by the government. The experience gap is wider when also accounting for the contracts under all the allocation mechanism. In the full data set, we observe that the firms approached by the government competed for 6.63 contracts, while firms that only participated in public auctions participated in only 3.35 contracts on average. These differences in experience are reflected also in gaps in the proportion of firms that have been rejected due to procedural issues.

To further explore the asymmetry between bidders, I perform a Chow-test of equality of coefficients, which consists of regressing the logarithm of the bids on a set of project characteristics[9],

[9] I control for the bidder's experience, the number of firms per auction, duration of the project, a dummy variable if it is a municipality project and a set of year dummies.

and comparing whether the causal relationship varies by the type of the firm. Hence, of the 2,784 bids, I run separate regressions for the 1,962 bids submitted by the firms approached by the government, and for the 822 bids submitted by the firms that only participated in public auctions. The Chow-test strongly rejects the equality of parameters of these two regressions. Finally, I compare the conditional bid densities for both types of firms controlling for the total volume of concrete. I perform a Kolgomorov-Smirnov test when evaluating the conditional densities at the 25th, 50th and 75th percentile of the amount of concrete, and I reject the null that the bids of each type of firm are drawn from the same distribution when the densities are evaluated at the 25th and 75th percentile, although I fail to reject when evaluating the densities at the 50th percentile of the total amount of concrete. For a display of the conditional cdfs, see Figure 5 in the Appendix.

Finally, I analyze the bid variability, and further study the determinants of the government's choice of allocation procedure, by looking at the correlation between firm and project characteristics with the level of the bids, and the choice of allocation mechanism. To assess the variability of the bids, I present a reduced-form analysis where I regress the log of the bids on a set of firm and project characteristics. The results are found in Table 2.

The only difference between the first and second column is that the latter includes both municipal and year fixed effects, whereas column one only includes year fixed effects. Although not shown, the project characteristics included in the regression are a dummy variable if the specification of the project is highly detailed, the number of signs, trees, posts, and amount of paint, whether the project includes sewage work, and whether it includes work on the potable water system. Here I focus on the specification with municipality fixed effects. When comparing the bids, firms approached by the government to participate in formats with less competition bid on average 3.3 percent higher than firms that only participate in public auctions. The number of bidders, as expected, has a negative effect on the bids, which favors the independent value framework (IPV). This result is consistent with Hong and Shum (2002) who also studied road construction auctions, and found that the common value framework is more fitting for larger projects, whereas the IPV framework seems to be appropriate for smaller ones, like the projects studied here. The firm's experience, measured by the number of projects for which the firm competed from 2011 to 2018, does not seem to have an effect on the level of the bid once we include the municipality fixed effects. Bids are higher for projects that take longer to complete, and although the difference is marginal, it may show that projects that take longer are more complex. Finally, whether the project is contracted by the municipality (compared to being contracted by the state), seems to have no statistical effect on the level of the bids.

Table 2: OLS: dependent variable = log(bids/m^3)

	(1)		(2)	
	Coef.	S.E.	Coef.	S.E.
Dummy = 1 if any Direct or I3P[1]	0.0856***	(0.0211)	0.0331*	(0.0179)
Firm's experience[2]	-0.0104***	(0.0021)	-0.00307	(0.00199)
Number of bidders	-0.0111***	(0.0013)	-0.00374**	(0.00152)
Duration of project (months)	0.0115**	(0.0050)	0.00725*	(0.00422)
Dummy = 1 if municipal project	-0.106***	(0.0303)	-0.0522	(0.0431)
Observations	2,784		2,784	
L	404		404	
R-squared	0.336		0.554	
Municipality FE	No		Yes	
Year FE	Yes		Yes	
Proj characteristics	Yes		Yes	

Standard deviations in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Data: public auctions. Other project characteristics included are: a dummy variable if the specification of the project is highly detailed, the number of signs, trees, posts, and amount of paint, whether the project includes work on the sewage potable water systems.

[1]I3P = auctions by invitation to three or more firms.

[2]The firm's experience denotes the number of auctions it participated in.

Political influence on the mechanism choice

To study the choice of mechanism, I investigate the correlation between the choice of allocation procedure with political factors, as well as with firm and project characteristics. Hence, I run a probit comparing the allocation procedures, where the dependent variable is equal to one if the allocation format is by direct allocation or auction by invitation, and zero if it is by public auction.

First, when looking at the project characteristics, the bigger the project, the more likely it will be allocated by public auction. For example, an increase of one standard deviation in the cubic meter of concrete would lead to a decrease in 11.4 percent in the probability that the mechanism chosen will be by directly allocation or auction by invitation. Likewise, if the project includes sewage work, there is a 9.8 higher probability that it will be allocated through a public auction. In other words, smaller and simple projects are allocated through mechanisms with less competition (Direct or I3P).

Table 3: Probit: dependent variable, dummy = 1 if Direct or Auction by Invitation (I3P)

	Marginal Effects	S.E.
M^3 concrete (hundreds)	-0.0002***	(2.43e-05)
Dummy = 1: includes sewage work	-0.093***	(0.023)
Duration of project (months)	-0.002	(0.002)
Dummy = 1: if one year before elections	0.062***	(0.022)
Dummy = 1: political party PAN[1]	-0.189***	(0.036)
Dummy = 1: political party PRD[1]	-0.033	(0.038)
Dummy = 1: other small political parties[1]	-0.012	(0.027)
Dummy = 1: Mun. and Gov. from the same party	-0.005	(0.027)
Total number of contracts in municipality	-1.54e-06	(6.07e-05)
Fund FISE (millions)[2]	3.76e-04***	(4.85e-05)
Dummy = 1: if municipality project	-0.068***	(0.024)
Pseudo R2	0.218	
Observations	1,707	
Proj. characteristics	Yes	

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Data: contract winners. The sample uses all allocation procedures. Other project characteristics included are: the number of signs, trees and posts to be installed, the surface to be painted, and whether the project included sewage work. Additionally, I control for: the bidder's experience, whether the bidder has an overlapping project, the amount of precipitation in the municipality, and a construction price index.

[1]During the sample period, the main political parties were the PRI, PAN, and PRD. The incumbent party PRI is left out.

[2]FISE is a state fund for social construction purposes.

When looking at political factors, the government chooses allocation mechanisms with a greater hiring discretion during the year before elections, where the probability of avoiding a public auction increases by 6.2 percent. This result is consistent with Abbott, Cabral, and Jones (2017), who study the strategic allocation of funds in times of elections. Two possible causes are corruption, where the government favors certain firms in exchange of support, and second, the need to speed the allocation of contracts during electoral times. Nevertheless, I cannot empirically test for these. I then look at how the choice of allocation procedure differs by political party. From 2011 to 2018, the main political parties were the PRI (the incumbent center-left party), PAN (the center-right main opposition party), and PRD (the left-leaning opposition party). Compared to the incumbent PRI, the PAN is 18.9 percent less likely to use direct allocations or auction by invitation, and the

PRD and other minor parties are equally likely as the PRI to use these procedures.

Finally, I look at the characteristics of the state or municipality that may influence the choice of mechanism. I consider three variables: the total number of contracts in a municipality, a state fund for social construction purposes denominated FISE, and finally whether the project was given by a municipality. We would expect a high volume of contracts would induce the government to prefer faster allocation mechanisms, avoiding public auctions, but the volume of contracts does not seem to influence the choice of procedure.

The reduced-form analysis of the bids is insightful and informative. Nevertheless, it does not allow us to assess the differences in the cost distributions between firms that are selected by the government to participate in settings with less competition, and firms that only participate in public auctions. Furthermore, we cannot conclude which mechanism is optimal from the point of view of the government. The structural approach that follows addresses these questions.

3 Structural Analysis of Procurement Auctions

3.1 Procurement Auction Model with Asymmetric Bidders

The format used by the government is a first-price sealed-bid procurement auction with a random reserve price, which means that the reserve price is not announced ex-ante. For the projects studied here, it is also not reported ex-post[10]. Nevertheless, at least from the contract information, I can still asses how binding is the reserve price because the bidder is informed if the bid was above it. In the full data set, I find the the reserve price is binding only in two percent of the data, so I model the auction without it[11].

Given the evidence of the negative effect of competition on bids, and Hong and Shum (2002)'s results, I model the auction under an IPV framework with asymmetric bidders. The model is hence based on Flambard and Perrigne (2006) (FP), but without a reserve price. Let n be the number of risk neutral bidders. Each bidder i can be of type 1 (bidders that, at some point, have either received a project by direct allocation or have been invited to participate in an auction) or type 0 (bidders that have only participated in a public auction), such that $n_0 + n_1 = n$. Let c_{ji}, for $i = 1, ..., n_j$ denote the cost of bidder of type $j \in \{0, 1\}$. The costs c_{1i} and c_{0i} are drawn from $F_1(\cdot)$ and $F_0(\cdot)$ respectively, defined on $[\underline{c}, \bar{c}]$. Let $f_0(\cdot)$ and $f_1(\cdot)$ be the continuous and differentiable

[10]Based on information from the project contracts, the government only reports the reserve price ex-post for three percent of the sample.

[11]For a model specification with random reserve price see Elyakime, Laffont, Loisel, and Vuong (1994, 1997) and Li and Perrigne (2003). An application for asymmetric bidders with a random reserve price follows directly by combining the models of Li and Perrigne (2003) and Flambard and Perrigne (2006).

cost densities with $f_1(\cdot) > 0$ and $f_0(\cdot) > 0$. Finally, the information set of bidder i of type j is $[c_{ij}, F_0(\cdot), F_1(\cdot), n_0, n_1]$.

At a Bayesian Nash Equilibrium, each bidder i of type 1 chooses his bid b_{1i} to maximize his expected profit $E[(b_{1i} - c_{1i})\mathbb{1}(b_{1i} \leq B_{1i})]$, where $B_{1i} = min[s_0(C_0), s_1(C_{1i})]$, $C_0 = min_i c_{0i}$ and $C_{1i} = min_{j \neq i} c_{1i}$, and $s_0(\cdot)$ and $s_1(\cdot)$ are the strictly increasing equilibrium strategies for types 0 and 1, respectively. Then, bidder i of type 1 chooses his bid b_{1i} that maximizes his expected profit:

$$(b_{1i} - c_{i1})\Pr[s_1^{-1}(s(b_{1i}) \leq C_{1i}) \text{ and } s_0^{-1}(s(b_{1i}) \leq C_0)],$$

or equivalently, it maximizes:

$$(b_{1i} - c_{i1})\{1 - F_1[s_1^{-1}(b_{1i})]\}^{n_1 - 1}\{1 - F_0[s_0^{-1}(b_{1i})]\}^{n_0}.$$

The bid b_{0i} is defined similarly for an individual i of type 0.

Following Guerre, Perrigne, and Vuong (2000) (GPV), differentiating the expected profit for firms of type 1 and type 0 with respect to b_{1i} and b_{0i} respectively, we are left with the following system of equations. For $i = 1, ..., n_1$, we have:

$$(b_{1i} - c_{1i})\left\{(n_1 - 1)\frac{f_1[s_1^{-1}(b_{1i})]}{1 - F_1[s_1^{-1}(b_1 i)} \frac{1}{s_i'[s_1^{-1}(b_{1i})]} + n_0 \frac{f_0[s_0^{-1}(b_{1i})]}{1 - F_0[s_0^{-1}(b_1 i)} \frac{1}{s_0'[s_0^{-1}(b_{1i})]}\right\} = 1. \quad (1)$$

Similarly, for $i = 1, ..., n_0$ we have:

$$(b_{0i} - c_{0i})\left\{(n_1)\frac{f_1[s_1^{-1}(b_{0i})]}{1 - F_1[s_1^{-1}(b_0 i)} \frac{1}{s_i'[s_1^{-1}(b_{0i})]} + (n_0 - 1) \frac{f_0[s_0^{-1}(b_{0i})]}{1 - F_0[s_0^{-1}(b_0 i)} \frac{1}{s_0'[s_0^{-1}(b_{0i})]}\right\} = 1. \quad (2)$$

The above system of equations does not have a closed form solution, but the results in Flambard and Perrigne (2006) allow to solve this problem extending the indirect approach of GPV for asymmetric bidders. The indirect approach starts from the differential equations (1) and (2), and uses the fact that although the costs are not observed, the bids are, and the equilibrium strategies relate the former to the latter. Flambard and Perrigne (2006) use the monotonicity of the strategy functions to relate the cost and bid distributions, noting that $G_j(\cdot) = F_j[s^{-1}(\cdot)]$, for $j = 0, 1$. In other words, the indirect approach uses the observed bid distribution to estimate the cost distribution, with the advantage that it avoids making parametric assumptions about $F_j(\cdot)$ or computing the equilibrium strategies $s_j(\cdot)$.

Identification and Estimation

As is standard in structural estimation, I assume that observed bids are the equilibrium outcomes. Given the above results, the model is given by $b_{1i} = s_1(c_{1i}, F_1, F_0, n_1, n_0)$, $i = 1, ..., n_1$ and $b_{0i} = s_0(c_{0i}, F_1, F_0, n_1, n_0)$, $i = 1, ..., n_0$.

The primitives of the model are $n_1, n_0, F_1(\cdot)$, and $F_0(\cdot)$, and the observables are n_0, n_1 and the bid distributions $G_0(\cdot|n_1, n_0)$, and $G_1(\cdot|n_1, n_0)$. Because of the one-to-one mapping at the equilibrium, then, the authors use the equalities $G_1(b_{1i}) = F_1(s_1^{-1}(b_{1i}))$,$G_0(b_{0i}) = F_0(s_0^{-1}(b_{0i}))$, $g_1(b_{1i}) = f_1(s_1^{-1}(b_{1i}))/\{s_1'(s_1^{-1}(b_{1i}))\}$, and $g_0(b_{0i}) = f_0(s_0^{-1}(b_{0i}))/\{s_0'(s_0^{-1}(b_{0i}))\}$ to rewrite the system of differential equations (1) and (2) as:

$$\begin{aligned} c_{1i} &= b_{1i} - \frac{1}{(n_1-1)\frac{g_1(b_{1i}|n_1,n_0)}{1-G_1(b_{1i}|n_1,n_0)} + (n_0)\frac{g_0(b_{1i}|n_1,n_0)}{1-G_0(b_{1i}|n_1,n_0)}}, \\ &\equiv \xi_1[b_{1i}, G_0(\cdot|n_1,n_0), G_1(\cdot|n_1,n_0), n_1, n_0], \end{aligned} \tag{3}$$

$$\begin{aligned} c_{0i} &= b_{0i} - \frac{1}{(n_1)\frac{g_1(b_{0i}|n_1,n_0)}{1-G_1(b_{0i}|n_1,n_0)} + (n_0-1)\frac{g_0(b_{0i}|n_1,n_0)}{1-G_0(b_{0i}|n_1,n_0)}}, \\ &\equiv \xi_0[b_{0i}, G_0(\cdot|n_1,n_0), G_1(\cdot|n_1,n_0), n_1, n_0]. \end{aligned} \tag{4}$$

Given that we observe $g_j(\cdot)$ and $G_j(\cdot)$ for $j \in \{0,1\}$, we identify the costs of each firm. A practical advantage of the identification above is that it also gives us the estimation method. For estimation, consider L auctions indexed by $\ell = 1, ..., L$. Let $\mathbf{z}_\ell$ be a vector of covariates that characterize the auctioned object ℓ, that it is observed by the econometrician. We observe $\{b_{1p\ell}, p = 1, ..., n_{1\ell}, b_{0q\ell}, q = 1, ..., n_{0\ell}, \mathbf{z}_\ell, \ell = 1, ..., L\}$. The model is conditional on $\mathbf{z}_\ell$ and the number of bidders $n_{1\ell}$ and $n_{0\ell}$. Equations (3) and (4) suggest that the first step is to estimate the ratios $g_j(\cdot)/(1 - G_j(\cdot))$ for $j = 0, 1$. I use then kernel estimators for the cumulative distribution and density functions, given by:

$$\hat{G}_1(b|\mathbf{z}, n_1, n_0) = \frac{\sum_{\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L} \frac{1}{n_1}\sum_{p=1}^{n_1} \mathbb{1}(b_{1pl} \le b) K_G\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zG}}\right)}{\sum_{l=\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L} K_z\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zG}}\right)},$$
$$\hat{G}_0(b|\mathbf{z}, n_1, n_0) = \frac{\sum_{\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L} \frac{1}{n_0}\sum_{p=1}^{n_0} \mathbb{1}(b_{0pl} \le b) K_G\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{0G}}\right)}{\sum_{l=\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L} K_z\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zG}}\right)},$$

$$\hat{g}_1(b|\mathbf{z}, n_1, n_0) = \frac{\frac{1}{h_{1g}}\sum_{l=1}^{L} \frac{1}{n_1}\sum_{p=1}^{n_1} K_g\left(\frac{b-b_{1pl}}{h_{1g}}, \frac{\mathbf{z}-\mathbf{z}_l}{h_{zg}}\right)}{\sum_{l=\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L} K_z\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zg}}\right)},$$
$$\hat{g}_0(b|\mathbf{z}, n_1, n_0) = \frac{\frac{1}{h_{0g}}\sum_{l=1}^{L} \frac{1}{n_0}\sum_{p=1}^{n_0} K_g\left(\frac{b-b_{0pl}}{h_{0g}}, \frac{\mathbf{z}-\mathbf{z}_l}{h_{0g}}\right)}{\sum_{l=\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L} K_z\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zg}}\right)},$$

where $K_G(\cdot)$ and $K_g(\cdot)$ represent kernel estimators, and h_{zG}, h_{zg}, h_{1g}, and h_{0g} some bandwidths, following the bandwidth selection procedure in FP. Then, in a second step, I use the equilibrium bids, the estimated conditional bid distributions $\hat{G}_1(\cdot|\mathbf{z}_\ell, n_1, n_0)$,$\hat{G}_0(\cdot|\mathbf{z}_\ell, n_1, n_0)$, along with their respective density functions, to estimate the pseudo costs by,

$$\hat{c}_{1p\ell} = b_{1p\ell} - \frac{1}{(n_1 - 1)\frac{\hat{g}_1(b_{1p\ell}|\mathbf{z}_\ell,n_1,n_0)}{1-\hat{G}_1(b_{1p\ell}|\mathbf{z}_\ell,n_1,n_0)} + n_0\frac{\hat{g}_0(b_{1p\ell}|\mathbf{z}_\ell,n_1,n_0)}{1-\hat{G}_0(b_{1p\ell},n_1,n_0)}}, \tag{5}$$

$$\hat{c}_{0p\ell} = b_{0p\ell} - \frac{1}{(n_1)\frac{\hat{g}_1(b_{0p\ell}|\mathbf{z}_\ell,n_1,n_0)}{1-\hat{G}_1(b_{0p\ell}|\mathbf{z}_\ell,n_1,n_0)} + (n_0 - 1)\frac{\hat{g}_0(b_{0p\ell}|\mathbf{z}_\ell,n_1,n_0)}{1-\hat{G}_0(b_{0p\ell},n_1,n_0)}}. \tag{6}$$

A well known problem of kernel density estimators is that they do not behave well at the boundaries of their support. This problem can be dealt with some trimming[12]. Then, in a third step, using the estimates $\{\hat{c}_{1p\ell}, \hat{c}_{1q\ell}, p = 1, ..., n_{1\ell}, q = 1, ..., n_{0\ell}, \ell = 1, ..., L\}$ of the sample after the trimming, I estimate the conditional densities $f_1(\cdot|\mathbf{z}_\ell)$ and $f_0(\cdot|\mathbf{z}_\ell)$ by,

$$\hat{f}_1(c, \mathbf{z}, n_1, n_0) = \frac{\frac{1}{h_{1f}}\sum_{\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L}\frac{1}{n_1}\sum_{p=1}^{n_1}K_g\left(\frac{c-\hat{c}_{1pl}}{h_{1f}}, \frac{\mathbf{z}-\mathbf{z}_l}{h_{zf}}\right)}{\sum_{l=\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L}K_z\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zg}}\right)}, \tag{7}$$

$$\hat{f}_0(c, \mathbf{z}, n_1, n_0) = \frac{\frac{1}{h_{0f}}\sum_{\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L}\frac{1}{n_0}\sum_{p=1}^{n_0}K_g\left(\frac{c-\hat{c}_{0pl}}{h_{0f}}, \frac{\mathbf{z}-\mathbf{z}_l}{h_{zf}}\right)}{\sum_{l=\ell=1,n_{1\ell}=n_1,n_{0\ell}=n_0}^{L}K_z\left(\frac{\mathbf{z}-\mathbf{z}_l}{h_{zg}}\right)}, \tag{8}$$

where $K(\cdot,\cdot)$ denotes the product of kernels, and h_{1f}, h_{0f} and h_{zf} some optimal weights estimated using the sample after the trimming. The comparison of $\hat{\xi}_1(\cdot)$ and $\hat{\xi}_0(\cdot)$, and of $\hat{f}_1(\cdot|\cdot)$ and $\hat{f}_0(\cdot|\cdot)$, informs us about the presence of asymmetry and cost differences between the two types of firms.

Practical Issues in Estimation

Given the curse of dimensionality in nonparametric conditional density estimators, I reduce the dimension of $\mathbf{z}_\ell$ to two, the cubic meters of concrete, to proxy for the size of the project, and a dummy for whether the project includes sewage work, to proxy for the complexity of the project[13]. I use a triweight-Kernel for the the cubic meters of concrete, as well as for the costs when estimating the cost function. For the dummy variable, I use the Kernel proposed by Aitchison and Aitken (1976) to smooth a binary variable. Notice also that when considering asymmetric bidders, the data requirements are greater than in the symmetric case. Hence, instead of conditioning the density estimators on specific values of n_1 and n_0, I stratify the sample according to two categories of the number of bidders of each type, similar to Hendricks, Pinkse, and Porter (2003) and Luo,

[12] Other methods to deal with this problem is to use bias-corrected kernel estimators, as proposed by Hickman and Hubbard (2015).

[13] Haile, Hong, and Shum (2003) suggest an alternative way to deal with the multimensionality of $\mathbf{z}_\ell$. The authors suggest to estimate the auction model using the residuals of the regression of the level of bids on a set of project characteristics, and then to adjust the estimation of $\hat{c}$ accordingly. I followed this approach for a robustness analysis and the results do not change. The results are available upon request.

Perrigne, and Vuong (2016). Hence, I consider four sub-samples of auctions, the first with low levels of competition of both types of bidders, $n_1 \leq 3$ and $n_0 \leq 3$ (subject to $n_1 + n_0 \geq 2$), two sub-samples with mixed levels of competition, and finally, the case with high levels of competition for both types of bidders with more than three bidders of each type. Finally, a known problem of the bid's distribution is that it tends to be skewed. As in Marion (2007), I therefore use a logarithmic transformation of the data to minimize this effect. Equation (5) and (6) are re-written as:

$$\hat{c}_{1i} = \exp(a) - \frac{\exp(a)}{(n_1 - 1)\frac{\hat{g}_{1a}(a)}{1-\hat{G}_{1a}(a)} + (n_0)\frac{\hat{g}_{0a}(a)}{1-\hat{G}_{0a}(a)}} - 1, \tag{9}$$

$$\hat{c}_{0i} = \exp(a) - \frac{\exp(a)}{(n_1)\frac{\hat{g}_{1a}(a)}{1-\hat{G}_{a1}(a)} + (n_0 - 1)\frac{\hat{g}_{0a}(a)}{1-\hat{G}_{0a}(a)}} - 1, \tag{10}$$

where $a \equiv log(1 + b)$, $\hat{G}_{ja}(\cdot)$ and $\hat{g}_{ja}(\cdot)$ are the corresponding estimated cumulative distribution and density functions of $\log(1 + b)$ for $j = 0, 1$.

3.2 Cost Efficiency Analysis

The objective of this sub-section is to use a stochastic frontier analysis (SFA) to estimate the firms' inefficiency. The SFA is an econometric approach that estimates the cost frontier, and measures the firms' inefficiency as the distance between the firms' cost efficiency to the frontier. Provided that a firm is inside the cost frontier at an inefficient point, it can reach the frontier in at least two ways. First, by reducing the level of inputs conditional on a level of output. The extent to which the firm can reduce the level of inputs is known as the firm's technical inefficiency. And second, it can reach the frontier by increasing the level of output conditional on a level of inputs. The extent to which this can be done is known as the firm's allocation inefficiency. Because in street pavement contracts the level of output is exogenously set by the government, I focus on the firms' technical inefficiency.

Under the SFA framework[14], there is a key role for the idiosyncratic error when approximating the cost function[15]. The error has typically two components, one is the usual disturbance that represents latent factors like measurement error, misspecification of the model or inherent randomness of the production process. And second, a latent variable that represents the technical inefficiency. This additional component is restricted to have positive values, and it is specific to each firm i, which will be denoted by η_i.

[14] For recent reviews of the SFA literature see Greene (2008), Kumbhakar, Wang, and Horncastle (2015), and Sickles and Zelenyuk (2019).

[15] In contrast to other more deterministic measures of the frontier, as the Data Envelop Approach (DEA).

A key variable in SFA is the cost of production, which is hard to obtain or approximate. A contribution of this paper is the use of auction methods as a first step to estimate the firms' costs, and then expand the analysis using tools from SFA. Given the long history of the SFA's literature, and the recent development of econometric methods for estimating auction models, there are many potential gains from combining these two literatures. To the best of my knowledge, this is the first use of auction methods to estimate the costs used in SFA.

When estimating the cost function, I use both the approximated costs from the previous section, and additional data on input prices in the production process of street paving. Given a level of output and exogenous input prices, the problem of the firm is to choose the input quantity that minimize the cost of production, nevertheless, I allow for the firms to be technically inefficient when choosing the level of inputs. That is, conditional on a certain level of output, they may use more inputs then necessary. Let $(w, x) \in \mathbb{R}^K \times \mathbb{R}^K$ denote the vector of input prices and quantities respectively, where K represent the total number of inputs, and let $z \in \mathbb{R}^+$ denote the scalar output. Then, the problem of the firm under technical inefficiency is:

$$\begin{aligned} &\min_{x \in X} \; w'x \quad \text{st} \quad z = h(xe^{-\eta}), \\ &F.O.C \quad \frac{h_k(xe^{-\eta})}{h_1(xe^{-\eta})} = \frac{w_k}{w_1}, \text{ for } k = 2, ..., K, \end{aligned}$$

where $\eta \geq 0$ stands for the input-oriented technical inefficiency and $h(\cdot)$ for the production function. Here η represents the percentage by which all the inputs are overused to produce the output level z. Notice that z was used as the first element of the of the vector of controls $\mathbf{z}$ in the auction model. It represents the total amount of concrete in cubic meters that the firm needs to produce, which is the sum of the amount of concrete needed to pave the street, to construct the sidewalk, a small ramp and concrete block besides the sidewalk. For the inputs, I use the prices of one cubic meter of concrete, the average daily wage in the construction industry, and the per-day rent of machinery.

Using the $K-1$ equations from the first order conditions, we can solve for the demand of inputs in their effective units $x_k e^{-\eta}$, and define the frontier cost function as:

$$C^*(w, z) = \sum_{k=1}^{K} w_k x_k e^{-\eta},$$

which represents the minimum costs given the input prices w, and output z. Now, when considering the actual costs incurred by the firm C^a, it can be shown that the relation between the actual and optimal cost can be represented as:

$$\ln C^a = \ln C^*(w, y) + \eta.$$

Notice then, that we can approxiamte the efficiency of a producer by the estimation of $e^{-\eta}$.

Estimation of the Cost Function

For the specification of the cost function, as it is standard in the literature, I assume a translog representation of $\ln C^*(w,z)$, and include a noise term ν and some controls.[16] If we use the estimated cost from the auction model as the actual cost, we have:

$$
\begin{aligned}
\ln \hat{c}_i =& \ln C_i^*(w,z) + \eta + \upsilon_i, \\
\ln \hat{c}_i =& \beta_0 + \sum_k \beta_k \ln w_{k,i} + \beta_z \ln z_i + \frac{1}{2}\sum_k \sum_{k'} \beta_{kk'} \ln w_{k,i} \ln w_{k',i} + \\
& \frac{1}{2}\beta_{zz} \ln z_i \ln z_i + \sum_k \beta_{kz} \ln w_{k,i} \ln z_i + \beta_{K+1} Controls_i + \eta_i + \nu_i.
\end{aligned}
$$

The symmetry restrictions on the cost function require that $\beta_{kk'} = \beta_{k'k}$, and homogeneity of degree one in input prices requires:

$$
\sum_k \beta_k = 1, \quad \sum_k \beta_{kk'} = 0 \ \ \forall k', \quad \sum_k \beta_{kz} = 0.
$$

A natural way of embedding this restrictions in the estimation procedure, is to normalize the actual cost and the input prices by the price of a chosen input. In the current exercise I use three input prices: the daily wage of a construction work, the price of concrete and the daily rent of machinery, which will be respectively represented by w_1, w_2 and w_3. To embed the prince homogeneity of the translog especification, I normalize the input prices by the price of labor, w_1. Re-writing the cost function, we have:

$$
\begin{aligned}
\ln\left(\frac{\hat{c}_i}{w_{1,i}}\right) =& \beta_0 + \beta_z \ln z_i + \beta_2 \ln\left(\frac{w_{2,i}}{w_{1,i}}\right) + \beta_3 \ln\left(\frac{w_{3,i}}{w_{1,i}}\right) + \frac{1}{2}\beta_{23} \ln\left(\frac{w_{2,i}}{w_{1,i}}\right) \ln\left(\frac{w_{3,i}}{w_{1,i}}\right) + \\
& \frac{1}{2}\beta_{zz}\Big[\ln z_i\Big]^2 + \frac{1}{2}\beta_{22}\Big[\ln\left(\frac{w_{2,i}}{w_{1,i}}\right)\Big]^2 + \frac{1}{2}\beta_{33}\Big[\ln\left(\frac{w_{3,i}}{w_{1,i}}\right)\Big]^2 + \\
& \beta_{2z} \ln\left(\frac{w_{2,i}}{w_{1,i}}\right) \ln z_i + \beta_{3z} \ln\left(\frac{w_{2,i}}{w_{1,i}}\right) \ln z_i + \beta_{K+1} Controls_i + \eta_i + \nu_i.
\end{aligned} \tag{11}
$$

The estimation of the model is by maximum likelihood, where identification is achieved by the parametric assumption on the error terms. A key advantage of making parametric assumptions on the error term, is that inefficiency determinants, such as the firm's type, can be included in the model. I assume that the statistical error ν_i is normally distributed, with mean zero and standard deviation σ_ν. For the inefficiency term, as in Wang (2002), I assume that it follows a truncated normal, where the mean depends on observable characteristics W (here the firm's type, whether the project started during the year before municipal elections, and whether the party of the municipality's major coincides with the party of the state's governor), and the standard

[16] The error term ν can be interpreted as coming from the error in the cost's estimation.

deviation is σ_η. Given the parametric assumptions on the error terms, where $\eta \sim \ N^+(\mu(W), \sigma_\eta^2)$, and $\upsilon \sim \ N(0, \sigma_\upsilon^2)$, the likelihood function is:

$$L_i = -\frac{1}{2}\ln(\sigma_\eta^2 + \sigma_\upsilon^2) + \ln\phi\left(\frac{\mu(W) - \epsilon}{\sqrt{\sigma_\eta^2 + \sigma_\upsilon^2}}\right) + \ln\Phi\Big(\frac{\mu_{*i}}{\sigma_*}\Big) + \ln\Phi\Big(\frac{\mu(W)}{\sigma_\eta}\Big), \tag{12}$$

where, $\epsilon = \eta + \upsilon$,

$$\mu_{*i} = \frac{\sigma_\nu^2 \mu(W) + \sigma_\eta^2 \epsilon}{\sigma_\nu^2 + \sigma_\eta^2} \quad \text{and} \quad \sigma_* = \frac{\sigma_\nu^2 \sigma_\eta^2}{\sigma_\nu^2 + \sigma_\eta^2}.$$

Using the MLE estimates, we can further estimate the firm's inefficiency by $E[\eta_i|\epsilon_i]$, or similarly, the firm's efficiency by $E[\exp(-\eta_i)|\epsilon_i]$. A full description of the estimates of these indices can be found in the Appendix, in sub-section B.

4 Results

Using the public auction data, I first describe the results of the structural auction model, followed by the results of the stochastic frontier analysis. Second, I compare the firm's bid behavior under public auctions relative to their behavior under auctions by invitation.

4.1 Cost and efficiency estimates: public auctions

As a first step, to test whether bidders behave according to the model, I plot the estimated equilibrium strategies for both types of firms conditional on the median value of the size of the project (measured by the total amount of concrete, z), and on whether the project includes sewage work. As in Flambard and Perrigne (2006), the model rationalizes the data if the firms' bids increase as the private cost increase. The plots of $\hat{\xi}_1^{-1}(\cdot|z, sewage)$ and $\hat{\xi}_0^{-1}(\cdot|z, sewage)$ are displayed in Figure 6 in the Appendix. The estimated equilibrium strategies are increasing on the estimated costs, which provides evidence that the model is supported by the data. I hence present the cost estimates in Table 4, where I present the results separately for projects with and without sewage work.

In projects with sewage work, type 1 firms, who have been approached by the government to receive a project by direct allocation or to participate in an auction by invitation, have a lower costs per cubic meter than firms that only participate in public auctions. Nevertheless, this relation is reversed when looking at projects without sewage work. This is reflected both for the average and median cost of all bidders, as well as for the winning firm's costs. The results for the winning firms is more convoluted. For projects with sewage work, type 1 firms have lower cost on average but

Table 4: Cost estimates

	Mean	Median	S.E.	Obs
Estimated firms' costs (thousands per m^3)				
Projects with sewage work				
Public auction: type 1, $\hat{c}_1$	10.813	8.304	(8.931)	256
Public auction: type 0, $\hat{c}_0$	11.538	9.005	(10.344)	631
Projects without sewage work				
Public auction: type 1, $\hat{c}_1$	7.038	5.800	(5.606)	475
Public auction: type 0, $\hat{c}_0$	6.116	4.958	(4.209)	1115
Estimated winning firms' costs (thousands per m^3)				
Projects with sewage work				
Public auction: type 1, $\hat{c}_1$	10.337	8.398	(6.951)	61
Public auction: type 0, $\hat{c}_0$	10.827	7.347	(11.017)	59
Projects without sewage work				
Public auction: type 1, $\hat{c}_1$	6.271	4.843	(5.418)	78
Public auction: type 0, $\hat{c}_0$	6.495	4.991	(4.552)	126

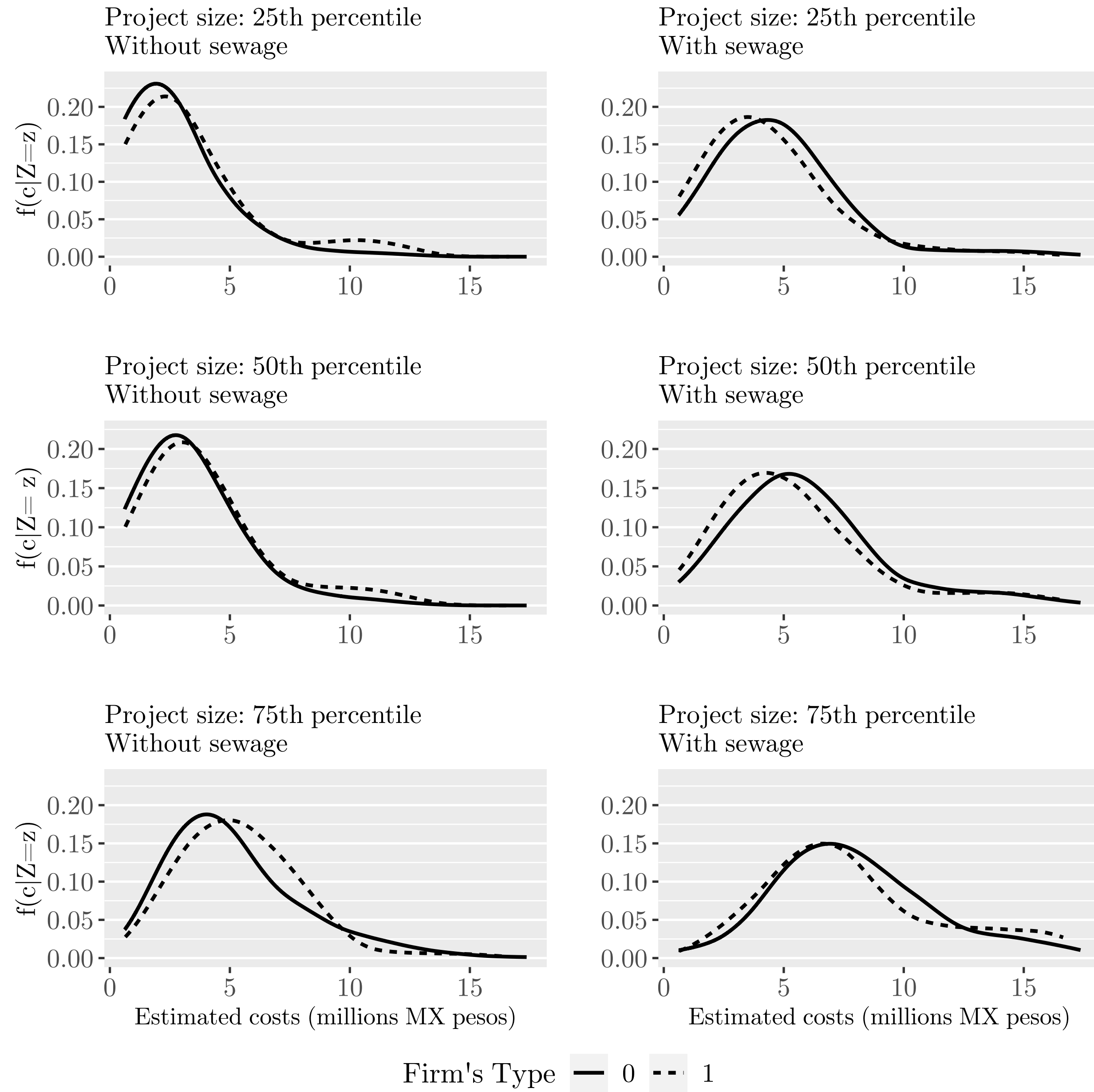
Note: public auction data, where 18 outliers have been dropped. $\hat{c}_1$ denotes the estimated costs of type 1 firms (firms that, in addition to participate in public auctions, have participated in an auction by invitation or received a project by direct allocation), and $\hat{c}_0$ denotes the estimated costs of type 0 firms (firms that only participate in public auctions). b_1 and b_0 denotes the bids of firm types 1 and 0 respectively.

have a higher median. As for projects without sewage work, the costs of both firms are similar, although lower for type 1 firms.

To further understand the cost differences between type 1 and type 0 firms, I plot in Figure 1 the estimated costs' distributions, conditional on different levels of the total amount of concrete z, and whether the project includes sewage work. Conditioning the cost distributions on the amount of concrete allows me to control for the size of the project, and conditioning the cost distribution for whether the project includes sewage work allows me to control for the contracts' complexity. The different project sizes I condition for correspond to the 25th, 50th and 75th percentile of the total amount of concrete used in a project. For all project sizes, firms selected to setting with less competition, type 1 firms, have lower costs for projects with sewage work, but higher costs for projects without sewage work[17]. That is, type 1 firms are more cost efficient in complex projects, but less so in simple ones.

[17]Kolmogorov-Smirnov tests of the equality of distributions are rejected for the conditional cost densities evaluated at different project sizes: z's 25th, 50th and 75th percentile

Figure 1: Conditional cost density, evaluated at different project characteristics (**z**)



Type 1: firms that, in addition to participate in public auctions, have participated in an auction by invitation or received a project by direct allocation. Type 0: firms that only participate in public auctions.

A possible explanation is that type 1 firms may use economies of scope to be more competitive in complex projects, where they leverage the cost complementarites of the different services they provide (sewage and pavement work). Alternatively, smaller and less experienced firms, consistent with product differentiation, may specialize in simpler projects where larger firms do not have a cost advantage when providing a single service.

Stochastic frontier analysis results

Using the cost estimates from the structural model, $\hat{c}_1$ and $\hat{c}_0$, along with augmented data on input prices, I estimate the cost function described in equation (12) by maximum likelihood. The three inputs used are concrete, labor, and capital. The price of labor is approximated using the daily wage of construction workers at the municipality level using census data from the National Institute of Statistics and Geography (INEGI). The census in Mexico is performed every 10 years and in between, they conduct a survey at a lower scale. I use the census of 2010 and the count of 2015 to approximate the wages at the municipality level, and interpolate the data to approximate the wages for the years in between and after 2015. For the concrete and rent of capital, I estimate the costs at the state level using market prices given by providers of construction material at each state. I then use an INEGI's monthly price index at the state level for the construction sector and rent of machinery to approximate the prices between 2011 and 2018.

I first check the theoretical requirements of the estimation of a translog cost function. As mentioned above, the homogeneity of degree one was embedded in the estimation by normalizing the cost and input prices by the price of one of the inputs. Here I normalize the prices by the price of labor. Two other conditions that need to be met are monotonicity and concavity in inputs prices and output. For reviewing the monotonicity condition, as in Khumbhakar, Wang, and Honcastle (2015), I revise the sign of the partial derivative of the log of costs with respect to the log of input prices. These derivatives are functions of $\ln z_i$ and $\ln w_{j_i}$ for $j = 1, ..., K$, and as such are observation-specific. There are no violations of monotonicity for output and price of labor, although I do find a violation in 45 and 23 percent of the observations for the prices of concrete and capital. Nevertheless, for the case of capital prices, these violations happen at the tails of the data. For testing concavity, I calculate the Hessian matrix with respect to input prices, which is also data-dependent and therefore verifiable. I find that only 13 percent of the observations present a concavity violation, but again, this happens at the tails of the data. With evidence that the model conforms to the data, I proceed to describe the results in Table 5.

The fit of the frontier is good (measured by the fit of the βs), and the returns to scale appropriate for the context of small construction projects, where we would expect gains to returns to scale. To aid in the numerical optimization of the likelihood, I assume that the variance of the error terms follow an exponential distribution. Hence, the constant for σ_ν represents $\exp(1.116) = 3.052$, and the constant for σ_η represents $\exp(-2.093) = 0.123$. As for the determinants of μ, as mentioned above, an important advantage of making parametric assumptions on the error term is that we can include observable determinants of inefficiency. I estimate the mean of the inefficiency term as a function of the firm's type, whether the project started one year before a municipal election, and whether the political parties of the municipality's mayor and state's governor were aligned. The coefficients are informative but not directly interpretable given the non-linearity of the model. For a more clear interpretation, I report in Table 6 the marginal effects of these variables on

Table 5: SFA - Cost function estimates

	Coef.	S.E.		Coef.	S.E.
Frontier			μ		
β_z	0.150	(0.246)	Dummy(Firm's type)	1.501	(1.210)
β_{zz}	0.093^{**}	(0.039)	Dummy(1yr. before elec.)	2.751	(2.090)
β_{w_2}	2.269^{***}	(0.358)	Dummy(Mayor and Gov.	-1.824	(1.436)
β_{w_3}	-1.291^{***}	(0.380)	from the same party)		
$\beta_{w_{2,2}}$	-2.386^{***}	(0.187)	Constant	-7.272	(6.721)
$\beta_{w_{3,3}}$	-2.272^{***}	(0.202)	σ_η		
$\beta_{w_{2,3}}$	2.356^{***}	(0.191)	Constant	1.116	(0.817)
$\beta_{2,z}$	-0.331^{***}	(0.055)	σ_ν		
$\beta_{3,z}$	0.329^{***}	(0.058)	Constant	-2.093^{***}	(0.064)
Wald Chi2			26591.41		
Returns to scale			1.303		
Observations			2482		
Controls			Yes		

Note: *** p<0.01, ** p<0.05, * p<0.1. The βs denote the fit of the cost frontier, where β_z is the coefficient for the normalized log of output, and β_{w_2} and β_{w_3} the coefficients for the normalized log of the second and third input prices (price of concrete and rent of machinery respectively). The normalization was made using the price of labor. μ and σ_η denote the mean and variance of the inefficiency term, and σ_ν the variance of the idiosyncratic error.

the unconditional mean of the inefficiency term, as well as on its unconditional variance. For a description of the estimation of the marginal effects, see the Appendix, sub-section B.1.

Table 6 shows that type 1 firms are 7.5 percent more input-oriented inefficient. That is, compared to type 0 firms, they use 7.5 percent more inputs to produce a certain level of output. This difference is significant, and it driven by the fact that the majority of projects do not include sewage work, the type of projects in which type 1 firms are less efficient. When looking at political factors influencing the firm's inefficiency, the timing of the project matters. If the project started during the year before municipal elections, the average level of inefficiency increased by 13.8 percent. All else equal, the overuse of inputs would translates in a 13.8 percent increase in costs. Finally, we observe that when the party of the municipality's mayor is aligned with the party of the state's governor, the average level of inefficiency decreased by 9.8 percent. Although I cannot empirically test the reasons behind this difference, a possible explanation is a better coordination between the municipality and state administration when the parties are aligned, which in turn may decrease delays due to bureaucracy, or side payments to speed up the process.

Table 6: SFA - Marginal Effects on the mean and variance of the inneficiency term ($E[\eta]$ and $V[\eta]$)

	Coef.	S.E.
Firm's type		
Marginal Effect on $E[\eta]$	0.075^{***}	(0.020)
Marginal Effect on $V[\eta]$	0.053^{***}	(0.014)
Dummy, 1 year before elections		
Marginal Effect on $E[\eta]$	0.138^{***}	(0.019)
Marginal Effect on $V[\eta]$	0.098^{***}	(0.017)
Dummy, Mun. Mayor and Governor from the same party		
Marginal Effect on $E[\eta]$	-0.098^{***}	(0.024)
Marginal Effect on $V[\eta]$	-0.065^{***}	(0.016)
Observations	2482	

Bootstrapped standard errors in parentheses, using 500 iterations.
*** p<0.01, ** p<0.05, * p<0.1 .

These differences take place in a setting with relatively high inefficiency. When calculating the efficiency index $E[\exp(-\eta)]$, on average, type 0 firms have a higher efficiency index, with a weighted average of 0.68 (i.e., on average, the minimum cost is 68 percent of the actual cost), compared to the weighted average of type 1 firms of 0.62. To compare the efficiency index between the two groups, I follow Färe, Grosskopf, and Zelenyuk (2004), and Sickles and Zelenyuk (2019), and weight each firm's efficiency index by its cost share of its respective group. For a further description of the differences in the efficiency index, I plot in Figure 7 in the Appendix the density of the unweighted efficiency index by firm's type. As a robustness analysis, I fit a corrected OLS and a Half-Normal model. A plot comparing the distribution of the different efficiency indexes can be found in the Appendix in Figure 9. The full results are available upon request. The corrected OLS model over-predicts inefficiency, whereas the Half-Normal present very similar results to the truncated normal. I perform Likelihood-Ratio (LR) tests to choose the model, and find that the truncated-normal dominates the other two. Finally, in sub-section B.4, I compare the results of the Truncated-Normal with estimates from model specifications that follow the scaling property of Wang and Schmidt (2002). I find that the marginal effects of the exogenous determinants of inefficiency, the main estimates I am after, change very little. Nevertheless, in order to achieve convergence under specifications with the scaling property, I need to restrict the number of parameters to be estimated. Hence, I present here the Truncated-Normal estimates and detail the above comparison in the Appendix, sub-section B.4.

States' cost-efficiency profiles

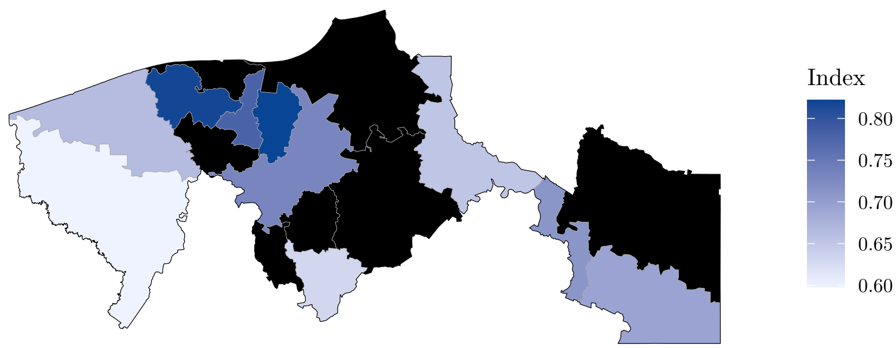
The results above are useful to study the efficiency profiles of a region. We can both aggregate the firm level estimates to study regional efficiency differences, and also identify the regions where the government's selection of firms to settings with less competition is poor. That is, we can identify where the government is selecting the least efficient firms within a region to be given a project by direct allocation or I3P. The former result can help policy makers in the regional targeting of policies that seek to enhance productivity, whereas the latter results can improve monitoring tools for the proper administration of public funds. In the next paragraphs I briefly describe state differences in the efficiency index, followed by an analysis at the municipal level of the state of Tabasco.

When I compare states, I weight each firm's efficiency index by its cost share of its respective region. See the Appendix, Figure 10, for a map at the state level. Note that the northern states (with the exception of Coahuila, the state with light blue among the states in the northern border), along with states in the gulf, have the most cost efficient firms. The states in the central region, along with the state in the far south, Chiapas, fare the worst. Nevertheless, within each state, there is high heterogeneity between municipalities. For example, in Figure 2 I focus on the state of Tabasco. In panel A, I plot the weighted average efficiency index, where we see a similar range as the one observed when comparing the efficiency between states. In panel B, I plot the unweighted average difference between the municipality's most efficient firm, and the average of type 1 firms (firms that are selected by the government to participate in settings with less competition). The higher the difference, the worse the government's selection of firms to participate in settings with less competition.

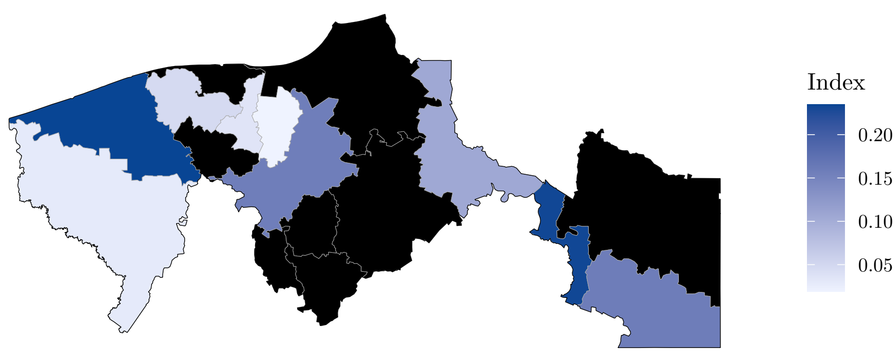
In Figure 2, the municipality to the far left is the municipality of Huimanguillo. Just above it, and second from the left, lies the municipality of Cardenas. From Panel A we observe that both municipalities have low efficiency levels compared to the other municipalities in the state. But from Panel B, we observe that Himanguillo's local government is selecting the most efficient firms within the municipality, whereas the municipality of Cardenas is doing the opposite. The additional information of Panel B points to the need of further monitoring in Cardenas to inquire about the selection procedure of the firms that receive projects by direct allocation or are invited to an auctions. These results can enhance the monitoring capabilities of the government in both the allocation of funds and in the selection of contract allocation procedures.

Figure 2: Efficiency Profile of the State of Tabasco

A. Efficiency index



B. Efficiency difference with most efficient firm in municipality



Note: In black if there are no projects within the municipality in the sample studied. The efficiency index is estimated by $E[\exp(-\eta_i)|\epsilon_i]$ and it ranges from 0 to 1. For interpretation purposes, a value of 0.6 denotes that the minimum cost is 60 percent of the actual cost.

4.2 Comparing auction formats

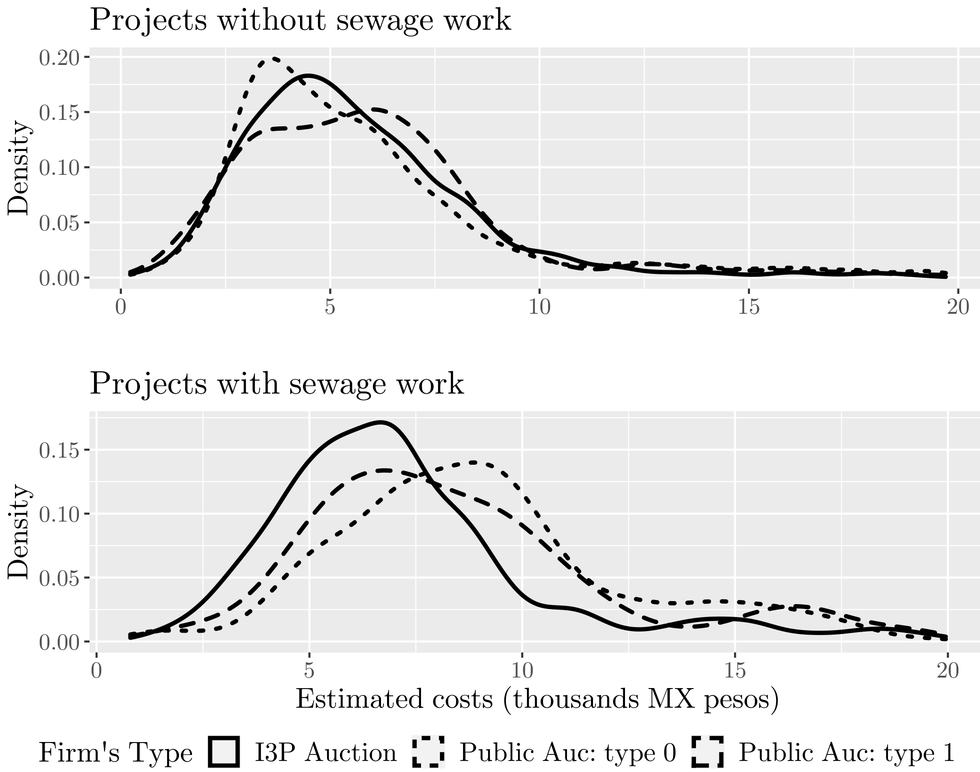
In this section I compare the firms' behavior under the two main auction formats: public auctions and auctions by invitation. Using only the sample of auctions by invitation, I estimate a symmetric procurement auction model following the indirect method of GPV, and again augment the model with input prices to conduct an SFA analysis. I then compare the cost and efficiency estimates of the firms under the I3P procedure, with the estimates using the public auction data.

The projects allocated under I3P are smaller than those allocated by public auction. On average, projects under I3P use 355.7 cubic meters of concrete, with a standard deviation of 358.8. The average for public auctions is 730.8, with a standard deviation of 574.9[18]. Also, fewer projects under

[18]See Figure 11 for a distribution of the size of the project by allocation mechanisms, and see Table 8 for

I3P include sewage work than in public auctions, 24 percent compared to 38 percent respectively. Given the little overlap in the distributions of the projects size by allocation mechanisms, I compare the distribution of the costs per cubic meter. The results are found in Figure 3. Again, I separate the cost estimates depending on whether or not the project includes sewage work. Notice that by definition, firms under I3P are type 1 firms[19].

Figure 3: Densities - Cost per m^3 of concrete



Type 1 firms participate both in public auctions and auctions by invitation. Public Auc: type 1 denotes their costs when participating under public auctions, and I3P Auctions denotes their costs when participating in auctions by invitation. Public Auc: type 0 denotes the cost of firms that only participate in public auctions.

From Figure 3, two patterns are important. First, type 1 firms, irrespective of the auction format, have lower costs than type 0 firms for projects with sewage work. Nevertheless, this relation is reversed for projects without sewage, which are more common. Second, type 1 firms present lower costs under I3P than in public auctions, specially in more complex projects. For a

a summary of the bid data by auction format.

[19] As a robustness analysis, I include in Figure 12 in the Appendix, the distribution of the costs conditional on the 75th percentile of the size of the projects under I3P. The results are similar to observed in Figure 3. Firms under I3P have a lower cost for projects with sewage, but this advantage decreases when looking at projects without sewage, their costs are similar to type 0 firms in public auctions

further description of the cost profiles under each mechanisms, I present in Table 10 in the Appendix the firm's average and median cost per cubic meter under each auction format. Furthermore, conditional on the firms' costs, I evaluate the conditional bid means at the 75th percentile of project size and costs of I3P projects. In complex projects, $E[b_{1,PA}|c,z] - E[b_{1,I3P}|c,z] = 4.4 - 3.5$, and in simple projects, $E[b_{1,PA}|c,z] - E[b_{1,I3P}|c,z] = 3.08 - 3.09$. In other words, type 1 firms are more aggressive under auctions by invitation than in public auctions when the project is complex, but bid similarly under public auctions if the project is simple.

A potential explanation of the first pattern, as we mentioned above, is that the larger size and higher experience of type 1 firms may allow them to leverage cost complementarities between different services (street pavement and sewage work). On the other hand, type 0 firms' higher relative efficiency for smaller and simpler projects, may be explained by the firms' product differentiation[20]. Concerning the lower costs for type 1 firms under I3P than in public auctions, and their respective lower bids in I3P, consistent with Roberts and Sweeting (2013), it is possible that the selection of firms is having a higher impact over the bids than the effect of higher competition without firm selection. Once selected to an auction by invitation for a complex project, the firms know they are facing other experienced firms, which forces them to bid more aggressively than in settings with no selection on their competitors.

Given that projects by direct allocation and invitation to an auction are usually smaller and without sewage work[21], a direct policy recommendation from the results above is to increase the use of public auctions for projects without sewage work. A simple calculation suggests a conservative savings estimate of opening up the simple contracts to public auctions of 4.5 percent per contract (which arises from the overall 7.5 percent efficiency difference between the two types of firms in public auctions, and the fact that type 0 firms win 61 percent of the projects without sewage), or approximately 10 million MX pesos per year.

Finally, to further analyze the firm's efficiency differences by auction format, I compare the results of the stochastic frontier analysis using the I3P data, with the estimates using public auctions. I mainly focus on the influence of political factors on the mean of the inefficiency term $E[\eta]$, and briefly comment on the distribution of the efficiency index. The results of the marginal effect of political factors over $E[\eta]$ are found in Table 7. In estimation, I again assume that η follows a Truncated-Normal, where its mean can be influenced by whether the project took place during the year before local elections, and whether the political party of the municipality's major coincides

[20]Absent economies of scope, type 1 firms may not have an advantage when delivering a single service in simple projects.

[21]Projects allocated through auctions by invitation are on average half the size of projects allocated through public auctions, and only 24 percent of them include sewage work, compared to 38 percent of contracts allocated through public auctions.

with the governor's party. Unlike the SFA analysis in the previous section, here I only use two inputs due to a lack of convergence when using three inputs with the I3P data. Therefore, for effects of comparison, I re-estimate the SFA analysis for the public auction data, but only using two inputs. The estimates using I3P data can be found in the first and second column of Table 7, and the re-estimated results using public auctions on the third and fourth column.

Table 7: SFA - Marginal Effects on the mean of inefficiency, $E[\eta]$, by auction procedure

	Auctions by invitation (I3P)		Public Auction	
	Coef.	S.E.	Coef.	S.E.
Marginal Effect on $E[\eta]$				
Firm's type			0.094^{***}	(0.021)
Dummy, 1 year before elections	0.087^{***}	(0.019)	0.125^{***}	(0.025)
Dummy, Mun. Mayor and Governor from the same party	-0.129^{***}	(0.015)	-0.166^{***}	(0.030)
Observations				

Bootstrapped standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1 .

The model uses two input prices, labor wages and the price of rent of capital. The controls included are a dummy for work on the water system, a dummy if the firm had an overlaping project, and a set of year dummies.

The marginal effects of political factors over the mean of the inefficiency term, $E[\eta]$, have the same direction irrespective of the auction format. Under I3P, the average level of inefficiency increased by 8.7 percent when the project takes place during the year before local elections. Likewise, when the municipality's major is aligned with the governor's party, the firm's average inefficiency decreased by 12.9 percent. The magnitudes of these effects are greater under public auctions. To further compare the efficiency of firms under the different auction formats, I plot in Figure 8 in the Appendix, the distribution of the efficiency index by auction format. Firms under I3P have a higher efficiency, which is mainly driven by their large cost advantage on projects with sewage work.

5 The Contracts' Allocation Electoral Cycle

Among possible inefficiency drivers in projects closer to an election, some main candidates stand out, the unduly payment of bribes for political favors, delays due to bureaucracy and red tape, and the increase of projects to satisfy the electorate. Due to data restrictions, I cannot test for the former, but I provide evidence that the latter may not be a driving factor. Specifically, I do not find a clear electoral cycle in the number of contract allocations.

The empirical evidence of distributive politics and electoral competition is large[22]. For the case of Mexico, Selod and Soumahoro (2019) show that politicians may use investment in federal highways to reward particular electorates[23]. Here I study the presence of political bias in the allocation of funds for small streets at the local level. To test for an electoral cycle, similar to Mironov and Zhuravskaya (2016), I group the data by municipality and calendar months, and analyze whether there are observable patterns in the months closer to an election. A large majority of municipalities have local elections every three years, and a minority after two or four years. Let $q = -6, ..., -1, 1, ..., 6$ denote the number of quarters away from municipal elections, let D_{qm} denote a dummy equal to one if municipality m is q quarters away from local elections, and let X_{tm} represent some controls at municipality m and calendar month t. I estimate:

$$\text{Number of contracts}_{tm} = \sum_{q=-6, q \neq 1}^{6} \beta_q D_{qm} + \theta X_{tm} + t + m + \varepsilon_{tm}, \tag{13}$$

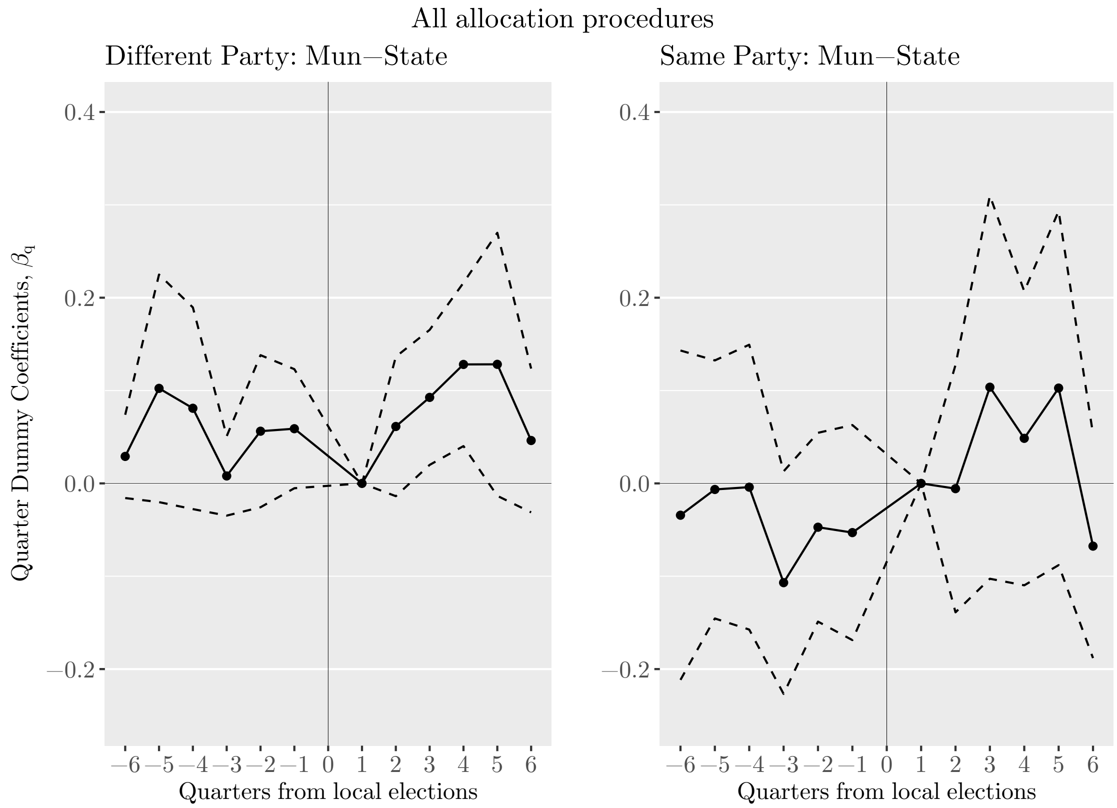
separately depending on the whether or not the major's party aligns with the governor's party. The controls include a dummy for work on the water system, a dummy if the firm has an overlapping project, a set of year dummies, and the duration of the project. To identify the electoral cycle we are interested in β_q. Notice that the quarter left out is the first quarter after an election takes place, so that the β_q estimates need to be interpreted relative to the first quarter.

Figure 4 presents the results when I use all types of allocation procedures in the sample. On the left panel I use the sub-sample for which the party of the major differed from the party of the governor, and in the right panel when they were aligned. In both cases, we do not see a clear pattern in the number of contracts allocated before local elections take place. I repeat the previous exercise by allocation procedure, and again I do not find an electoral cycle. The latter estimates are available upon request. Overall, the results suggest that the increase in inefficiency during the year before elections is not due to a higher number of contracts being allocated during this period, but rather because of a change in the conditions the same number of projects take place. The results presented are mainly a correlation, and do not imply a causality effect. A more in depth analysis goes beyond the purpose of this paper, but the preliminary evidence presented goes against other findings of an electoral cycle in the investment in highways. The influence of political factors on pavement contracts seems to be greater when these projects are of larger scale, as the projects

[22] For a review see Golden and Min (2013).

[23] More specifically, the authors find evidence of higher funding for highways in constituencies that elected legislators from the incumbent president's party.

Figure 4: Electoral cycle



Note: The dots display the β_q coefficients of the quarter dummy variables in equation (13) (Number of contracts$_{tm} = \sum_{q=-6,q\neq 1}^{6} \beta_q D_{qm} + \theta X_{tm} + t + m + \varepsilon_{tm}$), which represent the additional number of contracts allocated in a specific quarter relative to the number of contracts allocated in the first quarter after local elections take place. The dashed lines represent the 95% confidence intervals.

studied by Selod and Soumahoro (2019).

6 Conclusions

I study the allocation of street pavement contracts with hydraulic concrete in Mexico. By law, the government should conduct a public procurement auction for the pavement of streets, nevertheless, exceptions in the law allow the government to bypass a public auction and to either choose a firm of its preference or invite specific firms for an auction. In this paper, I test whether the government chooses the most efficient firms when bypassing a public procurement auction, and compare the firms' costs under different auction mechanisms. Finally, I study the influence of political factors on contract allocations.

To compare the firms selected to setting with less competition, with the firms that only participate in public auction, I use the fact that most firms that win projects by direct allocation or participate in auctions by invitation, also participate in public auctions. Hence, I study their bidding behavior in public auctions to recover their cost distribution. Furthermore, I augment the estimation of the pseudo costs with the price of inputs for street paving. Such data allows me to use a stochastic frontier analysis to estimate a cost frontier and an inefficiency term per firm, which is estimated by the distance of the firm's efficiency to the estimated cost frontier. To compare the auction mechanisms, I re-estimate the above for the sample of auctions by invitation, again conduct the stochastic frontier analysis for this sample, and compare the results with the estimates using the public auction data. Finally, with an estimate of the firms' efficiency profiles, along with the timing of the allocated contracts, I study the contracts' allocation electoral cycle.

I find that firms selected to receive projects by direction allocation or to participate in auctions by invitation are more experienced and have lower costs for complex projects (contracts that include sewage work). Nevertheless, for smaller projects, they are less cost efficient than firms that only participate in public auctions. Regarding the comparison between auction formats, the selected firms seem to bid lower in auctions by invitation than in public auctions when competing for complex projects. Whereas they behave similarly under both auction formats when competing for simple projects. Consistent with Roberts and Sweeting (2013), a potential explanation is that the firms selected to bid for a complex project know they are facing other experienced firms, which leads them to bid more aggressive than in settings where there is no selection on their competitors.

Overall, the above results suggest that the government would benefit from a greater use of public auctions for simple and small projects, with potential savings of around 4.5 percent per contract. This result is specially important given the current practice of using auctions by invitation for small and simple projects, as 75 of pavement contracts under auctions by invitation do not include sewage work. This policy is not optimal because the invited firms are not competitive in these type of projects. Opening up the small contracts to public auctions would have the double benefit of supporting smaller firms and achieving lower contract prices. On the other hand, the use of auctions by invitation for complex projects seems warranted, provided the government selects the most cost-efficient firms and that the number of bidders may not differ greatly to the level of competition we observe in public auctions.

When studying the influence of political factors on contract allocations, I find mixed results on the contracts' electoral cycle. On the one hand, local governments prefer allocation mechanism with greater hiring discretion during the year before municipal elections, where I document a 6 percent increase on the probability that the government will avoid public auctions. Nevertheless, I do not find evidence of an electoral cycle on the number of contracts allocated. As for the influence of political factors on the firms' efficiency, I find that during the year before local elections, the average inefficiency increases by 9.4 to 13.8 percent under public auctions (compared to other public auction contracts in non-electoral times). This increase in inefficiency is 12.5 percent for firms participating in auctions by invitation. The data allows me to rule out an increase in the number of contracts as a possible explanation for the increase in the average inefficiency. Finally, when the mayor's political party is aligned with the governor's party, firms are more efficient by 9.8 to 16.6 percent when they participate in public auctions, and by 12.9 percent when they participate in auctions by invitation. This increase in efficiency may be due to a decrease in bureaucracy or due to a better coordination between the local and state government. The mixed results on the presence of an electoral cycle, and the latent corruption concerns in Mexico, point to the need of further research studying the influence of political factors over different allocation mechanisms with varying degrees of hiring discretion on the government's part.

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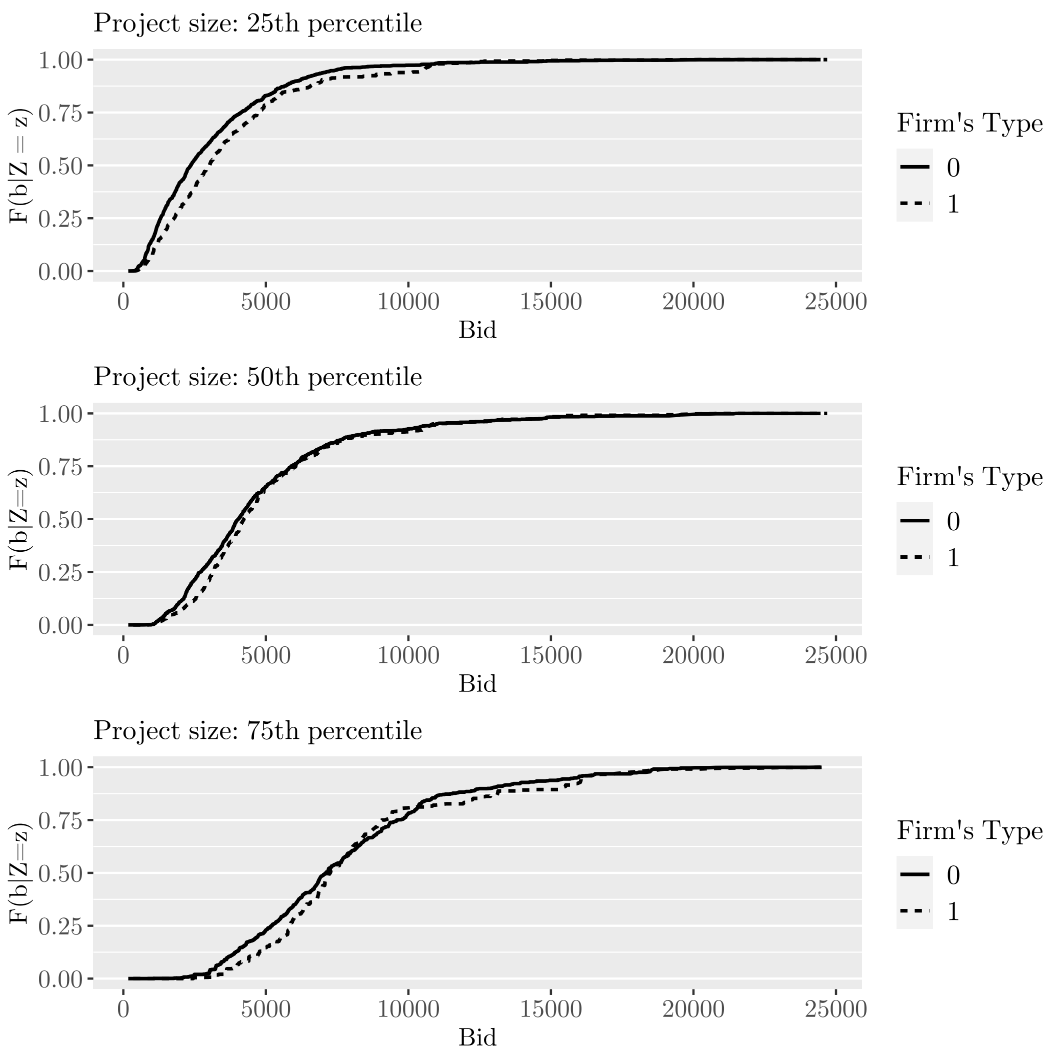
Appendix

A Estimation details of the procurement auction model

Evidence of asymmetry

In Figure 5 we see the conditional bid cdfs, evaluated at different project sizes, approximated by the total amount of concrete z. When evaluating the cdfs at z's 50th percentile, the distributions are quite similar, nevertheless, this changes when evaluating the cdfs for small and larger projects. Specially for smaller projects, type 0 firms dominate type 1 firms.

Figure 5: Conditional bid CDFs evaluated at different project sizes, z

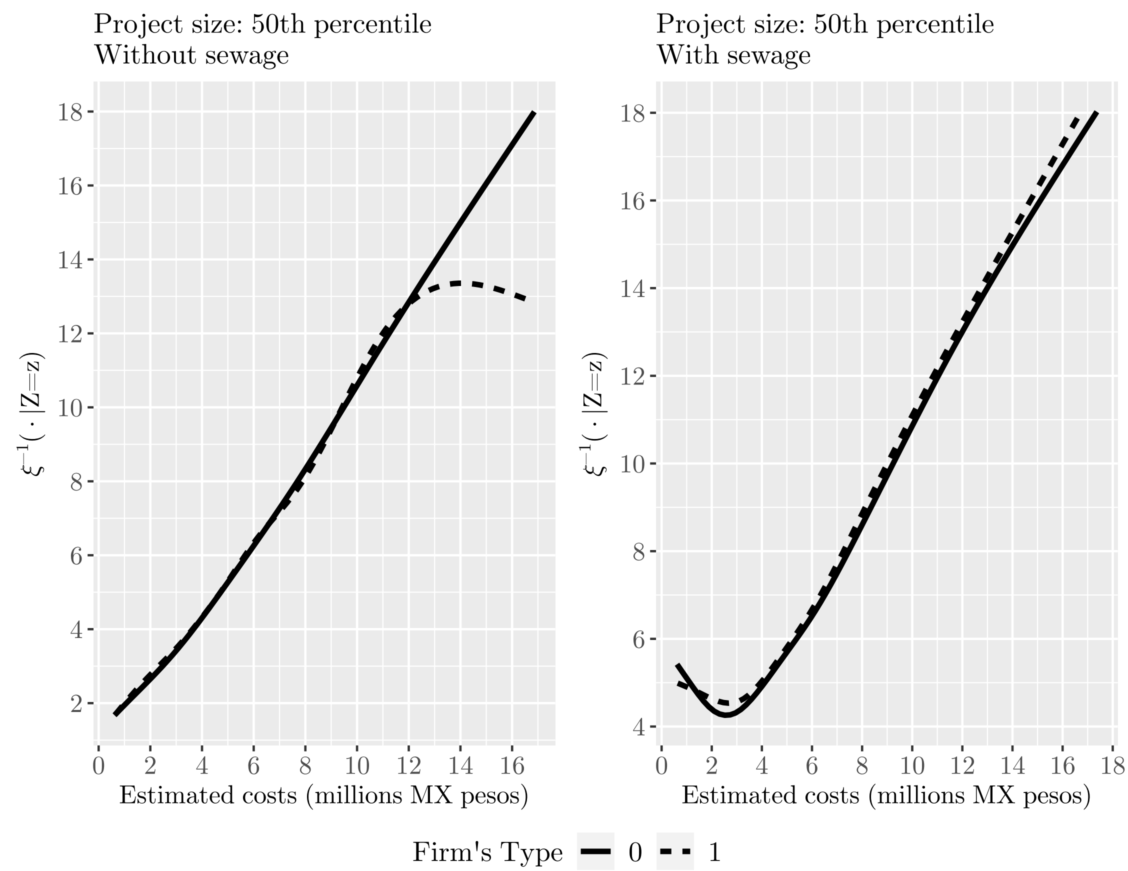


Type 1: firms that, in addition to participate in public auctions, have participated in an auction by invitation or received a project by direct allocation. Type 0: firms that only participate in public auctions.

Evidence for the model's support - public auction

A key assumption of the structural procurement auction model, is that the firm's strategy functions is strictly increasing in its cost. In Figure 6 I plot the estimated strategy functions and the estimated costs. As expected, the functions are increasing for both types of firms, with some few exceptions on the tails.

Figure 6: $\xi^{-1}(\cdot|z)$ evaluated at the median of the project size



Type 1: firms that, in addition to participate in public auctions, have participated in an auction by invitation or received a project by direct allocation. Type 0: firms that only participate in public auctions.

Bid data of auctions by invitation (I3P)

Find in Table 8 the bid data of auctions by invitation, and for easy of comparison, the bid data of public auctions from Table 1. Overall, the median bid per cubic meter is lower under I3P. The projects under I3P are half the size of projects allocated by public auctions, but take on average only 10 percent less time to complete. A lower proportion of I3P projects include sewage work, 24 percents against 38 percent of public auctions, and an equal proportion of projects are allocated by the municipality (compared to the state government) in both auction formats.

Table 8: Summary statistics, first-price sealed bid auctions - auctions by invitation and public auctions

	Mean	Median	S.D.	Min	Max	Obs
Auctions by invitation (I3P)						
Bids/m^3 concrete	7.96	6.66	6.17	0.52	86.9	3895
Winner: bid/m^3 concrete	7.70	6.46	5.85	0.81	65.1	1266
Number of bidders	3.08	3	0.66	1	11	1266
M^3 concrete	355.8	271.6	358.8	6.21	6185.8	1266
Dummy = 1 if proj. includes sewage work	0.24	0	0.43	0	1	1266
Duration of project (months)	3.13	2	5.45	0	49	1266
Dummy = 1 if municipal proj	0.83	1	0.38	0	1	1266
Public Auctions						
Bids/m^3 concrete (thousands per m3)	9.01	7.13	7.57	0.87	92.6	2784
Winning bid/m^3 concrete	9.40	7.45	7.49	1.31	62.1	404
Number of bidders: total	6.89	5	6.22	1	35	404
Num. bidders: at some point Direct/I3P	2.03	2	2.15	0	15	404
Num. bidders: only Public Auction	4.86	3	5.24	0	35	404
M^3 concrete	730.8	588.4	574.9	23.5	4072.9	404
Dummy = 1 if proj. includes sewage work	0.38	0	0.49	0	1	404
Duration of project (months)	3.44	3	3.91	0	49	404
Dummy = 1 if municipal project	0.84	1	0.36	0	1	404

B Estimation details of the stochastic frontier analysis

B.1 Estimation of the efficiency index and marginal effects on $E[\eta]$

Notice that the conditional distribution of η is known, so we can derive moments of the continuous function of $\eta|\epsilon$, where $\epsilon = \eta + \nu$. Following Battese and Coelli (1988), we can show:

$$E[\eta_i|\epsilon_i] = \frac{\sigma_* \phi(\frac{\mu_{*i}}{\sigma_*})}{\Phi\Big(\frac{\mu_{*i}}{\sigma_*}\Big)} + \mu_{*i},$$

$$E[exp(-\eta_i)|\epsilon_i] = exp\Big(-\mu_{*i} + \frac{1}{2}\sigma_*^2\Big)\frac{\Phi\Big(\frac{\mu_{*i}}{\sigma_*} - \sigma_*\Big)}{\Phi\Big(\frac{\mu_{*i}}{\sigma_*}\Big)}.$$

For the marginal effects of η's mean determinants, I follow Wang (2002). If $E[\eta_i] = \mathbf{w}_i'\boldsymbol{\delta}$, we have:

$$\frac{\partial E(\eta_i)}{\partial \mathrm{w}_r} = \delta_r \Bigg[1 - \Lambda_i \Big[\frac{\phi(\Lambda_i)}{\Phi(\Lambda_i)}\Big] - \Big[\frac{\phi(\Lambda_i)}{\Phi(\Lambda_i)}\Big]^2\Bigg],$$

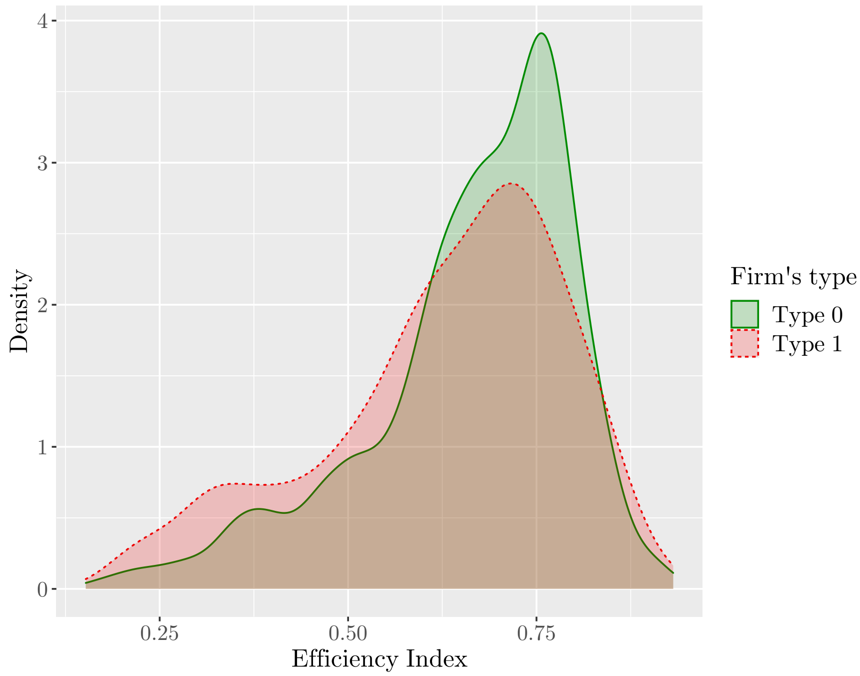
$$\frac{\partial V(\eta_i)}{\partial \mathrm{w}_r} = \frac{\delta_r}{\sigma_\eta}\Big[\frac{\phi(\Lambda_i)}{\Phi(\Lambda_i)}\Big](E(\eta_i)^2 - V(\eta)),$$

where $\Lambda_i = \mu_i/\sigma_\eta$.

B.2 Distribution of the efficiency index by firm's type, and allocation procedure.

See in Figure 7 the unweighted distribution of the efficiency index by firm's type, using the public auctions. In estimation, I use three inputs and assume that the inefficiency term η follows a Truncated-Normal, with its mean being influenced by three observable characteristics: the firm's type, whether the project takes place during the year before elections, and a dummy for party alignment between the major and governor. We see that type 0 firms have a higher efficiency index. This is mainly driven by the fact that they are more efficiency in projects without sewage work, which are more common than projects with sewage work.

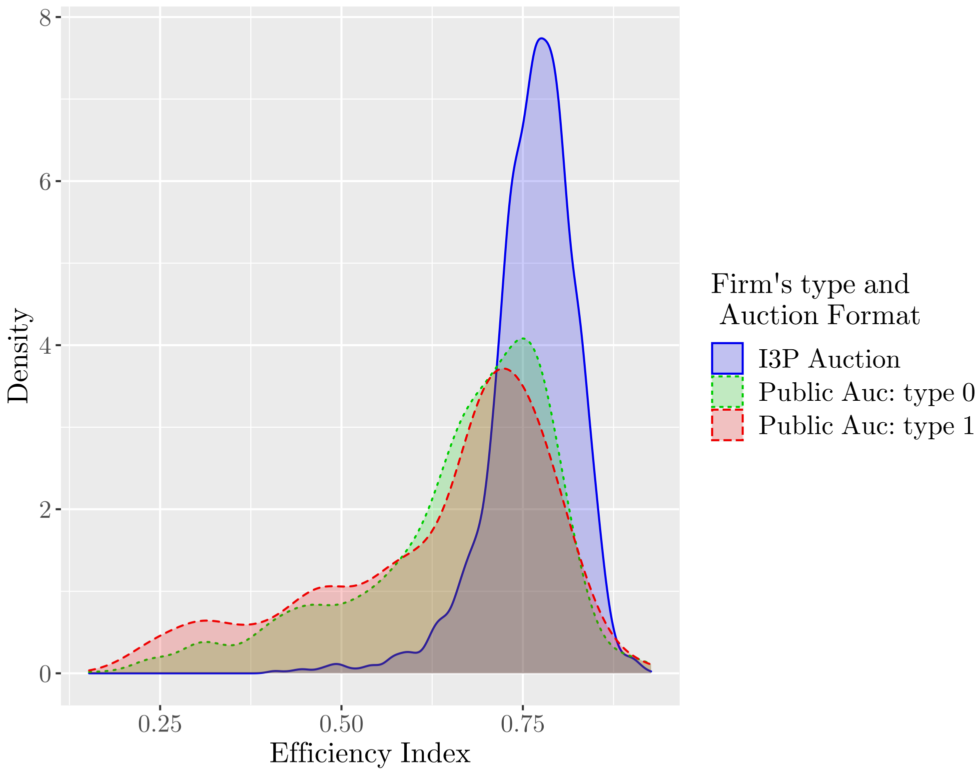
Figure 7: Densities - Efficiency index



Type 1: firms that, in addition to participate in public auctions, have participated in an auction by invitation or received a project by direct allocation. Type 0: firms that only participate in public auctions. The efficiency index is estimated by $E[\exp(-\eta_i)|\epsilon_i]$ and it ranges from 0 to 1. For interpretation purposes, a value of 0.6 denotes that the minimum cost is 60 percent of the actual cost.

In Figure 8 I present the efficiency index by firm's type for public auctions, and the efficiency index of firms under I3P auctions. Notice that by definition, firms under I3P are type 1 firms. The main difference with the previous estimation of the efficiency index, is that in the stochastic frontier analysis I only use two inputs. Hence the difference in the densities of public auctions when comparing Figures 7 and 8. Here we see a higher efficiency of firms under I3P. This result is mainly driven by their large advantage on projects with sewage work.

Figure 8: Densities - Efficiency index

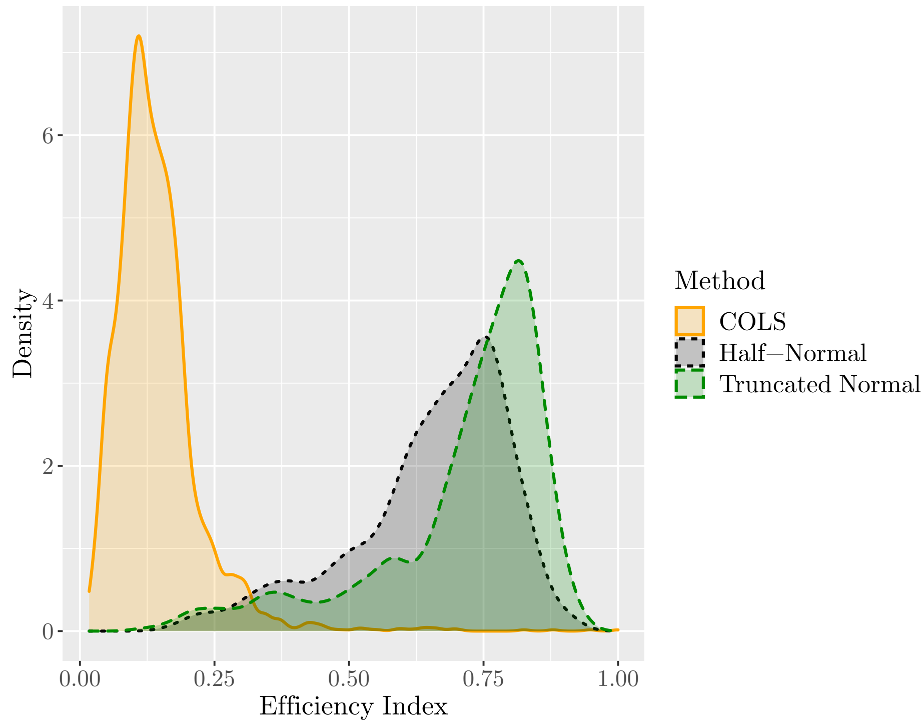


Note: Type 1 firms participate both in public auctions and auctions by invitation. Public Auc: type 1 denotes their efficiency index when participating under public auctions, and I3P Auctions denotes their efficiency index when participating in auctions by invitation. Public Auc: type 0 denotes the efficiency of firms that only participate in public auctions. The efficiency index is estimated by $E[\exp(-\eta_i)|\epsilon_i]$ and it ranges from 0 to 1. For interpretation purposes, a value of 0.6 denotes that the minimum cost is 60 percent of the actual cost.

B.3 Robustness analysis of the efficiency index: Truncated Normal vs COLS and Half-Normal

When estimating the SFA model, I estimate a corrected OLS (COLS) and a Half-Normal model as a robustness analysis. The full results are available upon request. In Figure 9 I display the efficiency indexes of these two estimates, along with the results from from the Truncated-Normal model. The COLS are very different, but this method is known to be especially sensitive to outliers. When estimating the model by maximum likelihood assuming a Half-Normal distribution of the inefficiency term, the results are similar to the model estimated using the Truncated-Normal specification. A Likelihood-Ratio test reveals that the Truncated-Normal model is the preferred specification.

Figure 9: Histogram - Efficiency index (COLS, Half-Normal and Truncated-Normal)



The efficiency index is estimated by $E[\exp(-\eta_i)|\epsilon_i]$ and it ranges from 0 to 1. For interpretation purposes, a value of 0.6 denotes that the minimum cost is 60 percent of the actual cost.

B.4 Robustness analysis of the efficiency index: model specification with scaling property

A comparison of the Truncated-Normal model with model specifications under the scaling property of Wang and Schmidt (2002), deserves further discussion. So far, under the Truncated-Normal specification, I have parameterized the mean of the inefficiency term as a function of external variables $\mathbf{w}$. Alternatively, Wang and Schmidt (2002) propose that the inefficiency term η may follow the form, $\eta_i \sim h(\mathbf{w}_i, \delta)\eta*$. With some abuse of notation, the function $h(\cdot) \geq 0$ does not represent the production function as above, but rather any observation specific non-stochastic function of the exogenous determinants of the inefficiency term, and $\eta* \geq 0$ is random variable, common to all observations. The authors call $h(\cdot)$ the scaling function, and $\eta*$ the basic distribution. Models with the scaling property are attractive because the shape of the inefficiency term η_i is the same for all firms, and $h(\cdot)$ scales the distribution. In comparison, for the Truncated Normal specification, where the mean of η is parameterized, each observation has a different truncation point.

As a robustness analysis, I fit two models that have the scaling property, a Truncated-Normal with the scaling property, as specified in Wang and Schmidt (2002), and a Half-Normal model with heteroscedasticity. Nevertheless, in order to achieve convergence, I need to restrict the translog specification of the frontier.

Table 9: Robustness analysis: comparing the Truncated-Normal with specifications with the scaling property

Specification restrictions			Marginal Effects	
Translog restrictions	Number of inputs	Type of firm	Dummy (1yr before elections)	Dummy (same party: mayor-governor)
Public Auctions				
Truncated Normal				
None	3	0.07	0.13	-0.09
None	2	0.09	0.12	-0.16
Truncated Normal with scaling property				
No quadratic	3	0.07	0.12	-0.17
Half-Normal				
No interactions	3	0.07	0.11	-0.18
No quadratic	3	0.07	0.11	-0.17
No interactions	2	0.05	0.10	-0.14
No quadratic	2	0.07	0.11	-0.18
Auctions by invitation (I3P)				
Truncated Normal				
None	3		-	-
None	2		0.08	-0.12
Truncated Normal with scaling property				
No quadratic	3		-	-
Half-Normal				
No interactions	3		0.07	-0.05
No quadratic	3		-	-
No interactions	2		0.07	-0.05
No quadratic	2		-	-

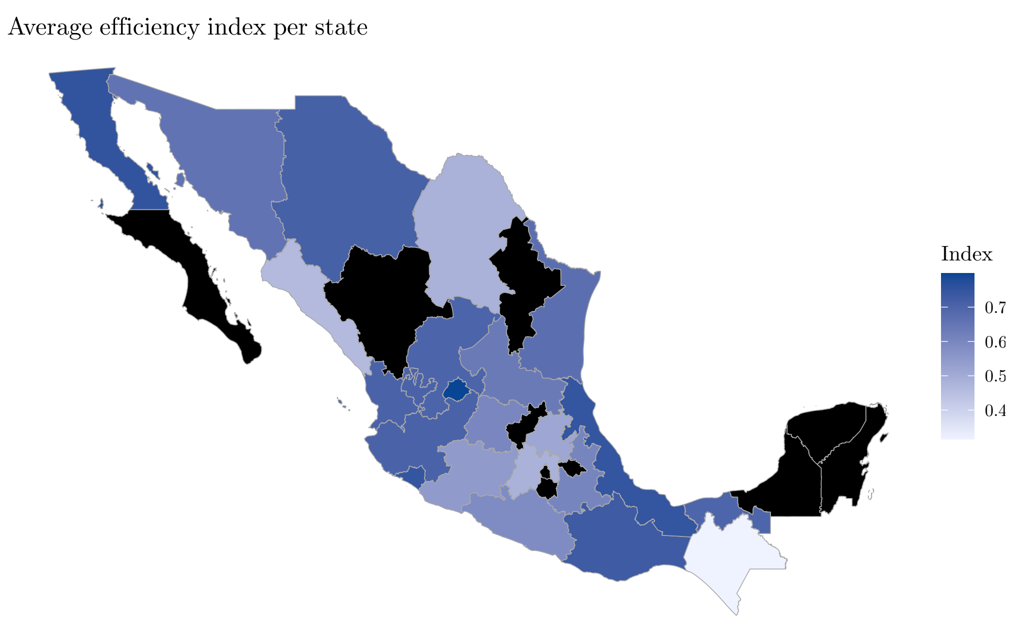
Note: the estimation of the missing rows did not converge. The marginal effects from the specifications with the scaling property are very similar to the estimates from the Truncated-Normal.

In Table 9, I present the estimates for various restrictions to the translog function and number of inputs used. The results displayed are the marginal effects of the exogenous determinants of inefficiency, the main estimates I am after. For comparison purposes, in the first two rows I display the Truncated-Normal estimates presented in section 4. As it can be seen from the analysis, the marginal effects vary little irrespective of the specification. Hence, my preferred model specification is the Truncated-Normal for two reasons: first, it does not require restrictions in the translog function, and second, the marginal effects are similar to the estimates from models with the scaling property.

B.5 Distribution of the efficiency index by state

In Figure 10 I aggregate the efficiency results estimated using public auctions. Following Sickles and Zelenyuk (2019), each firm's efficiency is weighted by their relative cost in their respective state. Overall, we see that the northern states are more efficient, along with the the states at the gulf. The state that fares the worst is Chiapas, in the south, consistent with the fact that it is a region that is hard to get into due to a difficult terrain.

Figure 10: Weighted average efficiency index per state



Note: States in black have no or less then 10 projects in the sample. The efficiency index is estimated by $E[\exp(-\eta_i)|\epsilon_i]$ and it ranges from 0 to 1. For interpretation purposes, a value of 0.6 denotes that the minimum cost is 60 percent of the actual cost.

C Cost estimates comparing auction mechanism

In Table 10 I present the cost estimates of the winning firms, both under public auctions and auctions by invitation (I3P). Given a fat tail in the cost distribution, I focus on the median estimates.

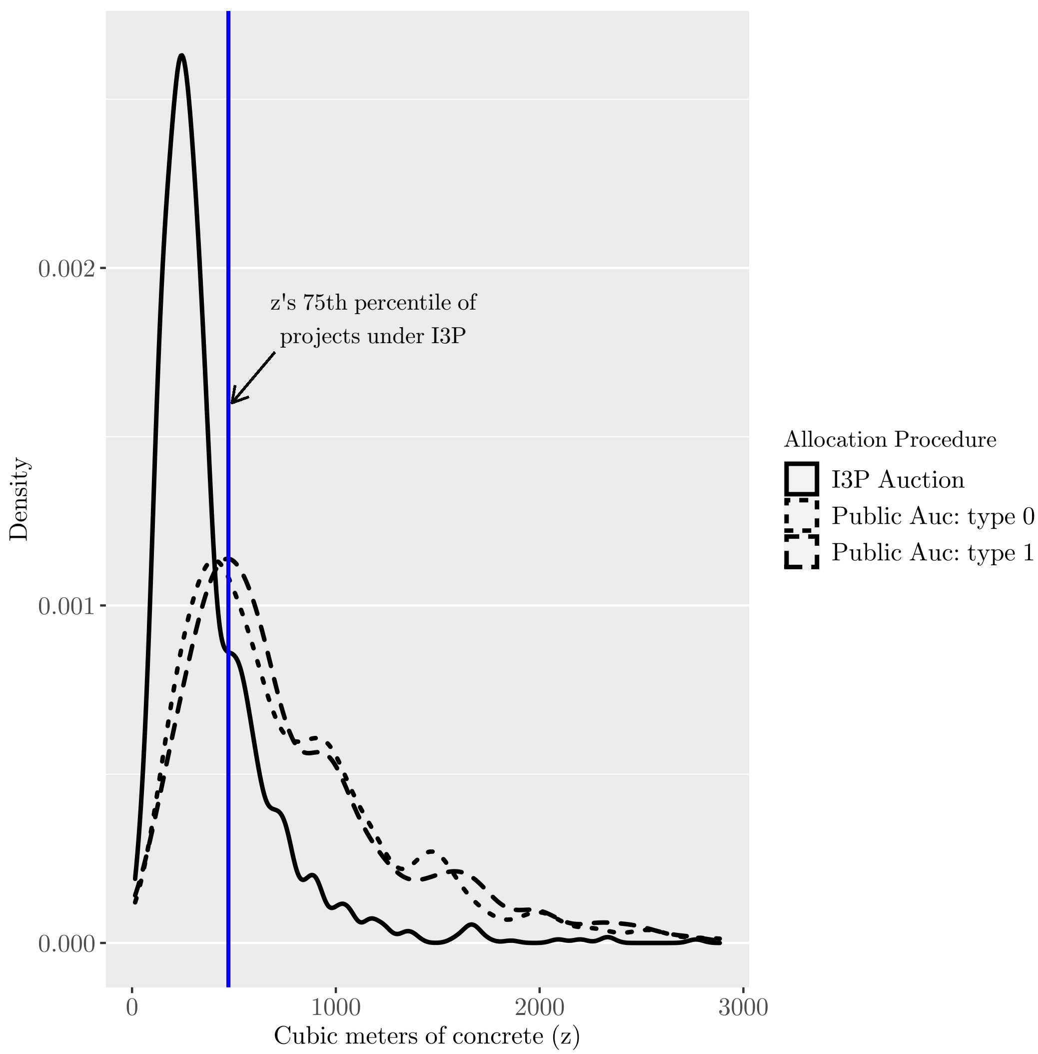
Table 10: Cost estimates

	Mean	Median	S.E.	Obs
Estimated firm's costs (thousands per m^3)				
Projects with sewage work				
Public auction: type 1, $\hat{c}_1$	10.813	8.304	(8.931)	256
Public auction: type 0, $\hat{c}_0$	11.538	9.005	(10.344)	631
I3P auction: type 1, $\hat{c}_{I3P}$	8.544	6.877	(7.050)	840
Projects without sewage work				
Public auction: type 1, $\hat{c}_1$	7.038	5.800	(5.606)	475
Public auction: type 0, $\hat{c}_0$	6.116	4.958	(4.209)	1115
I3P auction: type 1, $\hat{c}_{I3P}$	6.292	5.194	(5.041)	2302
Estimated winning firm's costs (thousands per m^3)				
Projects with sewage work				
Public auction: type 1, $\hat{c}_1$	10.337	8.398	(6.951)	61
Public auction: type 0, $\hat{c}_0$	10.827	7.347	(11.017)	59
I3P auction: type 1, $\hat{c}_{I3P}$	8.187	6.521	(6.619)	253
Projects without sewage work				
Public auction: type 1, $\hat{c}_1$	6.271	4.843	(5.418)	78
Public auction: type 0, $\hat{c}_0$	6.495	4.991	(4.552)	126
I3P auction: type 1, $\hat{c}_{I3P}$	6.104	4.994	(5.073)	734
Estimated firm's percentage returns (%)				
Projects with sewage work				
Public auction: type 1, $(b_1 - \hat{c}_1)/\hat{c}_1$	35.22%	16.92%	(40.82%)	61
Public auction: type 0, $(b_0 - \hat{c}_0)/\hat{c}_0$	24.73%	14.44%	(30.09%)	59
I3P auction: type 1, $(b_{I3P} - \hat{c}_{I3P})/\hat{c}_{I3P}$	36.65%	24.94%	(35.27%)	253
Projects without sewage work				
Public auction: type 1, $(b_1 - \hat{c}_1)/\hat{c}_1$	32.58%	17.15%	(41.18%)	78
Public auction: type 0, $(b_0 - \hat{c}_0)/\hat{c}_0$	28.99%	18.85%	(29.66%)	126
I3P auction: type 1, $(b_{I3P} - \hat{c}_{I3P})/\hat{c}_{I3P}$	39.48%	28.02%	(33.04%)	734

Note: $\hat{c}$ denotes the estimated cost, and b the observed bid.

The firms that participate under the I3P framework, overall, present a large advantage for projects with sewage work. Nevertheless, that advantage is not present for simpler projects without sewage work. Interestingly though, when we see the median percentage return, type 1 and type 0 firms have similar returns under public auction, but type 1 firms have higher returns under I3P. This pattern stands for both projects with and without sewage work, and is higher for the latter case. The fact that firms earn a higher return for project for which they are least efficient, is consistent with a corruption or collusion story among firms under I3P, but this analysis goes beyond the purpose of this paper.

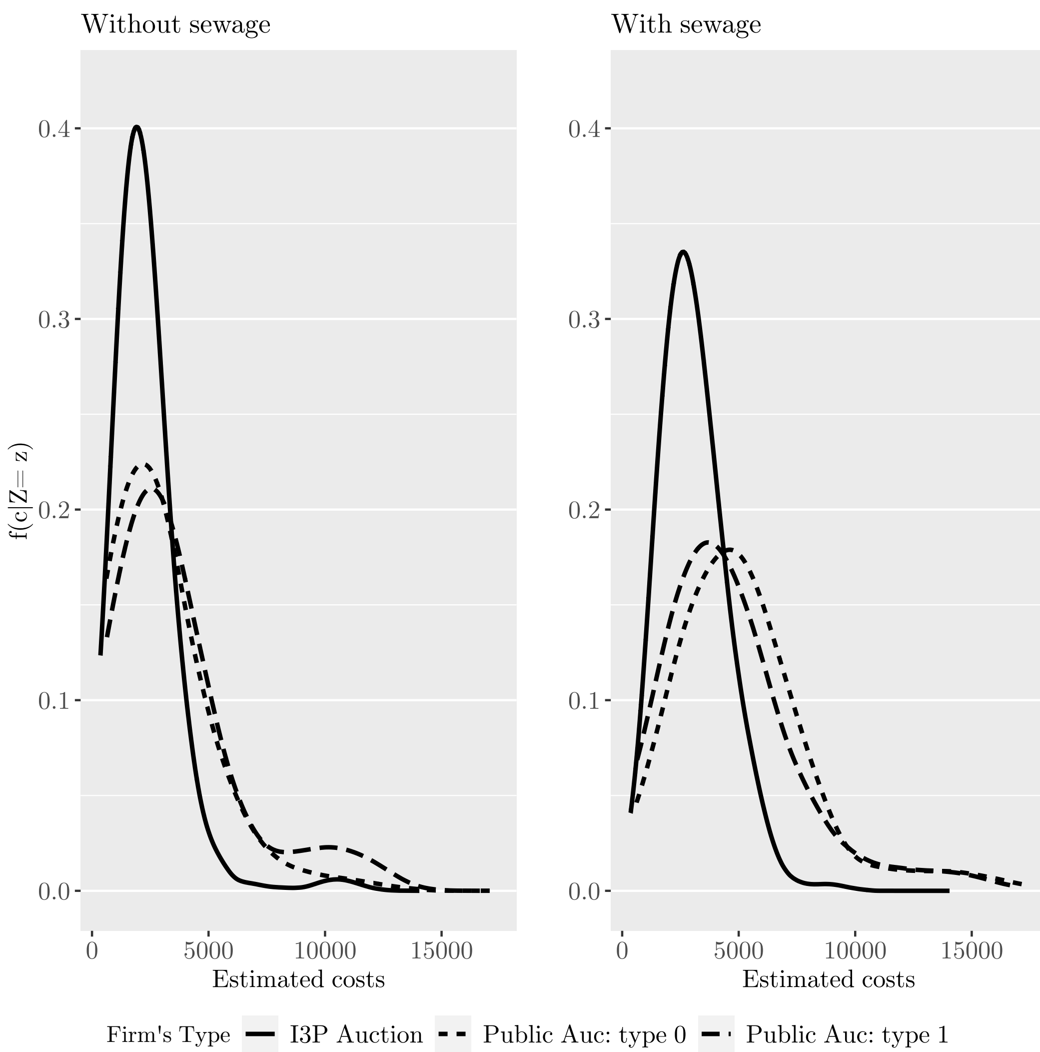
Figure 11: Density of the size of the project z, by allocation procedure



Type 1 firms participate both in public auctions and auctions by invitation. Public Auc: type 1 denotes their costs when participating under public auctions, and I3P Auctions denotes their costs when participating in auctions by invitation. Public Auc: type 0 denotes the cost of firms that only participate in public auctions.

In Figure 11, I plot z's distribution by allocation mechanism. As expected, when comparing type 1 to type 0 firms under public auctions, they participate in similar projects with type 1 firms taking part in marginally larger ones. The big difference comes when comparing projects allocated to I3P and public auction, with I3P projects being much smaller. The blue vertical line corresponds to z's 75th percentile of projects under I3P, amounting for 472.5 cubic meters of concrete, which is lower than the median project under public auctions that use 588.4 cubic meters of concrete.

Figure 12: Conditional cost density evaluated at z's 75 percentile of the projects under I3P



Type 1 firms participate both in public auctions and auctions by invitation. Public Auc: type 1 denotes their costs when participating under public auctions, and I3P Auctions denotes their costs when participating in auctions by invitation. Public Auc: type 0 denotes the cost of firms that only participate in public auctions.

Given the little overlap between z's distributions under I3P and public auctions, when comparing their cost distributions, I condition them on $z's$ 75th percentiles of projects under I3P. The conditional densities are found in Figure 12. Consistent with the results on Figure 3, projects under I3P have a lower costs on projects with sewage work, but this difference is reduced greatly for simpler contracts.