SÜMEYRA ATMACA
University of Ghent

RICCARDO CAMBONI
University of Padova

ELENA PODKOLZINA
HSE-NRU

KOEN SCHOORS
University of Ghent

PAOLA VALBONESI
University of Padova and HSE-NRU

SETTING RESERVE PRICES IN REPEATED PROCUREMENT AUCTIONS

October 2022
Marco Fanno Working Papers – 289

Department of Economics and Management "Marco Fanno"
University of Padova
Via del Santo 33, 35123 Padova

Setting reserve prices in repeated procurement auctions[*]

Sümeyra Atmaca[†], Riccardo Camboni[‡], Elena Podkolzina[§], Koen Schoors[¶], Paola Valbonesi[‖]

This version. October, 13th, 2022

Abstract

We use a large dataset of Russian public procurement auctions for standard gasoline over the period 2011-2013, to investigate how buyers set the *reserve price* - i.e. the buyer's announced maximum willingness to pay for the good awarded. We provide empirical evidence that repeated past contracts between a buyer and a supplier affect the reserve price set by this buyer in future auctions where the same supplier takes part and wins. Specifically, we find that in these auctions the reserve price, the level of competition, and the winning unit price are lower than in the average auction in the dataset. We conjecture that, in setting the reserve price for a new auction, public buyers exploit information gained about the winners of previous auctions. This intuition is supported by empirically studying the reserve price in a dynamic framework, which allows buyers to take into account information from previous procurement transactions with given suppliers. Finally, we show that our empirical results are in line with a simple theoretical setting in which the buyer collects information about one supplier's costs and exploits this in setting the reserve price in future auctions.

JEL codes: D44; H57.

Keywords: Public procurement; First-price auction; Buyer-supplier repeated interactions; Reserve price.

[*]We thank Chiara Fumagalli, Pavel Andreyanov, Ekaterina Zhuravskaya, Sergey Popov, Antonio Rosato and participants at the SIOE 2019, Perm 2020, EARIE 2021 (first draft) and EARIE 2022 (final paper), OLIGO 2022, 12th Conference on Economic Design in Padova University for their useful comments. Sergei Trunov and Anya Balsevich provided excellent research assistance for data collection. The article was prepared within the framework of the HSE University Basic Research Program and funded by the Russian Academic Excellence Project '5-100'. Financial support was provided the Italian Ministry of University and Education, Grant by PRIN 2017Y5PJ43 and by the Special Resarch Fund (BOF) of Ghent University, Grant BOF.PDO.2020.0034.01. All errors are ours.

[†]University of Ghent

[‡]University of Padova - corresponding author, Riccardo.Camboni@unipd.it

[§]HSE-NRU, Moscow. Elena passed away on 31.07.2022 prior to the submission of this paper. This is one of Elena's last works, and we aim to finalize it in her memory.

[¶]University of Ghent

[‖]University of Padova, paola.valbonesi@unipd.it and HSE-NRU, Moscow

1 Introduction

Public procurement markets represent about 12 percent of GDP in developed countries (OECD, 2019). In awarding contracts to suppliers, public buyers often rely on first-price auctions where suppliers bid a rebate on the reserve price, and the contract is assigned to the supplier with the highest rebate (i.e. the lowest-price supplier). In this setting, the reserve price - representing the announced maximum price the buyer is willing to pay for the good or service - is key to the auction's design and, overall, to the procurement procedure. Indeed, in the short-term, its level affects competition in the auction and the final price and, in the long-term, the dynamic efficiency of procurement markets.

The *optimum* reserve price depends on the information the buyer has on suppliers' production costs. Specifically, in a single −isolated in time− procurement purchase, the buyer can be faced with a large amount of asymmetric information *vis a vis* all suppliers: each supplier knows its production costs and the buyer does not. However, in repeated −over time− procurement purchases of the same good or service, the buyer may be able to collect and update information about the production costs of one or more suppliers,[1] and use it to set the reserve price and affecting procurement outcomes.

This paper empirically and theoretically investigates the reserve price in repeated −over time− procurement purchases of a *standard* good/service to document and rationalize how it is set. Using a large database on Russian first-price auctions for the procurement of gasoline, a commodity with minimum quality differentiation, we first provide empirical evidence of variations in reserve prices at the specific buyer-supplier pair level. In particular, we find that, in a non-negligible number of cases, the reserve price chosen by a procurer in auctions awarded to a given supplier is systematically lower than the reserve price set by the same procurer in similar auctions awarded to other suppliers. Running an econometric analysis, we then show that in these auctions both competition and the winning prices are lower than in the remaining part of our dataset. We conjecture and empirically provide evidence that, in these cases, the procurer is exploiting additional information gained over time on the characteristics of previous winners.

To rationalize our empirical results, we develop a simple theoretical setting where a procurer aims to purchase an item using a first price auction. We show that, when the procurer knows the costs of one supplier and this supplier wins the auction, the optimum reserve price set and the winning bid are lower than the ones the buyer would have set and paid without that information. This is in line with the procurer's traditional trade-off highlighted in the literature (see, e.g., Krishna (2009)): on the one hand, setting a lower reserve price decreases the expected winning bid but, on the other hand, it increases the risk of having no suppliers enter the auction.

Our empirical and theoretical findings highlight that repeated procurement purchasing could play a significant role in reducing asymmetric information about suppliers' costs and related distortions. Specifically, we add to two main strands of the literature. First, we contribute to the empirical literature supporting the benefits of buyer's discretion in procurement. In our analysis, in repeated procurement auctions,

[1] There are several means for the buyer to have information about a supplier's production cost: Camboni and Valbonesi (2021), using a dataset of procurement contracts for canteen services in Italy, showed that this is common in presence of an incumbent supplier.

buyer discretion in setting the reserve price leads to a lower number of bidders in the auction, and - unexpectedly - a lower final price. In a similar vein, Kang and Miller (2022) and Coviello et al. (2021) show that the procurer's actions to reduce competition is not always harmful. Using a regression discontinuity design on a dataset of Italian public work contracts, Coviello et al. (2017) find that giving additional discretion to a public buyer does not result in a higher final price and increases the likelihood of the same firm winning multiple contracts from the same buyer. We add to the literature with a set of new results based on the investigation of the procurer's discretion in the manipulation of the reserve price in a repeated setting where the buyer obtains information on at least one supplier's costs.

Second, we contribute to the literature studying the revenue-maximizing reserve price from the perspective of the auctioneer. In two seminal papers, Myerson (1981) and Riley and Samuelson (1981) show that, in a direct independent private value (IPV) auction − where the highest offer wins − and with risk-neutral bidders, the auctioneer should always set a reserve price that exceeds its true value by an amount that does not depend on the number of bidders entering the auction. Much of the literature limits the scope of this result: when bidders' values are correlated, the auctioneer's optimum reserve price approaches its true value as the number of bidders increase[2] (Levin and Smith, 1996); the optimum reserve price comes closer to the buyer's true valuation when the auctioneer or the bidders are risk-averse (Hu et al., 2010); finally, the reserve price can be manipulated to deter bidder collusion (Thomas, 2005) or to exploit bidders' bounded rationality (Crawford et al., 2009). Our findings highlight a setting where the seminal result of Myerson (1981) and Riley and Samuelson (1981) no longer holds, i.e. the case of repeated auctions where the buyer knows the cost of one bidder and exploits it to set the reserve price.

The remainder of this paper is structured as follows. In Section 2 we first describe Russian public procurement auctions and then illustrate the data on which we run our empirical analysis. The methodology and the empirical results are presented in Sections 3. Section 4 develops a simple model to investigate setting the optimum reserve price with or without information about a specific supplier. A discussion of the empirical and theoretical findings is set out in Section 5, along with the conclusions.

2 Data and institutional setting

We build a rich dataset of Russian public procurement contracts for gasoline, awarded using first price auctions. Gasoline sold in petrol stations is a largely standardized commodity.[3] This reduces the potentially confounding effects from unobserved quality differences in the supply.

On the demand side, Russian state agencies at all levels (federal, regional, local) are subject to the same procurement regulations and subsequent amendments.[4] Demand and supply in Russian public

[2] The same result is obtained when bidders have a reference based utility − i.e., the presence of an additional utility (disutility) when the price the bidder pays is lower (higher) than a certain reference point − and the reference point is affected by the reserve price (Rosenkranz and Schmitz, 2007).

[3] Gasoline differentiates according to its octane rating. In this paper, we consider only gasoline purchased at the petrol stations: this is a homogeneous good, because suppliers have no interest in differentiating the quality of the gasoline sold to public or private buyers in their petrol stations: indeed, supplying a lower quality to public buyers would negatively impact on their reputation in the larger private market.

[4] The Russian procurement system was unified by Federal Law 94 dated 21/7/2005. See: Roudik, P. (2011, March). Government Procurement Law and Policy: Russia. Retrieved November 25, 2016, from http://www.loc.gov/law/help/govt-procurement-law/russia.php.

procurement markets are matched through the online centralized platform containing all publicly awarded contracts: our dataset collects information from such platform.[5] Specifically, our original dataset includes information at auction level about each public buyer (name and address) awarding a contract to purchase gasoline for petrol stations, the characteristics of the gasoline to be procured (volume, octanes), the reserve price, the procedure chosen, and the delivery time and place. Moreover, it records the auction outcomes, i.e., the number of bidders and the number of bids, the name of the winning bidder and the price, as well as which three firms submitted the lowest bids.

According to Russian public procurement regulations, gasoline can be purchased through sealed bid auctions, electronic open auctions (e-auctions)[6] or single-source contracts.[7] We focus on the former two competitive procedures which award contracts to firms bidding the lowest price. All in all, our original dataset covers the period 1/2011-12/2013 and contains 171,784 auctions in 83 Russian regions.[8] From the original sample we drop a) outsourced procurement to centralized agencies acting as intermediaries, and b) observations with an unknown supplier identity, volume or unit reserve price.[9] As a result, our final dataset includes information on 81,813 auctions.

We also observe the monthly regional market price per liter of gasoline purchased through petrol stations:[10] we use this information as a proxy for differences in the costs of the raw material at regional level.

Descriptive statistics are presented in Table 1.[11] Sealed bid auctions account for 70 percent of the total number of auctions in our database, and e-auctions account for the remainder; 60 percent of the total number of auctions were conducted by federal agencies. The volume and unit reserve price are on average 8,103 liters and 29.4 RUB whereas the mean of the market price equals 27.9 RUB. Furthermore, the average reserve price - calculated as the average unit reserve price multiplied by the average volume - is equal to 238,231 RUB (about 2,900$ at the exchange rate in that moment). The average number of applicants is 1.8, the average number of non-excluded bidders is 1.6, and in about 50% of our sample only one firm took part in the auction. Finally, the related contract price mark-up - calculated as the percentage difference between unit contract price and market price - ranges between -0.4 and 0.5.

3 Empirical strategy and results

3.1 Identification of reserve price discounts

In a procurement tender each public buyer, when setting reserve prices, takes into account the item's market price, market competition, specific contract conditions, and publicly available information on

[5] http://www.zakupki.gov.ru. From January 2011 all agencies subject to FL 94 must use this centralized platform.

[6] In 2011, electronic open auctions replaced the earlier outcry auctions. Electronic auctions are mandatory for contract values above 500,000 RUB and where the total value of the procurement of similar goods per quarter and procurer exceeds 500,000 RUB.

[7] We exclude single-source contracts from the sample, because these contracts are non-competitive, and can be used only for procuring goods and services produced by natural monopolies, military or cultural goods, works or services, and in cases of emergency (Article 55, Federal Law 94).

[8] Major amendments to Russian procurement law were introduced in 2014, hence our dataset excludes years after the reform.

[9] Observations with excessive outliers in the unit reserve price (outside 5-95 percentiles) were dropped.

[10] Source: Federal State Statistics Service (http://www.gks.ru/).

[11] The description of the variables can be found in the Appendix.

Table 1: Summary statistics

	Observations	Mean	SD	Min	Max
1 bidder	81,813	0.5	0.5	0	1
Applicants	81,813	1.8	0.8	0	12
Bidders	81,813	1.6	0.7	0	12
Contract price mark-up (p)	79,810	0	0.1	-0.4	0.5
E-auction	81,813	0.3	0.5	0	1
Exclusion	81,813	0.1	0.3	0	1
Federal	81,813	0.6	0.5	0	1
Lnvolume	81,813	9	1.2	4.6	15.8
Market price	81,813	27.9	2.4	18.3	41.3
Mixed	81,813	0	0.1	0	1
Municipal	81,813	0.2	0.4	0	1
Notbidding	81,813	0	0.2	0	1
Unit reserve price (r)	81,813	29.4	2.8	23.2	36.5
Transaction 2	81,813	0.2	0.4	0	1
Transaction $\geq$3	81,813	0.5	0.5	0	1
Transformed unit reserve price (r')	81,813	0	1.7	-18.9	11.9
Voluntary e-auction	81,813	0.1	0.3	0	1
Win	133,286	0.6	0.5	0	1

Notes: *1 bidder* is a dummy variable equal to 1 if the number of bidders is 1, *applicants* is the number of applicants, *bidders* is the number of bidders, *p* is the winning bid per liter of gasoline minus the market price divided by the latter, *e-auction* is a dummy variable equal to 1 if electronic open bid auction and 0 if sealed bid auction, *exclusion* is a dummy variable equal to 1 if the procurer excludes at least 1 applicant from the auction, *federal* is a dummy variable equal to 1 if the procurer is at federal level, *lnvolume* is the natural logarithm of the contract volume, *market price* is the weighted average of monthly market prices of different gasoline types, *mixed* is a dummy variable equal to 1 if the procurement contains other items, *municipal* is a dummy variable equal to 1 if the procurer is at the municipal level, *notbidding* is a dummy variable equal to 1 if an applicant allowed to bid refrains from bidding, *r* is the reserve price per liter of gasoline, *transaction 2* is a dummy variable equal to 1 for the second transaction of the buyer-supplier pair, *transaction ≥3* is a dummy variable equal to 1 for later transactions of the buyer-supplier pair, *r'* is the transformed unit reserve price of gasoline, *voluntary e-auction* is a dummy variable equal to 1 if e-auction is not mandatory but voluntary and *win* is a dummy variable equal to 1 if the bidder is the winner of the auction. The sample is restricted to the estimation sample of the unit reserve price (Table 2).

suppliers' production (marginal) costs. Controlling for all of these factors, our empirical strategy studies whether the reserve price chosen by a buyer exhibits a regularity in case of repeated past interactions between the winning bidder and that buyer. To this aim, we estimate the unit reserve price r_{ijt} in awarding the contract t by a public buyer i to a supplier j as a function of a set of controls, year fixed effects and buyer-supplier pair fixed effects:

$$r_{ijt} = \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \sum \gamma_s year_t + \mu_{ij} + \epsilon_{ijt} \tag{1}$$

where $\boldsymbol{X}_{ijt}$ denotes observed contract and procurer characteristics, $\sum year_t$ are year fixed effects and μ_{ij} are buyer-supplier pair fixed effects. In particular, $\boldsymbol{X}_{ijt}$ includes monthly local gasoline market prices and the contract volume, to control for market and contract characteristics; the natural logarithm of the nominal contract value, to capture the effect of contract size; dummy variables for the government level of the public buyer (federal, regional, local), to account for differences between public buyers in managing public procurement. The year fixed effects absorb possible changes in market trends or regulation.

From equation (1), it is possible to derive the public buyer i fixed effect μ_i as the average[12] of all the buyer-supplier pair fixed effects μ_{ij} including that specific buyer:

[12]We attach equal weights to each supplier (i.e., we use an unweighted average). In this way, we avoid the skewing of public buyer fixed effects by the suppliers that obtained most contracts.

$$\mu_i = \frac{1}{k}\sum_{j=1}^{k}\hat{\mu}_{ij} \tag{2}$$

In a fair and competitive auction, we expect the winning supplier's' identity to be uncorrelated to the reserve price set by any given public buyer. Indeed, the winner of the auction, and even the identity of all the bidders taking part, are unknown at the moment the public buyer sets the reserve price, i.e. we do not expect μ_{ij} to deviate significantly from μ_i.

However, empirically, μ_{ij} can exceed or fall short w.r.t μ_i: in this paper, we focus on downward deviations in the reserve price for specific procurer-supplier pairs. Upward variations in the reserve price may be explained by corruption or other forms of collusion and are studied in a companion paper (Atmaca et al., 2021). We perform a t-test with variance σ_i and degrees of freedom *df* (Satterthwaite, 1946) [13] to assess in our dataset which μ_{ij} are significantly smaller than μ_i:

$$\sigma_i^2 = \frac{\sum(\hat{\mu}_{ij} - \overline{\mu}_i)^2}{n_i} \tag{3}$$

$$df = \frac{(\frac{\hat{\sigma}_{ij}^2}{n_{ij}} + \frac{\sigma_i^2}{n_i})^2}{\frac{(\hat{\sigma}_{ij}^2/n_{ij})^2}{(n_{ij}-1)} + \frac{(\sigma_i^2/n_i)^2}{(n_i-1)}} \tag{4}$$

A negative and significant difference $\mu_{ij} - \mu_i$ identifies a systematic *reserve price discount* in a specific buyer-supplier pair, recorded in relation to the reserve price set by that buyer for the same good.

For the identification of the reserve price discount, our empirical strategy requires multiple suppliers interacting with the same buyer. Indeed, we are unable to identify a reserve price discount if public buyers negotiate with one supplier only, because in this case, by definition, $\mu_{ij} - \mu_i = 0$.

This empirical strategy is adequate in an environment where several buyers are purchasing a homogeneous good on a regular basis through repeated contracts with different suppliers, i.e., markets for basic commodities like paper, sugar and pharmaceuticals, among others.

We estimate equation (1) on our dataset of 81,813 auctions (see Section 2). The results are presented in Table 2.[14] As expected, the monthly regional average market price per liter turns out to be a significant determinant of the contract-specific reserve price per liter.[15] The contract volume has a positive and significant effect on prices. Procurement at the municipal level involves higher prices per liter than procurement at the regional or federal level and mixed purchases.[16]

We then turn to the fixed effects for each buyer-supplier pair μ_{ij}. We construct a binary variable $-$ *Reserve price discount* $-$ with value 1 in the case where $\mu_{ij} - \mu_i$ is significantly smaller than zero at the

[13] This test assumes that μ_{ij} and μ_i are approximately normally distributed. The test is robust to small deviations from this assumption by the central limit theorem

[14] Estimated with the Stata command by Nichols (2008).

[15] Note that for contracts procuring multiple types of gasoline, we construct the market price as the weighted average of the monthly regional market prices of the different types of gasoline in the contract, with the volume of each type relative to the total contract volume as weights.

[16] Our analysis focuses on purchases of gasoline without any related products, but in a small number of cases related products were mentioned in the description of the purchase, even if not reported as supplied goods at the contract stage. We marked these cases as mixed purchases.

Table 2: Identification of reserve price discounts

	r
	(1)
Market price	0.898***
	(0.004)
Lnvolume	0.061***
	(0.008)
Federal	0.248
	(0.214)
Municipal	0.169***
	(0.053)
Mixed	0.772***
	(0.110)
Constant	4.304***
	(0.205)
Year FE	x
Buyer-supplier FE	x
Observations	81,813

Notes: The dependent variable r is the reserve price per liter of gasoline. *Market price* is the weighted average of monthly market prices of different gasoline types, *lnvolume* is the natural logarithm of the contract volume, *federal* is a dummy equal to 1 if the procurer is at the federal level and *municipal* is a dummy equal to 1 if the procurer is at the municipal level. *Mixed* is a dummy variable equal to 1 if the procurement contains other items. Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

5% significance level, and with value 0 otherwise.[17]

Table 3 provides the results. 1,111 out of 10,932 buyer-supplier pairs (10.2%) are identified as pairs which recorded a reserve price discount, representing 9,325 out of 51,330 (18.2%) of the auctions in our dataset.[18] 502 of the 2200 suppliers uniquely identified in our dataset (22.8% of the total) were involved at least once in a reserve price discount relation i.e., a buyer-supplier pair where $\mu_{ij} - \mu_i$ is significantly smaller than zero. Nearly three-quarters of them (371 out of 502) won auctions with and without the reserve price discount,[19] providing supporting evidence that our identification strategy is not driven by time-invariant characteristics of the suppliers.

[17]The method is extensively discussed in Atmaca et al. (2021), where the authors assess the power of the test, the robustness of the model specification and provide simulation results.

[18]In only 51,330 of the initial 81,813 auctions can we identify or rule out reserve price discounting. The other 30,483 auctions mainly involve buyers who concluded contracts with only one supplier. They are not used in the remainder of this paper. Statistics on the number of interactions are provided in Table 3.

[19]Additionally, for the suppliers with at least one reserve price discount relation, the ratio between this supplier's number of price discount relations and its total number of relations (for which we can tell whether the reserve price discount is present or not) is, on average, equal to 0.4.

Table 3: Reserve price discount

	Auctions		Buyer-supplier pairs	
Reserve price discount	Observations	%	Observations	%
0	42,005	81.8	9,821	89.8
1	9,325	18.2	1,111	10.2
	51,330	100	10,932	100

Note: The sample is restricted to the estimation sample of the unit reserve price (Table 2).

3.2 Effect of reserve price discounts

In this section, we run an econometric analysis to focus on the effect of reserve price discounts on competition in auctions (3.2.1), on the probability of winning (3.2.2), and on the winning price (3.2.3).

3.2.1 Reserve prices, discounts and competition

We test the effect of reserve price discounts on competition as follows:

$$C_{ijt} = \alpha_1 Reserve\,price\,discount_{ij} + \alpha_2 Lnvolume_{ijt} + \alpha_3 r_{ijt} + \boldsymbol{X}_{ijt}\boldsymbol{\Delta} + \epsilon_{ijt} \tag{5}$$

where, competition C_{ijt} is addressed by five different proxies.

Applicants counts the number of suppliers that, given the reserve price, decide to enter the qualification stage of the procurement auction. *Exclusion* measures the public buyer's discretion concerning a supplier's participation by constructing a dummy equal to 1 if the public buyer excluded at least one applicant at the qualification stage, reducing competition.[20] *Notbidding* captures suppliers that are applicants, have not been excluded, but eventually refrain from participation: we construct a dummy equal to 1 if at least one non-excluded applicant decides after all not to bid in e-auctions. *Bidders* measures the number of suppliers that placed a bid in the auction. Finally, *1 bidder* is a dummy equal to 1 if only one bidder placed a bid in the auction. We employ logistic regressions to model competition, with the exceptions of *Applicants* and *Bidders*, where a Poisson regression is more appropriate.

Our key explanatory variable is the *Reserve price discount*, a dummy equal to 1 for auctions where this situation has been identified: where the reserve price discount strategy is adopted, we expect the number of applicants in the auction to decline, ($\alpha_1 < 0$). Indeed, if the buyer sets a lower than usual reserve price, suppliers with higher costs will choose not to take part in the auction. We also add controls for the quantity $-$ *Lnvolume*, i.e. the natural logarithm of the contract volume $-$ and for the unit reserve price r (per liter). Finally, $\mathbf{X}$ contains additional control variables: year and region fixed effects, and two binary variables to control for the auction procedure. The first, *e-auction*, is equal to 1 fore-auctions and 0 for sealed bid auctions; the second, *voluntary e-auction* is equal to 1 for e-auctions below the 500,000RUB threshold.[21]

Table 4, Columns 1 to 5, set out our estimations of equation (5). Column 1 shows that the number of applicants decreases in the presence of the reserve price discount. This effect is significant at 1% significance level.

[20] Public buyers could exclude bidders from the auction by arguing that they are not in full compliance with all technical specifications, clauses and conditions of the contract.

[21] E-auctions are mandatory if the reserve price exceeds 500,000 RUB. Below the threshold of 500,000 RUB procurers could choose between the auction procedures. Note also that, like Barreca et al. (2016), we drop auctions around the 500,000 RUB threshold because public buyers may try to avoid mandatory e-auctions by staying just below the threshold of 500,000 RUB (3,809 observations are dropped).

Table 4: Effect of reserve price discounts

	Auction competition					Probability of winning			Contract price
	Applicants	Exclusion	Notbidding	Bidders	1 bidder				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Reserve price discount	-0.033***	0.067	-0.057	-0.034***	0.117***	0.266***	0.360***	0.441***	-0.010***
	(0.005)	(0.046)	(0.073)	(0.0047)	(0.029)	(0.035)	(0.048)	(0.059)	(0.001)
Lnvolume	0.045***	0.131***	0.144***	0.036***	-0.164***				$3 \cdot 10^{-4}$
	(0.002)	(0.021)	(0.038)	(0.002)	(0.013)				$(3 \cdot 10^{-4})$
Unit reserve price	0.001	-0.021**	-0.030*	0.003***	-0.027***				0.016***
	(0.001)	(0.009)	(0.016)	(0.001)	(0.006)				$(1 \cdot 10^{-4})$
E-auction	-0.369***	-1.445***		-0.417***	2.416***	-0.199***	0.009	-0.058	0.003***
	(0.008)	(0.073)		(0.007)	(0.04)	(0.036)	(0.063)	(0.073)	(0.001)
Voluntary e-auction	-0.013	-0.383***	-0.054	0.011	-0.120**	-0.045	0.017	0.012	0.003***
	(0.009)	(0.111)	(0.097)	(0.008)	(0.048)	(0.047)	(0.067)	(0.075)	(0.001)
Bidders						-1.319***	-1.381***	-1.528***	-0.022***
						(0.018)	(0.023)	(0.028)	$(3 \cdot 10^{-4})$
Constant	-0.180***	-4.042***	-3.239***	-0.207***	2.788***	4.160***			-0.514***
	(0.055)	(0.710)	(0.824)	(0.059)	(0.336)	(0.277)			(0.007)
Year FE	x	x	x	x	x	x	x	x	x
Region FE	x	x	x	x	x	x			x
Buyer FE							x	x	
Buyers							2,898	2,287	
Observations	47,521	47,521	15,579	47,521	47,521	56,816	42,171	30,396	46,437

Notes: The dependent variables are: (1) the number of applicants, (2) a dummy variable equal to 1 if the procurer excluded at least one applicant from the auction, (3) a dummy variable equal to 1 if a not excluded applicant decides not to bid, (4) the number of bidders, (5) a dummy variable equal to 1 if the number of bidders is 1, (6)–(8) a dummy variable equal to 1 if the bidder is the winner of the auction, (9) the winning bid per liter minus the market price divided by the latter. *Reserve price discount* is a dummy variable equal to 1 if reserve prices on buyer-supplier level are significantly lower than reserve prices on buyer level, *lnvolume* is the natural logarithm of the contract volume, *unit reserve price* is the reserve price per liter of gasoline, *e-auction* is a dummy variable equal to 1 if e-auction and 0 if sealed bid auction, *voluntary e-auction* is a dummy variable equal to 1 if e-auction is not mandatory but voluntary and *bidders* is the number of bidders. Sealed bid auctions with reserve price $\in$ [490,000;510,000] RUB are dropped because of possible manipulation of the reserve price. The unit of observation is a single auction, except in columns (6)–(8) where it is the single bid. The sample in column (3) is restricted to e-auctions and in column (8) it is restricted to suppliers who have at least one reserve price discount relation. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

In Column 4, the effect on the final number of bidders is similar in size and significance to the effect on the number of applicants. Note that the final number of bidders may deviate from the number of applicants if applicants are either excluded by the buyer or decide not to take part in the bidding stage. Columns 2 and 3 indicate that auctions with reserve price discounts experience neither more exclusions of suppliers by buyers, nor more spontaneous decisions to leave the (electronic) auction afterwards. These variables, usually interpreted as a proxy for corruption or auction manipulation, show that buyers do not adopt a reserve price discount strategy along with other actions to reduce competition in the auction. Indeed, the downward effect of the reserve price discount strategy on auction competition is already fully present at the first stage, i.e. when potential suppliers decide whether or not to enter the auction.
Finally, Column 5 shows that auctions with a reserve price discount are also significantly more likely to have only 1 bidder.

3.2.2 Probability of winning an auction with the same buyer

We now study whether suppliers in a reserve price discount relationship are more likely to win an auction managed by the buyer in that relationship. In doing so, we exploit the information on the identities of the bidders taking part in each auction. For each participant, we estimate the probability of winning auctions with buyer i, bidder b at time t, estimating the following logistic regression:

$$P(win)_{ibt} = \beta_1 Reserve\,price\,discount_{ib} + \beta_2 Bidders_{ibt} + \boldsymbol{X}_{ibt}\boldsymbol{\theta} + \epsilon_{ibt} \tag{6}$$

where *Bidders* is the number of bidders in the auction and $\boldsymbol{X}$ is a vector of controls including binary variables for the auction procedure − as discussed in the previous section − and fixed effects for either year and regions, or for public buyers.
Table 4, Columns 6 to 8, sets out our estimates of equation (6). Suppliers are more likely to win the auctions organized by buyers with whom they form a reserve price discount pair, i.e. $\beta_1 > 0$ in all specifications.
Note that, for e-auctions, procurers are required to disclose the identity of the three best bids. In our database, the number of participants is often equal or lower than three (the mean number of bidders is 1.6, see Table 1). Nevertheless, as a robustness check, in Column 8 we restrict the sample to auctions for which we have information on all bidder identities. Our result remains robust.

3.2.3 Winning bid

Finally, we investigate the relation between reserve price discounts and contract prices. The contract price is determined by the characteristics of the auction and the procedure used - as chosen by the public buyer - but also by exogenous market conditions (e.g., an increase in raw material costs). To remove the latter, as dependent variable p_{ijt} we use the relative difference between the contract price[22] and the

[22]The contract price per liter is adjusted for outliers (outside 1-99 percentiles) deviating from the estimation sample of the unit reserve price regression.

monthly regional market price per liter of gasoline. The independent variables are the same as used in the two previous subsections:

$$\begin{aligned} p_{ijt} = {} & \delta_1 Reserve\,price\,discount_{ibt} + \delta_2 r_{ijt} + \delta_3 Bidders \\ & + \delta_4 Lnvolume_{ijt} + \boldsymbol{X}_{ijt}\boldsymbol{\zeta} + \epsilon_{ijt} \end{aligned} \tag{7}$$

Table 4, Column 9, presents our estimates of equation (7) and shows that a reserve price discount has a negative impact on the final contract price, net of exogenous variations in the market conditions.

3.3 Reserve price discount over time

In the previous section we provide empirical evidence of a consistent number of reserve price discounts, in the presence of repeated interactions between the same buyer and supplier. This evidence is puzzling because the procurer chooses the reserve price before the auction is awarded. It leads us to suspect that the buyer is using additional information about the winning bidder gained from previous auctions. This intuition is corroborated by the observation that, for buyer-supplier pairs where a reserve price discount is observed, the supplier has a significantly higher probability of winning any auction managed by that specific buyer. Accordingly, in this section we empirically investigate the unit reserve price in a dynamic framework, taking into account whether the procurer had interacted with the winning supplier before. To shed light on this, we exploit our unit reserve price model, equation (1). Using the estimated coefficients β and γ_s, we define the *standardized* unit reserve price r'_{ijt} as the reserve price net of differences in observable characteristics and year effects, i.e., the reserve price a public buyer would have set for a good with homogeneous observable characteristics $\boldsymbol{X}^0$ for all the observations at time $t = 0$:

$$r'_{ijt} = r_{ijt} - \boldsymbol{X}_{ijt}\boldsymbol{\beta} - \sum \gamma_s year_t \tag{8}$$

In equation (1), differences in r'_{ijt} are explained by buyer-supplier pair fixed effects. We now introduce a new specification, with additional variables representing the time order of transactions for buyer-supplier pairs. In particular, we introduce dummy variables capturing the first, second and subsequent (third or later) transactions between specific buyers and winning bidders, and see how they interact with the dummy *Reserve price discount*. For example, we introduce a dummy variable − *Transaction2* − capturing whether public buyer j is interacting for the second time with the winning supplier i. The new specification is the following:

$$\begin{aligned} r'_{ijt} = {} & Transaction\,2_{ij} + Transaction\,2_{ij} \times Reserve\,price\,discount_{ij} \\ & + Transaction \geq 3_{ij} + Transaction \geq 3_{ij} \times Reserve\,price\,discount_{ij} \\ & + \delta_{ij} + \epsilon_{ijt} \end{aligned} \tag{9}$$

where δ_{ij} are buyer-supplier pair fixed effects. Equation (9) still exploits within group variation (δ_{ij}) but differentiates between transaction time and whether the reserve price discount was present or not. Since data are left-censored, we may not always observe the first transaction between public buyers and winning bidders. To ensure that we label the order of transactions correctly, we drop pairs that had a transaction in the first 6 months of the sampling period because these are likely to have had prior transactions. For pairs first occurring in our data only 6 months after the start of the sampling period, on the other hand, the first interaction can be identified with greater confidence. Dropping pairs with transactions in the first 6 months therefore improves the accuracy of our identification.

Table 5: Reserve price discount over time

	r'
	(1)
Transaction 2	0.035*
	(0.019)
Transaction ≥3	0.089***
	(0.019)
Transaction 2 × Reserve price discount	-0.134**
	(0.066)
Transaction ≥3 × Reserve price discount	-0.261***
	(0.055)
Constant	-0.023*
	(0.014)
Buyer-supplier FE	x
Buyer-supplier pairs	7,437
Observations	30,321

Notes: The dependent variable r' is the transformed unit reserve price of gasoline. *Transaction 2* is a dummy variable equal to 1 for the second transaction of the buyer-supplier pair. *Transaction ≥3* is a dummy variable equal to 1 for later transactions of the buyer-supplier pair. *Reserve price discount* is a dummy variable equal to 1 if reserve prices on buyer-supplier level are significantly lower than reserve prices on buyer level. Standard errors in parentheses. p<0.01, ** p<0.05, * p<0.1

Table 5 provides the results. The dependent variable is the transformed unit reserve price. Both interaction terms have a negative and significant effect, suggesting that the way public buyers change the reserve price over (the transaction) time differs between auctions characterized by the presence or absence of the reserve price discount strategy. In the former case, our results highlight that the transformed unit reserve price decreases over transaction time: its linear prediction in the first, second and third transaction time is equal to, respectively, -0.552, -0.651, and -0.724. In the latter case, on the other hand, the linear predictions are equal to, respectively, 0.067, 0.102 and 0.156. All these results are significant at the 99% confidence interval, and the predicted values for the first and third (or later) transaction times are, in both cases, significantly different from each other.

4 A simple theoretical model

The crucial result of our empirical analysis is that, in a non-negligible number of auctions in our dataset, the reserve price shows a regularity, i.e. with a discount if the winning supplier in that auction has had previous interaction(s) with the buyer. This is puzzling, as the reserve price is set before the identity of the winning supplier is known to the public buyer. In auctions exhibiting this reserve price discount, we find that the winning price and participation in the auction are lower than in the remainder of our dataset.

We conjecture that public buyers are exploiting information gained at previous auctions and during the performance of prior or ongoing contracts. This is supported by empirically studying the reserve price in a dynamic framework, taking into account whether the buyer had previously interacted with the winning supplier. Interestingly, our analysis shows that unit reserve prices drop over the transaction time only for buyer-supplier pairs which feature the reserve price discount strategy.

In this section we show that our empirical results are in line with a simple theoretical setting in which the buyer has information about the supplier's characteristics and exploits them in setting the reserve price. Specifically, we first characterize the optimum reserve price when the buyer has information about a supplier's costs: we show that when the contract is awarded to the supplier whose costs are known to the buyer, the winning price is lower than the one the buyer would have paid without that information. We then discuss how our results change moving from a single to a repeated interaction setting.[23]

We consider a risk-neutral public buyer who aims to purchase a single item (i.e. a standard good/service). The buyer assigns a value V to the item and, running a first-price auction (FPA, henceforth), awards the contract to the lowest-price bidder. In designing the FPA, for the single item awarded, the buyer sets a reserve price r, i.e. the public buyer's announced maximum willingness to pay. All the suppliers' offers above r are automatically discarded.

We assume two potential suppliers enter the FPA and compete to win the contract. Supplier $i \in \{1, 2\}$ records a cost c_i to execute and deliver the contract; note that c_i is also the minimum payment required by the supplier i to provide the buyer with the item. Moreover, we assume that c_i is independently and identically distributed on the interval $[0, \omega]$ according to the increasing distribution function F; and that F admits a continuous density $f = F'$ and has full support. Each supplier knows the realization of its cost c_i, and that other bidder's costs are independently distributed according to F.

Both suppliers are risk neutral and maximize their expected profits. The winning supplier's i profit from the procurement contract is given by the difference between its bid b_i and its cost c_i. The bidding function for a FPA in a procurement setting,[24] given the reserve price r and considering a supplier with cost $c_i \leq r$, is:[25]

$$b(c_i, r) = r\frac{1 - F(r)}{1 - F(c_i)} + \frac{1}{1 - F(c_i)} \int_{c_i}^{r} y \cdot f(y)\, dy \tag{10}$$

Consider now the setting in which the buyer knows the costs of one of the two suppliers (bidders): we denote the observed cost with $\bar{c}$. Note that in this setting - on the one hand - the bidders' equilibrium strategies are no different from those in a standard FPA (where one supplier's costs are unknown). On the other hand, the buyer, by observing $\bar{c}$, will consider this cost in choosing r which maximizes its expected

[23] All calculations are provided in the online Appendix.

[24] Note that the bidding function in a procurement auction (where the lowest bid wins) is reversed compared to a traditional direct auction (where the highest bid wins, see, e.g., Krishna, 2010), but the mechanism is similar. Holt (1980) provides a description of the proof that the equilibrium bidding strategy in procurement auctions is indeed symmetric.

[25] We assume that a supplier with costs $c_i > r$ does not enter the auction.

payoff Π^O. With this aim, the buyer can alternatively set a reserve price $r \geq \bar{c}$ or $r < \bar{c}$. Specifically, in the first case, at least the known bidder (with $\bar{c}$) takes part in the auction, and the probability that it wins the auction is $(1 - F(\bar{c}))$. In the second case, with $r < \bar{c}$, the contract is awarded only if the unknown supplier has a cost equal to or lower than the reserve price: this happens with a probability equal to $F(r)$ and the buyer is expected to pay $E[m(c,r)|c < r]$, where $m(c,r)$ stands for the bid by a supplier with cost c, multiplied by its probability of winning. Formally, when the buyer observes $\bar{c}$, the expected payoff is:

$$\Pi^O(r) = \begin{cases} V - (1 - F(\bar{c}))b(\bar{c}) - F(\bar{c}) \cdot E[m(c,r)|c < \bar{c}], & \text{if } r \geq \bar{c} \\ F(r) \cdot (V - E[m(c,r)|c < r]), & \text{if } r < \bar{c} \end{cases} \tag{11}$$

By algebra, we obtain the following first order condition of Π^O w.r.t. r:

$$\frac{\partial \Pi^O}{\partial r} = \begin{cases} -(1 + F(\bar{c}))(1 - F(r)), & \text{if } r \geq \bar{c} \\ Vf(r) + (1 - F(r))[\lambda(r) \cdot (V - r) - 1], & \text{if } r < \bar{c} \end{cases} \tag{12}$$

where $\lambda(r) = \frac{f(r)}{F(r)}$.
Note that (12) is negative defined when $r \geq \bar{c}$, i.e. for the buyer it is never optimal to set a reserve price higher than $\bar{c}$. If $r < \bar{c}$, the known supplier does not take part in the auction.
Define, if applicable, $\hat{r} \in [0, \bar{c}[$ as the reserve price r such that $\frac{\partial \Pi^O}{\partial r} = 0$; note that $\hat{r}$ is independent of $\bar{c}$. We can now proceed in characterizing the reserve price r^* that globally maximizes the buyer's expected revenue $\Pi^O(r)$, and how it changes as a function of the known supplier's cost. We consider the case in which $V \geq \bar{c}$, i.e., the buyer values the item to be procured more than the production cost of the known supplier.
In this setting, it is possible to prove that r^* can have only two values. Specifically:

- $r^* = \hat{r}$ if $\hat{r} \in]0, \bar{c}[$ exists and $\Pi^O(\hat{r}) > \Pi^O(\bar{c})$;
- else, $r^* = \bar{c}$

Consider a known supplier with costs $\bar{c} = 0$. Then, $r^* = 0$. In general, as long as $\bar{c} \leq \hat{r}$, then $r^* = \bar{c}$. In this case, the more efficient the known supplier, the lower the observed $\bar{c}$, the optimum reserve price r^*, and the resulting price paid by the buyer. For less efficient suppliers, i.e. when $\bar{c} > \hat{r}$, the buyer faces a choice. On the one hand, it can exclude the known bidder, setting $r^* = \hat{r}$. Or it can still set $r^* = \bar{c}$. In the former case the expected price paid if the contract is awarded is lower than in the latter, but the risk is that no bidders take part in the auction. Which of the two alternatives should be preferred depends on the models parameters and the actual costs of the known bidder.
Let us consider the case where the buyer knows the supplier's costs and this supplier is the winning bidder. The reserve price the buyer set and the winning bid the buyer pays are equal to $\bar{c}$. Both this reserve price and the winning bid are lower than the ones the buyer would have set and paid without the information concerning the supplier's costs; indeed, they could not be any lower, if the supplier is willing to take part in the auction. Consider now competition in the auction: the winning supplier is,

by definition, the most efficient; and no other bidder with costs greater than $\overline{c}$ could enter the auction. As a result, auctions awarded to the known supplier have only one participant.[26]

The simple theoretical model we have presented is a static, one-shot game. We now move on to a dynamic setting, i.e. a setting where the buyer periodically procures the needed item in repeated and sequential auctions. Here, we assume the buyer maximizes its long-term surplus by setting the reserve price in each auction. Accordingly, the optimum reserve price in $t = 1$, r_1, depends on the known supplier costs' $\overline{c_0}$ at $t = 0$. Similarly, in $t = 2$, the buyer sets a reserve price r_2 using the information on $\overline{c_1}$ gained in $t = 1$, and so on.

In this model, how the buyer learns the $t = i$ winning bidder costs $\overline{c_i}$ becomes crucial. It can be in one of two ways: either the buyer learns $\overline{c_i}$ by observing the execution of the contract, or through the winning supplier's bid in $t = i$. In the former case, the predictions of the static model above do not change. The intuition behind this is that the buyer's awareness of $\overline{c}$ in $t = 1$ is independent of the winning supplier's bid in $t = 0$. Specifically, consider a setting with two periods, $t = \{0, 1\}$. Supplier i with costs c_i wins the auction in the initial period, $t = 0$. Then, in $t = 1$, the buyer sets a reserve price r_1 equal to, at most, supplier i's costs: $r_1 \leq c_i$; as a result, whether or not it is awarded the contract, supplier i makes zero profit from this auction. Solving via backward induction, supplier i bidding strategy in $t = 0$ is equal to the standard bidding behavior in a static FPA.

This is no longer true assuming the buyer learns about the supplier's costs by observing their bids: in this case, a fully rational bidder notices that its bidding behavior in the earlier rounds influences the reserve prices set in later rounds, and so makes the offer strategically (Amin et al., 2013). Such a level of bidder sophistication seems highly unlikely given the average contract value in our empirical setting.

5 Conclusion

In a standard one-shot auction for a standard item, the public buyer has no information about supplier costs. Accordingly, the reserve price it sets is uncorrelated with the identity of the winning bidder. In repeated auctions where the buyer periodically procures the needed item and notes - from time to time - the winner's bid and the execution of the contract, such a lack of correlation seems no longer to apply. We provide empirical evidence in this respect running our analysis on a large dataset of Russian public procurement auctions for gasoline.

Our identification strategy relies first on identifying *buyer j - bidder i pairs* in repeated transactions. We then consider the buyer's reserve price setting in these transactions and define the *reserve price discount* as the presence of a positive and statistically significant difference between the average reserve price set by a buyer j and the average reserve price set by the same buyer in all the auctions awarded to the supplier i, after considering contract and procurer characteristics.

We find that, in auctions with a *reserve price discount*, both the winning price and the number of

[26] These results may seem stark compared to what is observed in the real world. They rely on assuming that the buyer is perfectly aware of the winning supplier's costs, and this assumption makes the model tractable. To obtain a more flexible representation of the real word, noise can be added to the buyer information. Noise can be modelled as a mean zero random error $e \sim \mathcal{N}(0, \epsilon)$ on the information the buyer has for the known supplier costs, where ϵ is small. We leave this extension of the model to future research.

bidders taking part in the auction are lower than in the remainder of our dataset. We posit that, in these auctions, public buyers are exploiting information they have gained from previous auctions. This hypothesis is supported by empirically studying the reserve price in a dynamic framework, taking into account whether the procurer had previously interacted with the winning supplier.

Finally, we propose a simple theoretical setting to explain our empirical results. Specifically, we assume that the buyer gains information on the supplier's actual production costs in an initial auction, at time $t = 0$. Then, we assume that the buyer uses this information at time $t = 1$ to set the reserve price in a new auction. As a result, at $t = 1$, in auctions where the winning bidder is the firm supplying at $t = 0$, our model predicts that the reserve price the buyer sets is lower than the one the buyer would have set without the information about $t = 0$ supplier production costs. Both the winning price and the level of competition in the auction are lower in the former case than in the latter, which is in line with our empirical evidence.

Our results suggest that repeated procurement purchasing increases the information available to public buyers and could, through this channel, play a relevant role in reducing the final price paid with public money. This is a positive outcome in the short term, but the long-term implications are less clear: the reserve price discount reduces the competition in the market and, in the long run, this can lead to lower innovation rate. Indeed, a long and repeated relationship between buyer and supplier in a public procurement setting is not always advisable as it can reduce the possibility to interact with new, innovative and efficient suppliers.

A straightforward policy implication from our analysis is that information on past procurement outcomes should be shared in an easily accessible way between all public buyers. How to share this information in a way that does not reduce competition is left to future investigations.

References

Amin, K., Rostamizadeh, A., Syed, U., 2013. Learning prices for repeated auctions with strategic buyers. In: Burges, C., Bottou, L., Welling, M., Ghahramani, Z., Weinberger, K. (Eds.), Advances in Neural Information Processing Systems. Vol. 26. Curran Associates, Inc.

Atmaca, S., Schoors, K., Podkolzina, E., 2021. Corrupt reserve prices. Ghent University, Faculty of Economics and Business Administration.

Barreca, A. I., Lindo, J. M., Waddell, G. R., 2016. Heaping-induced bias in regression-discontinuity designs. Economic Inquiry 54 (1), 268–293.

Camboni, R., Valbonesi, P., 2021. Incumbent and entrant bidding in scoring rule auctions: A Study on Italian canteen services. The B.E. Journal of Economic Analysis Policy 21 (1), 1–43.

Coviello, D., Guglielmo, A., Lotti, C., Spagnolo, G., 2021. Procurement with manipulation. Mimeo.

Coviello, D., Guglielmo, A., Spagnolo, G., 2017. The effect of discretion on procurement performance. Management Science 64 (2), 715–738.

Crawford, V., Kugler, T., Neeman, Z., Pauzner, A., 2009. Behaviorally optimal auction design: Examples and observations. Journal of the European Economic Association 7 (2-3), 377–387.

Hu, A., Matthews, S., Zu, L., 2010. Risk aversion and optimal reserve prices in first- and second-price auctions. Journal of Economic Theory 145 (3), 1188–1202.

Kang, K., Miller, R. A., 2022. Winning by default: Why is there so little competition in government procurement? The Review of Economic Studies 89 (3), 1495–1556.

Krishna, V., 2009. Auction theory. Academic Press.

Levin, D., Smith, J. L., 1996. Optimal reservation prices in auctions. The Economic Journal 106 (438), 1271–1283.

Myerson, R., 1981. Optimal auction design. Mathematics of Operations Research 81 (1), 58–73.

Nichols, A., 2008. FESE: Stata module to calculate standard errors for fixed effects. URL `https://ideas.repec.org/c/boc/bocode/s456914.html`

Riley, J. G., Samuelson, W. F., 1981. Optimal auctions. The American Economic Review 71 (3), 381–392.

Rosenkranz, S., Schmitz, P. W., 2007. Reserve prices in auctions as reference points. The Economic Journal 117 (520), 637–653.

Satterthwaite, F. E., 1946. An approximate distribution of estimates of variance components. Biometrics Bulletin 2 (6), 110–114.

Thomas, C., 2005. Using reserve prices to deter collusion in procurement competition. The Journal of Industrial Economics 53 (3), 301–326.