



DO AUCTIONS IMPROVE PUBLIC PROCUREMENT? EVIDENCE FROM THE CZECH REPUBLIC

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Abstract

This paper explores the effect of various contract-awarding procedures in public procurement on the price of the contract. We provide a theoretical model that compares prices in different procedures and tests whether there is a significant price difference between the procedures using data from Czech public procurement. The model predicts that auctions are more efficient than negotiations given the same number of suppliers, and open procedures are more efficient than closed procedures if high-cost firms are selected for the closed procedure. In accordance with the first prediction, we find that open auctions are more efficient than open negotiations. Concerning the second prediction, we find that closed procedures are less efficient than open procedures, which suggests that procurers tend to select relatively more costly firms to participate in closed procedures. Comparing all four awarding procedures, we find that open auctions are the most efficient procedure used in the Czech Republic. We estimate that the inefficiencies due to the use of other contract-awarding procedures are substantial.

Keywords

Auctions, Negotiations, Public Procurement, Contract-awarding Procedures

I. Introduction

Efficient public procurement plays a key role in modern economies, as it ensures the reduction of wasteful activities and saves taxpayers' money. The public procurement outlays of member states of the European Union are estimated to account for 16% of the

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European Union's GDP. It is, therefore, difficult to overestimate the importance of efficient public procurement in a modern economy.

The procurement contract is commonly awarded to the potential seller by one of four mechanisms: open auction, closed auction (i.e. an auction with a restricted number of suppliers who are chosen by the procurer), open negotiation, and closed negotiation. This raises the central question of the relative efficiency of different procurement-awarding procedures. This paper contributes to discussion of this problem by exploring whether different procurement procedures result in significantly different prices. In particular, we focus on the difference between auctions and negotiations and on the difference between open and closed procedures.

The difference between auctions and negotiations has been studied theoretically by Bulow and Klemperer (1996), who show that an auction with $N+1$ participants is always preferable for the seller to a negotiation with N participants. Applied to a procurement context, this result shows that, from the perspective of the agency, competitive procurement is preferable to negotiations with a single supplier, no matter how cleverly these negotiations are designed. On the other hand, some theoretical studies have highlighted the failures of open auction procedures and claim that negotiations or closed auction can be more efficient. An important issue in auctions is the traditional concern of competition policy – preventing collusive behavior. Marshall and Marx (2007) show that a cartel is stable in a one-shot first-price independent private value auction, where side payments among cartel members are permitted. Therefore, in order for auctions to be an efficient mechanism, it is essential that the market is not collusive. Bajari and Tadelis (2001) argue that more complex transactions will likely be plagued by ex post adaptations, and these are best administered with negotiations. In contrast, simple transactions are best served by auctions, which induce strong cost-reducing incentives. There are several papers that study price differentials between auctions and negotiations in specific industries, but the evidence is mixed. Kjerstad (2005) studied the price differentials in procurements of medical equipment. He shows that auctions do not yield significantly lower prices than negotiations. A similar conclusion was reached by Vellez (2011) based on data from the Italian healthcare sector. Lalive and Schmutzler (2011) use data from the public procurement of the regional passenger railway service in Germany, and they claim that auctions result in significantly lower prices than negotiations.

In addition, the literature on the effect of closed and open procedures is inconclusive. The auction literature emphasizes the efficiency properties of auctions with many bidders as a means to introduce competition and decrease the procurer's expenditure. However, Heijboer and Telgen (2002) and Bajari et al. (2009) show that some procurers deliberately choose to restrict the number of competing firms or even engage in negotiations with a single candidate. Levin and Smith (1994) offer a theoretical explanation for this practice. They present a model of auction in which each potential bidder has the same entry costs. Equilibrium in the model is given by a mixed strategy in which each bidder enters the auction with some probability and incurs the entry cost. Levin and Smith (1994) then show that it may be beneficial for the auctioneer to invite a smaller but fixed number of bidders than to rely on free entry which produces a stochastic number of bidders. This

conclusion is confirmed by Li and Zheng (2009), who present a more general auction model and show that a higher number of potential bidders may result in less aggressive behavior and a higher price for the procurer. The difference between open and closed procedures therefore remains an empirical question. The empirical literature investigating the effect of competition focuses on the auctions with a common value aspect. Hong and Shum (2002) investigated procurement auctions for road construction and paving held by the state of New Jersey in order to assess the effect of higher competition. They found that the median procurement price increases with competition due to the winner's curse effect. In this paper, we investigate price differentials among the four procurement-awarding procedures using data from Czech public procurement contracts from 2006 to 2014. In order to be able to interpret the results, we also developed a simple theoretical model that compares the prices obtained in the four procurement-awarding procedures. In addition to the existing literature, the theoretical model includes the assumption that by restricting competition, the procurer may influence not only the number of suppliers but also their efficiency. In the closed procedure, the procurer may invite more or less efficient suppliers into the contract-awarding procedure. The difference between open and closed procedures then depends not only on the number of suppliers but also on whether the procurer chooses suppliers with higher or lower costs. In the empirical analysis, we estimate an econometric model in order to compare the prices of the different contract-awarding procedures and test the predictions of the theoretical model. In contrast to the existing literature, we used data from various industries. Therefore, our conclusions are more general in the sense that they do not depend on the specific characteristics of a particular industry.

II. Theoretical model

The theoretical model consists of one procurer and potentially many suppliers or bidders. We index suppliers by $i = 1, \dots, N$. Let S denote the set of suppliers and N denote the number of suppliers. Every supplier i observes some private information $c_i \in [\underline{c}, \bar{c}]$. The parameter c_i denotes the costs of the particular supplier. Each individual parameter c_i is independently distributed according to the uniform distribution. The corresponding cumulative distribution function is therefore $F(c_i) = (c_i - \underline{c})/(\bar{c} - \underline{c})$. The vector $c = (c_1, \dots, c_n)$ is the profile of suppliers' types. Let P denote the price paid by the buyer for the good. The seller's preferences are defined as follows. She obtains the payoff $P - c_i$ if she is chosen to supply the good, and she obtains zero payoff if she is not chosen. The procurer's preference is lexicographic. It means that the procurer is willing to buy the good at whatever price or, in other words, that the disutility of not buying the good is prohibitively large. Only when the good is bought does the procurer start comparing the prices of the good, preferring the lowest prices possible. In particular, we suppose that his preferences are given by the utility function $u(P) = \bar{c} - P$ if the good is bought.

We consider two types of contract-awarding procedures: auction and negotiation. Auction is modelled as a first-price procurement auction with independent private values. Negotiation is modelled as a sequential bidding system of take-it-or-leave-it offers. In the negotiation, the procurer first chooses a supplier and presents a price offer. If the supplier

accepts the price, a contract is concluded. If she declines, the procurer will make a new offer to another supplier. Bargaining continues until either one of the suppliers accepts the offer made to her, or all of them decline, in which case no procurement will be made.

First-price auction

In the first-price auction, each supplier submits a sealed bid b_i . Because the distribution of costs is uniform, it is common in auction theory to suppose that the bidders follow symmetric equilibrium strategies that have a linear form $\beta(c_i) = ac_i + b\bar{c}$. Now, we have to find coefficients a and b and show that the profile of strategies forms Bayes-Nash equilibrium. Supplier i wins the auction if she submits the lowest bid, that is whenever $b_i < \beta(c_j)$ for all $j \neq i$. The expected payoff of bidder i can therefore be written as $(b_i - c_i)(1 - F(\beta^{-1}(b_i)))^{N-1}$. By maximizing this payoff, we derive the best response function of bidder i , which is

$$b_i = \frac{\bar{c}(a + b) + c_i(N - 1)}{N} \quad (1)$$

At a symmetric equilibrium it has to hold that $b_i = \beta(c_i)$ which yields the following solutions for coefficients $a = 1/N$ and $b = (N - 1)/N$. After substituting into the best response function (1), we get the equilibrium strategy of seller i which is given as follows

$$\beta(c_i) = \frac{\bar{c} + (N - 1)c_i}{N} \quad (2)$$

In the first-price auction, the expected price is given by the bid from the bidder with the lowest costs. The expected value of minimum cost among N sellers is $c_{min} = (\bar{c} + N\bar{c})/(N + 1)$. By substituting this value into the equilibrium strategy (2), we get the expected price paid by the procurer in the first-price auction

$$P_{\text{auction}}(N) = \frac{2}{N + 1}\bar{c} + \frac{N - 1}{N + 1}\bar{c} \quad (3)$$

Negotiation

Now, we derive the equilibrium and the expected price in the negotiation procedure. For a fixed order of suppliers, we denote the sequence of prices the procurer is offering to the suppliers as $(b_n, \dots, b_1)$. If the first supplier accepts a take-it-or-leave-it offer b_n , then the good is tendered to the first potential supplier and the game ends. If it is rejected, then another offer b_{n-1} , is made to the next supplier. This process continues until one supplier accepts the offer. If no supplier accepts the offer, then no trade takes place. Let V_n denote the procurer's expected payoff if she negotiates with N sellers and behaves optimally.

This game has a unique subgame perfect equilibrium outcome. Subgame perfection requires a supplier to accept the offer whenever his expected payoff is strictly positive. In any

subgame in which the supplier receives an offer b_i , the supplier's best response is to accept the offer if $b_i > c_i$, and reject it if $b_i < c_i$. When $b_i = c_i$, the seller is indifferent, but this occurs with zero probability. This mechanism generates a unique subgame perfect equilibrium outcome characterized by trade with the first supplier if his cost lies below the offer b_n , with the second if the first supplier's cost lies above b_n , and the second supplier's cost lies below b_{n-1} , and so on.

The sequence of offered prices can be found by backward induction. Consider first the last subgame where there is only one supplier left. Because the procurer has lexicographic preferences, she does not want to risk not buying the good, and therefore offers $b_1 = \bar{c}$. The supplier accepts the offer and procurer's expected payoff V_1 is equal to zero. The solution to the procurer's problem in the preceding subgames can be expressed recursively. Consider the subgame where the procurer gives the offer to the seller i . The procurer chooses b_i in order to maximize his expected payoff

$$U(b_i) = (\bar{c} - b_i)F(b_i) + (1 - F(b_i))V_{i-1} \quad (4)$$

In the subgame with two sellers, the procurer offers price b_2 in order to maximize his payoff $U(b_2) = (\bar{c} - b_2)F(b_2)$. Solving this problem yields the optimal price $b_2 = (\bar{c} + \underline{c})/2$ and the procurer's expected payoff $V_2 = (\bar{c} - \underline{c})/4$. Suppose therefore that the expected payoff is a linear function of the difference between maximum and minimum possible costs, i.e. $V_{i-1} = \alpha_{i-1}(\bar{c} - \underline{c})$. By maximizing the payoff function $U(b_i)$ with respect to b_i , we obtain the optimal price in subgame i , which is given as

$$b_i = \frac{(1 - \alpha_{i-1})\bar{c} + (1 + \alpha_{i-1})\underline{c}}{2} \quad (5)$$

By substituting the optimal price into the expression (4), we get the procurer's expected payoff from the negotiation with i players:

$$V_i = \left(\frac{1 + \alpha_{i-1}}{2} \right)^2 (\bar{c} - \underline{c}) \quad (6)$$

We can see that the procurer's expected equilibrium payoff is given by the recursive formula $V_i = \alpha_i(\bar{c} - \underline{c})$ where $\alpha_i = (1 + \alpha_{i-1})^2/4$ and $\alpha_1 = 0$. By definition of the procurer's utility function, we know that the equilibrium payoff is equal to the difference between maximum costs and expected negotiated price, i.e. $\alpha_N(\bar{c} - \underline{c}) = \bar{c} - P(N)$. It follows from this equation that the expected price in negotiation with N sellers $P_{neg.}(N)$ is given by the following formula

$$P_{neg.}(N) = \alpha_n \underline{c} + (1 - \alpha_n) \bar{c} \quad (7)$$

Model predictions

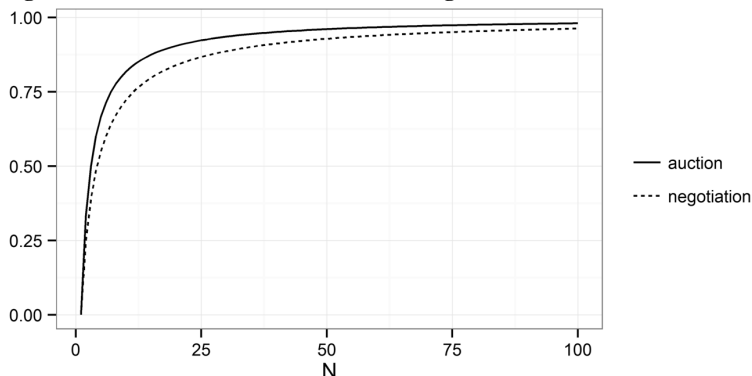
The model gives several predictions concerning the difference between the contract-awarding procedures. We present the predictions in terms of two measures that play a distinct role in the following empirical analysis. The first measure is the difference between the expected price and maximum cost divided by the maximum cost. We call this variable price margin and we denote it as $M(N)$. Note that price margin is always non-positive. The absolute value of the price margin measures how much as a percentage the procurer paid less compared to the maximum cost. The second important measure is the change in the price margin induced by the entrance of an additional supplier into the procurement. We call this variable the marginal supplier's contribution and we denote it as $C(N)$.

Consider first the difference between the open auction and the open negotiation. In both types of procurement procedure the expected price can be written as a convex combination of minimum and maximum cost, i.e. $P(N) = \delta_n \underline{c} + (1 - \delta_n) \bar{c}$ where the coefficient δ_n is different for auctions and negotiations. If we substitute this expression into the price margin, we get the following expression for the price margin:

$$M_{open}(N) = \frac{P(N) - \bar{c}}{\bar{c}} = \delta_n (\underline{c}/\bar{c} - 1) \quad (8)$$

The price margin depends on the coefficient δ_n and on the ratio between the maximum and minimum cost, which measures the degree of suppliers' heterogeneity. The degree of suppliers' heterogeneity is the same in both procurement procedures and the margin therefore depends only on the coefficient δ_n . Obviously, higher values of coefficient δ_n imply lower margins. Note that a lower margin implies a lower price because the margin is non-positive. As the coefficient δ_n approaches one, the expected price approaches the minimum cost. Figure 1 shows the value of the coefficient δ in auction and negotiation for a different number of suppliers. The value of the coefficient for auctions is always higher than the value of the coefficient for negotiations. This implies the first prediction of the model: the price margin in auctions is lower than the price margin in negotiations given the same number of suppliers. This means that auctions generate a lower contract price than negotiations and are, therefore, more efficient for the procurer.

Figure 1: Coefficients δ_n for auction and negotiation



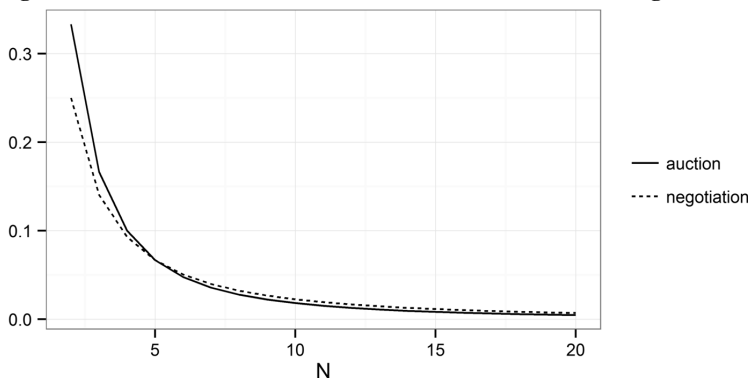
Source: Author's own calculation

The marginal supplier's contribution in the open procurement can be written as follows:

$$C_{open}(N) = M(N) - M(N - 1) = (\delta_n - \delta_{n-1}) (\underline{c}/\bar{c} - 1) \quad (9)$$

The marginal seller's contribution depends only on the difference between coefficients δ_n and δ_{n-1} . Figure 2 shows how the value of the difference $\delta_n - \delta_{n-1}$ in auctions and negotiations depends on the number of suppliers. We can see that the marginal supplier's contribution is decreasing in both procedures. Moreover, the marginal supplier's contribution is higher in auction, if the number of suppliers is small enough. In our particular case, it has to be less than five.

Figure 2: Difference of coefficients $\delta_n - \delta_{n-1}$ for auction and negotiation



Source: Author's own calculation

Now we focus on the difference between the open and closed contract-awarding procedure. In a closed procedure, the procurer invites potential sellers into the contract-awarding procedure. She can therefore influence the degree of the suppliers' heterogeneity. If the procurer chooses the potential suppliers randomly, then there will be no difference between

the open and closed procedure with the same number of suppliers. Suppose, on the other hand, that the procurer chooses suppliers that are more effective than the rest of the sellers. In particular, we assume that the procurer never invites a seller with the cost higher than c^l where $c^l < \bar{c}$. In this case, the margin and the marginal seller contribution are given by the following formulas:

$$M_{low}(N) = \frac{(\delta_n \underline{c} + (1 - \delta_n) c^l)}{\bar{c}} \quad (10)$$

$$C_{low}(N) = (\delta_n - \delta_{n-1}) \left(\frac{\underline{c} - c^l}{\bar{c}} \right) \quad (11)$$

It holds that $M_{low} < M_{open}$, which implies that the margin and the contract price in the closed procedure is lower than the margin and the price in the open procedure if the procurer invites low-cost suppliers. The closed procedure is therefore more efficient for the procurer. If we compare the marginal supplier's contribution, we can see that the marginal supplier's contribution is higher in the closed procurement than in the open, $C_{low} > C_{open}$. Because both values are negative, the presence of an additional supplier lowers the price more in the open procurement than in the closed procurement ($|C_{open}| > |C_{low}|$). Finally, we examine a situation where the procurer selects suppliers that are less effective than the rest of the suppliers. Suppose that the procurer never invites a supplier that has a lower cost than c^h where $c^h > \underline{c}$. The margin and the marginal supplier's contribution are then given by the following formulas:

$$M_{high}(N) = \frac{(\delta_n c^h + (1 - \delta_n) \bar{c})}{\bar{c}} \quad (12)$$

$$C_{high}(N) = (\delta_n - \delta_{n-1}) \left(\frac{c^h - \bar{c}}{\bar{c}} \right) \quad (13)$$

If we compare the margin and marginal supplier's contribution in the open procurement and in the closed procurement with high cost suppliers, we get the following results. Firstly, it holds that $M_{high} > M_{open}$, which implies that the open procurement procedure is more efficient if the procurer invites high-cost suppliers. Secondly, the marginal supplier's contribution in the open procurement is lower, $C_{high} > C_{open}$. This shows that the presence of an additional supplier lowers the price more in the open procurement than in the closed procurement with high cost suppliers.

III. Data

We used data from the official public procurement database (Czech Bulletin of Public Procurement⁴) administered by the Czech Ministry for Regional Development. Our dataset consists of all valid public procurements of ordinary goods and services (form 3 in the database) published in the database from January 2006 to December 2014.

⁴ The web interface of the database is available at <http://www.vestnikverejnýchzakazek.cz>.

Data preparation

Our observations consist of individual procurement projects. If a project (and hence its database record) consisted of several parts, we divided it into these parts. Therefore, our observations on procurement are for these individual parts.

For each observation, we have the following values: 1) the identification of the procurement (identification numbers of the contract and its part), 2) the year when the procurement was awarded and when it was published in the public procurement database, 3) the price of the contract expected ex ante by the procurer and the ex post price of the contract, 4) the type of the contract-awarding procedure (open auction, closed negotiation, open negotiation, and closed auction; other types were eliminated because their share in the data was negligible), 5) the type of procurer (public body, ministry, national agency, regional agency, regional authority, and other; the category “other” includes procurers of the type denoted as other by the database, procurers of unknown type, and EU institutions; there are only seven observations for EU institutions in the database), 6) the CPV (Common Procurement Vocabulary) code of the procurement describing what kind of industry supplied the particular good, and 7) the number of suppliers.

For each observation, we calculated the price ratio equal to true ex post price / price expected ex ante (the price ratio is below one when the ex post price of the contract is lower than expected, and vice versa) and the price margin equal to $(\text{price ratio} - 1) \times 100$. The price margin measures the percentage difference between the price expected ex ante and the ex post price (e.g. the price margin equal to -5 means that the ex post contract cost is 5% lower than expected). We divided auctions into industry types according to the first two digits of the CPV codes, creating the broadest usable industry classification.

Our original dataset consisted of 122,091 observations on procurement parts. However, some of these observations had to be eliminated for the following reasons. Firstly, some procurers disregarded the official database structure and filled individual bids as parts of the offered contract. When we detected this mistake, we eliminated all the bids except the lowest one (which is supposed to win). This correction reduced the size of our data set to 103,786 observations.

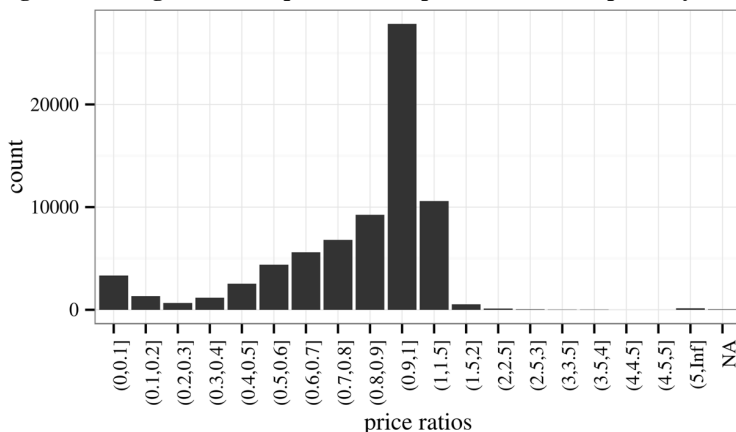
Secondly, some observations were not complete or were obviously wrong. We eliminated all observations where any measured variable was either missing or obviously wrong, or where the number of suppliers was equal to zero (since such contracts could not have been awarded). This elimination reduced our data set to 81,828 observations.

Thirdly, we eliminated unusual contract-awarding procedures, leaving only the four most common ones (open auction, closed negotiation, open negotiation, and closed auction), because the available data are not sufficient for the reliable estimation of contracts with other types of awarding procedures. For the same reason we also eliminated procurements with industry types for which we had less than 500 observations (we control for the industry type in our econometric models). These eliminations reduced our data set size to 74,517 observations with 24 industry types.

Fourthly, some price ratios were unreasonably high (sometimes in millions or even infinite) or low (sometimes in millionths), see Figure 3. This typically happens when the procurer filled in the price expected ex ante and the corresponding ex post price in different units

of measurement, e.g. when she stated the expected price for the whole service project and the ex post price as an hourly wage of the service providers. To avoid such distortion, we eliminated all observations with price ratios below 0.25 or above 5. This seems to eliminate the worst mistakes while retaining most of the data. This last correction resulted in the final working dataset consisting of 69,362 observations.

Figure 3: Histogram (non-equidistant) of price ratios in the partially restricted dataset



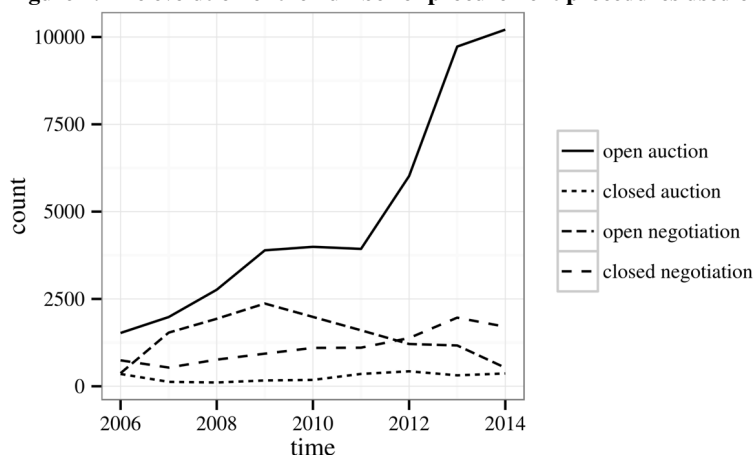
Source: *Czech Bulletin of Public Procurement*

Basic facts about public procurement in the Czech Republic

Before proceeding to the results, it is useful to present the basic facts about public procurement in the Czech Republic, in particular the distribution of the price margins, the frequency of the use of the individual contract-awarding procedures, and how the number of suppliers depends on the contract-awarding procedures being used. The distribution of the price ratios (before the trimming described in the previous section) is presented in Figure 3. It shows that most ex post contract prices are lower than expected. Most often, the ex post prices are only slightly lower than expected, but there are also many cases when the ex post prices are only small fractions of the expected prices. However, there are also many cases when the ex post prices are higher than expected.

Figure 4 shows the evolution of the frequencies of the individual contract-awarding procedures over time in our dataset. The open auction has been used most often in the whole period, and its share continues to rise. The second most often used procedure in most years was the open negotiation. The importance of this procedure has decreased significantly in the latest years. The third most important procedure is the closed negotiation. The frequency of this procedure has recently risen.

Figure 4: The evolution of the number of procurement procedures used over time



Source: Czech Bulletin of Public Procurement

Table 1 shows that all types of procurers use all types of contract-awarding procedures, although in slightly varying shares. Most public contracts are procured by regional authorities, public bodies, and ministries.

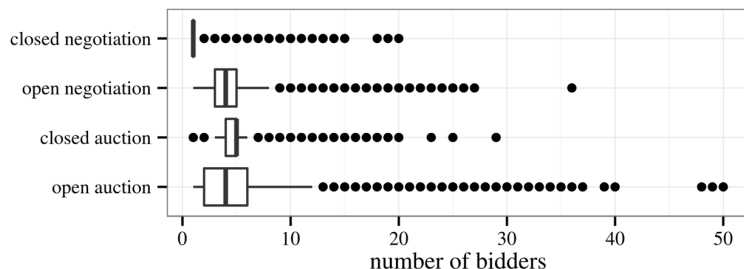
Table 1: The structure of procurement procedures used by various procurers

	open auction	closed auction	open negotiation	closed negotiation	Total
other	5,768	343	1,149	1,610	8,870
public body	11,245	196	2,289	1,760	15,490
ministry	6,891	129	1,351	2,001	10,372
national agency	4,326	161	1,421	1,111	7,019
regional agency	2,767	277	1,664	974	5,682
regional authority	13,045	1,288	4,830	2,766	21,929

Source: Czech Bulletin of Public Procurement

Figure 5 shows the distribution of the number of suppliers for each contract-awarding procedure. The most participants are, on average, present in closed auctions (5.3), then in open auctions (4.92), and open negotiation (4.49). With a large gap, the fewest suppliers are present (i.e. are invited) in closed negotiations (1.47). However, since the dispersion of the number of suppliers differs drastically among the contract-awarding procedures, the mean does not tell the whole story. The box plot shows that there are many open auctions in our data set with very few suppliers; however, there are also many open auctions with a large number of suppliers there – many more than in any other contract-awarding procedure.

Figure 5: Number of suppliers in individual contract-awarding procedures



Source: Czech Bulletin of Public Procurement

IV. Results

To assess the relative performance of the four contract-awarding procedures used in public procurement in the Czech Republic, we estimated several econometric models. We used the price margin defined above as the dependent variable because it has an intuitive meaning: how much (as a percentage) the procurer paid more or less than expected (a positive price margin means paying more) because of the use of a particular contract-awarding procedure. It also directly corresponds to the variable M derived in the theoretical model. To be able to interpret the price margin in this way, we assume that procurers set their price expected ex ante in a systematic way. This assumption is quite realistic for public procurers because they have to follow appraisal rules set out by the law or public authorities.

The theoretical model presented in section 2 showed that the price margin depends not only on the contract-awarding procedure but also on the heterogeneity of suppliers. Since the heterogeneity of suppliers as well as appraisal rules can vary depending on the type of supplying industry, we have to control for industry type. We use the industry type (the first two numbers of the CPV code) for this purpose. We also have to control for the year when the contract was awarded because the supplier's cost of various goods and services may vary over time, while the appraisal rules may not fully adjust to these changes. The major source of the price fluctuations in our data sample seems to be the great recession that occurred within the investigated time period. We use the year when the contract was published in the official database as the control because the date of contract-awarding is unreliable (especially in the earlier years, the procurers filled the date in many mutually incompatible formats, and hence the date cannot be always interpreted unambiguously). This substitution seems to be quite secure because the time lag between the awarding of the contract and publishing it in the official database is negligible for our purposes.

Table 2: Regression models; controls for years and CPV divisions are omitted to save space; ON stands for the open negotiation, CA for the closed auction, and CN for the closed negotiation; (* $p < 0.1$; ** $p < 0.05$; * $p < 0.01$)**

	(1)	(2)	(3)	(4)
open negotiation	3.924*** (0.246)	3.548*** (0.248)	1.572*** (0.238)	2.947*** (0.411)
closed auction	13.514*** (0.484)	13.244*** (0.484)	10.821*** (0.463)	10.441*** (0.982)
closed negotiation	15.140*** (0.262)	14.999*** (0.262)	6.518*** (0.271)	6.023*** (0.374)
body public		−0.660** (0.314)	0.002 (0.300)	−0.014 (0.300)
ministry		−4.603*** (0.342)	−3.357*** (0.327)	−3.330*** (0.327)
national agency		1.021*** (0.369)	0.659* (0.353)	0.646* (0.353)
regional agency		−0.134 (0.387)	−0.207 (0.369)	−0.215 (0.369)
regional authority		−1.270*** (0.291)	−0.673** (0.278)	−0.674** (0.278)
number of suppliers			−2.132*** (0.026)	−2.111*** (0.028)
ON * no. of suppliers				−0.307*** (0.074)
CA * no. of suppliers				0.067 (0.163)
CN * no. of suppliers				0.370** (0.158)
Constant	−4.084*** (0.839)	−2.896*** (0.866)	4.686*** (0.832)	4.308*** (0.837)
Observations	69,362	69,362	69,362	69,362
R ²	0.126	0.130	0.206	0.206
Adjusted R ²	0.125	0.129	0.206	0.206

Source: Author's own calculation

The parameter estimates of the econometric models are presented in Table 2. Models (1) and (2) are the basic estimates of the performance of the contract-awarding procedures. The contract-awarding procedures are included as dummies (the contrast is the open auction). We control for the year and CPV division (model 1) and also for the procurers' type (model 2; "other" procurers are the contrast). Both models show that all other contract-awarding procedures perform worse than the open auction: open negotiation raises the true ex post price in comparison with the open auction in average by about 4% of the ex ante expected price, the closed auction by 13%, and the closed negotiation by 15%. All the differences are statistically significant. Models (1) and (2) also suggest that the open procedures lead on average to lower prices than the closed procedures. On average, auctions also lead to lower prices than negotiations. However, it is more important for the performance of the contract-awarding procedure if the procedure is open than if the contract is awarded by auction or negotiation.

Model (2) shows that the results of model (1) are robust. Moreover, it also shows that not all procurers are equal. In particular, ministries are able to get much better price margins than other entities, while the national agencies get worse price margins than other entities. However, this finding must be interpreted carefully. It can either mean that ministries are better at setting auctions and carrying out negotiations than other agencies, or that their prices expected ex ante are biased upward relative to the estimates of the other agencies; the opposite holds true for the national agencies.

Model (3) confirms the theoretical prediction, as it shows that the average price margin in auctions is lower than the price margin in negotiation even if we control for the number of suppliers. The model shows that an increase in the number of suppliers decreases the price margin.

Model (4) allows for different marginal effects of the number of suppliers for the individual contract-awarding procedures (the contrast is the open auction again). The impact of an increase of the number of suppliers is higher in the open procedures than in the closed ones: it is highest in open negotiation than in the open auction and closed auction (the latter has a somewhat lower impact but the difference is statistically insignificant), and is lowest in the closed negotiation.

Model (4) also allows for comparison of the performance of the individual contract-awarding procedures, given the same number of suppliers. The first three models' parameters present how much the individual contract-awarding procedures increase the ex post price (as a percentage) in comparison with the open auction when the number of suppliers is zero. However, it seems more reasonable to evaluate the procedures' performance at a number of suppliers equal to 5, which is about the average number of suppliers for all the procedures except the closed negotiation. The open auction is still the best available procedure. When the number of suppliers is equal to 5, the open negotiation raises the ex post price by 1.41% in comparison with the open auction (the difference is statistically significant at any reasonable confidence level), the closed negotiation by 7.87%, and the closed auction by 10.77% (or 10.44% if we set the statistically insignificant interaction term to zero). The seemingly superior performance of the closed auction to the closed negotiation in models (1) and (2) is thus caused by a much higher number of suppliers in the first procedure in comparison with the latter one: the average number of suppliers in closed auctions is 5.3, while in the closed negotiations it is only 1.47.

Next, we used our theoretical model to interpret the empirical results. The theoretical model gives three predictions. First, it predicts that the average price in auctions will be lower than the average price in negotiations, given the same number of suppliers. Our results support the predictions of the theory in the case of open procedures. In the case of closed procedures, the results show that negotiations are more efficient than auctions. This may suggest that the procurers invite less efficient suppliers into the closed auctions than closed negotiations.

Second, the theoretical model predicts that the effect of an additional supplier will be the same in open and in closed procedures if, and only if, the suppliers are selected randomly. The effect of closed procedures on procurement prices depends on whether the procurer invites more or less efficient suppliers, if the number of suppliers is the same. If the procurer invites more efficient sellers, than the average price will be lower and the effect of an additional seller will be lower compared to the open procedure. If the procurer invites less efficient sellers, than the average price will be higher but the effect of an additional seller will be lower compared to the open procedure. Since the marginal effect of an additional supplier is lower in closed negotiations than in the closed auctions, we can conclude that the procurers do not select the suppliers randomly. Furthermore, since the ex post prices are, on average, higher in the closed negotiations than in the open ones, we can conclude

that the procurers invite less efficient suppliers. The same might also hold true for the closed auctions, but the evidence is weaker here since the interaction term is positive but statistically insignificant.

V. Estimated loss due to the use of inefficient procurement procedures

The evidence presented confirmed the theoretical prediction that the open auction is, *ceteris paribus*, the most efficient procurement procedure used by public procurers in the Czech Republic. However, Czech public procurers often use other less efficient procedures (see Figure 4). One might wonder how much they have lost due to their use. The available data do not allow us to calculate the exact losses; however, we can guess their order of magnitude by a simple calculation. We used the fact that the first three regression parameters of model (2) show how much of a percentage of the price expected *ex ante* was lost due to the choice of the particular contract-awarding procedure. Thus we can estimate the hypothetical loss on each contract as $P_j^e \times \pi(x_j)$ where P_j^e is the price of contract j expected *ex ante*, x_j is the contract-awarding procedure used in the contract j , and $\pi(x)$ is the regression parameter for the procedure x (it is zero for the open auction). This calculation assumes that 1) the number of suppliers is endogenous to the contract-awarding procedure, 2) the open auction could have been used in all procurements, and 3) the procurers' cost for each procurement procedure is the same. In this manner, we get the estimated total loss on our working data sample for the years 2006 to 2014 as 96 billion CZK. This estimate is very crude and is likely to overestimate the actual losses on our working dataset. On the other hand, it does not count the procurements we eliminated from our working dataset. Still, it suggests that the losses due to the use of inefficient contract-awarding procedures may be substantial.

VI. Conclusion

We have contributed to the literature in two ways. We developed a simple theoretical model that compares the efficiency of the four procurement-awarding procedures: open auction, closed auction, open negotiation and closed negotiation. We assumed that in closed procedures the procurer may choose not only the number of suppliers, but may also select suppliers with high or low costs. We also tested the predictions of the model on data from Czech public procurement contracts from 2006 to 2014.

The main findings of this paper are: firstly, open auctions are more efficient for the procurer than open negotiations if the number of suppliers is the same in both procedures. This result is in accordance with the prediction of our model. In addition, open auctions are also more efficient than open negotiations if evaluated with the actual number of suppliers. Secondly, our model predicts that, with the same number of suppliers, closed auctions should be *ceteris paribus* more efficient than closed negotiations. The data do not support this conjecture. The reason might be that procurers choose on average more costly suppliers in closed auctions than in closed negotiations. However, closed auctions

are more efficient than closed negotiations with the actual number of suppliers, which is much higher in closed auctions than in closed negotiations. Thirdly, our model predicts that closed procedures can be more or less efficient than open procedures, depending on whether procurers choose relatively less or more costly suppliers for closed procedures. Our finding that closed procedures are less efficient compared with open procedures suggests that procurers tend to select relatively more costly firms.

Even though it is possible, in theory, that closed procedures outperform open procedures under some conditions, our empirical findings suggest that open auctions are the most efficient contract-awarding procedure used in the Czech Republic. We also tried to quantify the inefficiencies due to the use of other contract-awarding procedures. Using only the procurement contracts from our working data subsample, we found efficiency losses in the order of tens of billions of CZK.

There are some limitations to the results presented. We assumed that neither the quality provided by suppliers, nor additional payments over and above the contracted prices (e.g. due to ex post adaptations) differ systematically among the contract-awarding procedures. If there were such systematic differences, they might have justified the use of the seemingly less efficient negotiations and closed procedures. However, since neither data on quality, nor on extra payments are available, we cannot test this hypothesis and have to leave it to further research.

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