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The Revenue Ranking of Open versus Sealed Auctions: Evidence from a Field Experiment in Department of Defense Automated Procurement

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Contents

Introduction

The principal aim of this paper is to test the revenue equivalence theorem using a novel data set of on-line procurement auctions conducted under both open and sealed bid formats. The revenue equivalence theorem, due to Vickrey (1961), is a fundamental result of economic theory which states that under certain reasonable conditions, the expected winning bid is the same in both the open-bid and sealed-bid first price auction formats. The main virtue of the dataset we use is that it covers repeated procurements for the production of identical items, which allows the researcher to control substantially for potential unobserved heterogeneity arising from differences in the item being auctioned. Limiting the effect of unobserved heterogeneity gives us more confidence that the variation in winning bids that we observe is indeed driven by random variation in the underlying costs of producing the item (as is usually assumed), rather than to an omitted variable, namely, unobserved differences in the items themselves.

Another advantage of the data we study in this paper is that we observe many items that were auctioned both under sealed- and open-bid formats (in an arguably randomized fashion), providing a field experiment in which to compare revenue. We are aware of only a handful of examples in the literature of auction data from the field containing auctions with varying formats. With data where auction format does not vary (or varies in a non-random way), researchers have had to use structural estimates derived from bidder behavior under one format to predict outcomes under a different format, though without being able to verify their predictions empirically.

Previous tests of revenue equivalence using field data

Previous authors have tested the revenue equivalence theorem using data from different auction formats. In this section we summarize some of their findings. To our knowledge, no published study has found revenue dominance of open auctions over first-price sealed bid, which is a canonical result of Milgrom and Weber (1982) in an affiliated values environment with symmetric, non-colluding and risk-neutral bidders. This is somewhat surprising given the widespread actual use of open bid auctions, though perhaps less so because the available data has been limited to environments that typically do not satisfy the canonical assumptions. Indeed, studies of datasets that do contain variation in auction format have had to rely on some deviation from the standard assumptions to explain the evidence.

Johnson (1979) and Hansen (1986) studied timber auctions in western U.S. states following the 1976 law that required exclusive use of sealed bidding. Johnson initially reported that sealed-bid auctions generated higher revenue, but Hansen found that the differences were attributable to sale characteristics. Furthermore, as Hansen indicates, there is some question as to whether auction format was truly exogenous, as the adoption of the law and its repeal appear to have been very sensitive to strong lobbying efforts.

Schuster and Niccolucci (1993) and Stone and Rideout (1997) also find higher revenue from sealed-bid auctions using a different dataset of U.S. timber auctions. Potential explanations they offer for this finding include risk aversion as well as the presence of a resale market. The latter provides an incentive to shade one's bid under open bidding as a way to influence resale negotiations. A final possibility is the potential for collusive behavior under open bidding.

The timber data have been revisited more recently by Athey, Levin and Seira (2004). They find revenue equivalence in the California region, but higher revenue from the sealed bid format in the Northern region. They focus on two departures from the standard model: collusive behavior and heterogeneous bidders. Some bidders have manufacturing capability and some do not. They also hypothesize that collusion may be more likely to succeed in an open auction format. They then construct an independent private values model with endogenous entry and two bidder types that implies higher revenue under sealed-bid first-price auctions. The intuition is that sealed-bid auctions attract substantially more weak bidders, resulting in higher revenues. For the Northern region, they cannot fully explain the observed price difference, and offer a model of collusive behavior to account for it. They find that even a small amount of collusion can result in sizable increases in predicted prices.

Our paper is closest in spirit to a handful of papers that have relied on randomized variation of auction format in field data. Lucking-Reiley (1999) used a field experiment varying auction formats for otherwise identical "Magic: the Game" collectors cards. His focus, somewhat different from ours in this paper, was on testing the revenue equivalence between Dutch and first-price formats, as well as between second-price and English formats. He ran about 200 pairs of auctions for the same card, where within each pair auctions varied only in format. He found about 30 percent revenue dominance of Dutch auctions over first-price, sealed-bid auctions. Under symmetric private values or affiliated values auctions, theory indicates that the Dutch auction and first-price auction should have the same revenue. Thus, the results contradict theory. This may be attributable to the larger number of bidders who participated in the Dutch auctions. Another possible explanation is bidder impatience, making them willing to bid higher to end the auction early.

On another 200 auction pairs he found revenue equivalence between English and second-price auctions, consistent with theoretical predictions under symmetric private-values auctions but not under symmetric common values auctions, in which English auctions should have higher revenue. Because the environment is not known, it is uncertain whether these results are consistent with theory.

For Canadian timber auctions, Paarsch (1989, 1991) rejects the hypothesis that the estimated underlying value distributions of bidders are the same across the two formats. Theory would predict they ought to be under the independent private values paradigm. He provides some evidence that bidders were not risk neutral. He finds also that participation and price both were lower in English auctions.

A novel approach to comparing the revenue performance under various auction formats is provided by Shneyerov (2006), who studies sealed-bid municipal bond auctions in California. Pseudo-values of the bidders are estimated using the sealed-bid auction data and an assumption of an affiliated value environment. These pseudo-values identify the counterfactual winning bid in a second-price sealed-bid auction. The same pseudo-values also can be used to estimate an upper bound on the expected revenue from an open auction. Shneyerov estimates that open auctions would yield at most 11 to 19 percent higher revenue than sealed auctions. Indeed this finding may find support (and future empirical testing) in the nascent growth of open auctions in this venue.

In Koh et al. (2007) the authors examine a dataset of 64 monthly auctions for Singapore vehicle licenses, which changed format from sealed to open in 2002. Their model uses macroeconomic variables to account for observable cross-auction heterogeneity in the value of the vehicle licenses. They estimate the relationships to these variables during the sealed-bid period, then use these parameter estimates to forecast what the sealed-bid prices would have been during the open auction period. Comparing these prices to the actual open period prices, they find lower revenue under open bid auctions. They attribute this revenue ranking to risk aversion on the part of individual buyers.

Theoretical overview

In this section we describe and review the key theoretical results. We discuss the basic structure of the bidding game, the differences in equilibrium bidding in the open and sealed bid formats in private, common, and affiliated values environments, and the implications for the relative performance of the two formats.

Primitives – notation and definitions

A single procurement contract is put up for bid. There are n risk-neutral bidders. Let N be the set of bidders. We assume that auction participation costs are negligible, so that the number of bidders is fixed and known.

Each bidder i has a cost c_i and receives a private signal x_i. A standard normalization is imposed on the signals X (because they contain only ordinal information), such that $X_i = \mathrm{E}[c_i|x_i]$.

The informational environment is characterized by a joint distribution of costs and signals, given by $\mathrm{F}(c_1, c_2, \ldots, c_n, x_1, x_2, \ldots, x_n)$. In general, we expect each bidder's cost to depend in some fashion on the signals of its competitors. A bidder's own signal is informative such that the expected cost c strictly increases in x for all realizations of i's opponents' signals.

We do not observe the values for c and x. We observe the auction format (sealed or open), the full set of bids, and values for a set of auction-specific variables (e.g., item, quantity, date). Conditional on observable sale characteristics, we treat each procurement auction as an independent draw from the joint distribution F. Each bidder would receive a payoff $p - c_i$ from winning the procurement at price p.

Equilibrium bidding under open and sealed formats

In a first-price sealed-bid auction, bidders submit bids simultaneously and the contract is awarded to the lowest bidder at their bid. By contrast, in an open, descending-bid auction, all bidding is observed, and the contract is awarded to the lowest announced bid at that bid. By convention we adopt the "button auction" model of Milgrom and Weber (1982) in which bidders exit observably and irreversibly as the price "ticks down" until only one bidder remains.

In a private-value environment, we have $E[c_i \mid x_i, x_j] = E[c_i \mid x_i]$ for all i. Thus observing one's own signal x_i is sufficient to know one's own cost c_i. The private value environment exists when each bidder's valuation of the auctioned item is known to himself, but no bidder knows the other bidder's valuations. In a private values environment, knowing other bidders' information does not affect any bidder's valuation of the auctioned item. In other words, if a bidder knew all the private information that other bidders held, his valuation of the auctioned item would not change (though the bidding strategy could change). With symmetric independent private values, the costs are modeled as independent draws from identical distributions. With affiliated private values, the costs are modeled as a single draw from F, where the costs are statistically affiliated.[1]

A simple private value example might be an auction for a bottle of wine. Each bidder assesses the qualities of the specific vintage and has a personal valuation of those qualities. If each bidder's assessment and valuation do not depend on other bidders' quality assessments, then a private values environment exists. In a procurement auction context, a private values environment exists if a bidder's estimate of his own cost of producing the item up for bid cannot be improved by knowing other bidders' information.

By contrast, a common values environment exists when one bidder's information is useful to another bidder. A common value environment is characterized by the following assumption: $E[c_i \mid x_i, x_j]$ is in-

[1] Loosely speaking, affiliation means that large values for any of the variables make other variables more likely to be large than small. For a formal definition, see Milgrom and Weber (1982).

creasing in x_j for all i, j, and x_j. This means bidders do not know their own costs precisely at the time of bidding and would update their beliefs about their own costs in light of the information held by other bidders. In the "pure common values" case, the value of the auctioned item is the same to each bidder, but each bidder's information about that value differs. Specifically, $c_i = c$ for all i, with each x_i a signal for the unobserved c. If a bidder knew the information that the other bidders had, he could form a different, and presumably more accurate, valuation of the auctioned item.

An affiliated values environment allows the valuation to depend on both a common element and private element. An example might be a bid for a large, technically-demanding design project. In this case, there is a common value because the technical challenges and material costs are uncertain but would be the same for all bidders. However, there are also private values because the production process and the skills and wages of the engineers and production staff might differ. The affiliated values environment includes the pure common values and private values models as special cases.

In an English open auction, regardless of the informational environment, a dominant strategy is for a bidder to bid the minimum amount under anyone else until his cost (or expected cost) is reached, and then to drop out. Because all bidders will follow this strategy, the bidder with the lowest cost will win the auction with a bid that falls just below the second lowest cost. The transaction price is the second lowest cost.

In the first-price sealed-bid auction, the actual choice of the bid represents a tradeoff for the bidder between the probability of winning and the value of winning. Bidding low makes it more likely that the bid is the lowest received and thus the winning value, but it also reduces the profit from winning. Conversely, a high bid means that the vendor is unlikely to win, but the profit from winning is very high. The bid is selected to maximize the expected payoff, considering both the probability and value of winning. In equilibrium, optimal bids equal to expected cost conditional on one's signal plus some shading, and are decreasing in cost.

Equilibrium when bidders can withdraw or revise bids up or down

One unique feature of the DIBBS open auction rules is that bidders are allowed to withdraw or revise their bids without paying any fine or fee during the auction period. With such a feature it is possible to model the bidding game in a way that approximates optimal bidding under either the sealed-bid or traditional open-bid format. For instance, bidding can be modeled as a sequence of "rounds." In each round, bidders can simultaneously submit, revise, or withdraw their bids. In such a game, only the last round bids matter, and because these are submitted simultaneously, the game reduces to a sealed-bid auction at the last time period. Any bidding before then will be "cheap talk."

Instead of all bids being simultaneously submitted at the last round, we can also imagine a model in which only one bid among those submitted in each round is randomly selected to be updated. Specifically, assume that in each round, there is a profile of standing bids, and bidders have the opportunity to change their standing bid. Among all those wishing to revise their bid in each period, only one is selected at random and allowed to do so. As the auction end draws closer, there is a progressively lower chance of having a bid go through (so that one's standing bid becomes more likely to be binding). Then we expect (without proving) that the optimal strategies should approximate the standard open-bid auction strategies of bidding up to one's value.

Whichever of the two models best approximates reality for the auctions we study, we expect equilibrium behavior in DIBBS open bid auctions to lie somewhere between the standard first-price sealed bid equilibrium and the standard open-bid auction equilibrium. As a result, we expect the revenue ranking results described above to hold at least weakly.

As an aside, one potential empirical benefit to allowing bidders to withdraw and revise bids is that more complete bid information can be generated. In a traditional open-bid auction with binding bids, we may not observe bids from any bidder whose cost exceeds the current best bid. When bids can be revised, however, such bidders may still want to enter a bid, just in case the bidder with the best bid decides to revise or withdraw before the auction ends. Thus with revisions allowed, truncated empirical bid distributions under open bidding may be less likely.

Revenue rankings: theoretical results

The revenue equivalence theorem is attributable to Vickrey (1961) and was later generalized by, among others, Myerson (1981), Riley and Samuelson (1981) and Milgrom and Weber (1982). This theorem roughly states that, given independent private values and symmetric bidders, the expected winning bid is the same in both the open-bid and sealed-bid first price auction formats. In particular, the symmetric Bayesian Nash equilibrium of the bidding game implies that the expected value of the winning bid should equal the second highest bidder's valuation. This result suggests that in environments well-approximated by the one characterized above, auctioneers need not be overly concerned with the format chosen.

Departures from the symmetric, independent private values paradigm, however, imply that revenue equivalence need not hold and some auction formats will generate more revenue (or yield lower cost, in the case of procurement auctions). For instance, Milgrom and Weber (1982) demonstrate the following results for auctions in symmetric, affiliated (private or common) values environments:

From the auctioneer's perspective, the expected transaction price in the auction can be ranked from best to worst as:

- Open-bid, first-price (English) auction
- Sealed-bid, second-price auction
- (Tie) sealed-bid, first-price auction and Dutch auction

The intuition for the ranking of auctions is that the auction formats differ in how much information the bidders can infer from bids, and how much control the winning bidder has in setting the transaction price. The more the price depends on private information, the more the vendors will hedge their bids, allowing them to bid a price above their cost. Because the first-price, sealed-bid auction is based on the winning bidder's price alone, and additional information from the auction does not cause bidders to bid more aggressively, the bidder is best off, and the auctioneer is worst off. In the second-price auction, there is less hedging because the price depends on a second bidder's information, which will be correlated with the first bidder's valuation because the valuations are affiliated. In the English auction, the price depends on several bids as each bidder incorporates other bidder actions as signals of their information, so that the price depends even less on private information.

In theory the rankings of formats can be reversed if we relax some of the other assumptions regarding the underlying bidding game. For instance, studies have shown in particular that when bidders are asymmetric, risk averse, or can collude, sealed-bid auctions can dominate open-bid. For example, Maskin and Riley (1984) showed that with risk-averse bidders and independent, private values, sealed-bid auctions can dominate open-bid auctions. Risk averse bidders are more likely to insure against losing by bidding more aggressively. They give up some net payoff conditional on winning in exchange for a higher probability of winning.

For the purposes of the present analysis, we assume the bidders are symmetric, risk neutral, and are not overtly or tacitly colluding. We assume the only source of differences among the commodities being auctioned is the extent to which information about production cost is independent or affiliated. Therefore we expect to find either revenue equivalence or revenue dominance of open bidding.

Institutional background and data description

DIBBS auction history and rules

In August 1999, Defense Supply Center Columbus (DSCC) implemented an automated system for soliciting, evaluating and selecting bids, called Procurement Automated Contract Evaluation (PACE). This automated sealed-bid first-price auction mechanism was intended to replace, for selected items, conventional procurements. Procurements under $25,000 (the threshold was later raised to $100,000) that met the criteria for routine purchases were processed through PACE.

PACE solicitations are posted to DSCC Internet Bid Board System (DIBBS), and registered suppliers respond with their bids. Bidders can submit bids that deviate from the solicitation, though these bids will be considered only if the best bid does not meet solicitation criteria. When the solicitation closes, bids that are not eligible for automated awards are temporarily ignored, and the system evaluates the bids that comply with the solicitation criteria. The evaluation includes price adjustments for surplus materials and inspection at origin rather than destination, and applies a price-reasonableness algorithm to the lowest bid. If the lowest bid satisfies the price-reasonableness algorithm and final automated checks for contractor responsibility, the vendor is automatically selected, notified, and sent a contract. If the lowest resulting bid fails the algorithm or final checks, then PACE does not select a vendor and a manual selection process is used. PACE does not apply best-value criteria, though these criteria may be used in the manual selection process. Essentially, PACE implemented and automated a sealed-bid, first-price auction for selected items.

In August 2000, DSCC modified the PACE program to conduct first-price, open-bid procurement auctions on DIBBS for a subset of product classes. These auctions modified the procedures of the PACE procurements that had already been initiated. Specifically, they notified the vendors that the purchase would be an auction, and the vendors had to agree to let their bids be published, anonymously, on the DIBBS website. At the end of the bidding period, PACE applied the same evaluation and selection criteria.

This implementation of open-bid auctions resulted in a set of rules that differs from most commercial auctions. DIBBS auctions typically last 14 days and have a firm closing time. For each auction, not only are price quotes published for DIBBS auctions, but other factors that affect price-related evaluation, such as Buy American status, are published as well. DIBBS allows bids to be revised upward and to be withdrawn. The possibility that PACE will reject the lowest bid and revert to a manual vendor selection process that may involve best value criteria, rather than the lowest evaluated price criterion, encourages bidders to submit a bid even if it is above the lowest current bid.

DSCC limited DIBBS auctions primarily to Federal Stock Classes 2530 (vehicle brake, steering, and wheel parts) and 5961 (semiconductors and related equipment). In September and October 2000, two additional FSCs — 4730 (fittings for hoses, pipes, tube, lubrication, and railings) and 5930 (switches)—were included in the reverse auctions. DSCC stopped reverse auctions on these items because the cumulative demands on the computer systems were overtaxing the systems. The FSCs were selected because the DSCC thought that they had promise for reasonable returns from implementing open auctions, though they did not inform us of any specific studies that indicated these FSCs would have abnormally high returns. Within theses FSCs, any item that met the criteria for a PACE award was issued as an auction solicitation.

In October 2000, DSCC further modified its automated procurement system by implementing a FAST award feature for some purchases with expected cost below $2500. In a FAST purchase, DSCC posts an indicator of whether a purchase was FAST eligible, though we do not observe it in the data. Bids are evaluated each day beginning with the fourth day following the solicitation issue, and the first bid that meets the price reasonableness criteria and an unannounced reserve price is selected. Thus, the closing date for the item is not fixed. FAST bids are not publicly displayed.

In late 2006, as part of an effort by DLA to centralize purchasing software across all supply centers, DIBBS ceased running open-bid auctions, but continued conducting sealed-bid auctions.

DIBBS auction data

The DIBBS auction data used in this analysis contain the results of the sealed-bid and open-bid auctions conducted from inception in 1999 through 2007. The sealed-bid data consist of 110,353 contracts for 46,318 different items totaling $272 million. The open-bid data consist of 6,790 contracts for 3,591 different items, totaling $50 million in awards. For automated solicitations (with the exception of those that were FAST eligible) each participating vendor's final bid and the date of that final bid are available. The DIBBS data include not only the purchases made using open-bid auctions, but also purchases made using conventional procurement practices both before and after auctioning and the PACE awards made before auctions were implemented. Conventional procurements in the FSCs selected for auctions occurred when one of the criteria for an automated purchase did not hold. Thus, some NSNs would never be auctioned—critical safety items, for example. Some NSNs were purchased using auctions, conventional procurements, or FAST purchases, depending on the circumstances of the purchase.

Unfortunately, the data do not reveal the circumstances of the purchase. However, the only criteria that would normally change for an item that was once auctioned would be the priority of the item or satisfying the cost reasonableness criterion. Thus, if high-priority purchases include a price premium, comparisons of conventional purchases with auction purchases would lead to an overstatement of auction savings. This would apply to both conventional purchases made once auctions were initiated, and to conventional purchases made before the auctions were initiated, because the purchases include an unknown mix of both high-priority and routine purchases. However, PACE purchases before the implementation of open auctions applied the same criteria to the purchases that are applied to the auction. Thus, comparisons of prices resulting from PACE sealed-bid purchases and PACE open-bid auction purchases provide a reasonably unbiased estimate of the effect of using open auctions.

Tables 1 and 2 provide statistics on the data. Table 1 focuses on the data based on the final purchase category. Table 2 focuses on data based on the solicitation type. For each FSC, the columns in the table are determined by the history of the purchases of the NSNs. The first column is composed of NSNs that had at least one open-bid auction; the third column is composed of the data for NSNs that had no open-bid or sealed-bid auctions—all purchases were manual best-value procurements. Some key observations:

- Generally, the set of NSNs that did not have automated procurements were typically larger purchases than the ones that did, though still with a mean cost well below the threshold required for automated open- and sealed-bid auctions (Table 1, rows 5 and 23). This difference appears to be mostly due to the higher quantity (rows 4 and 22). NSNs that had open auctions have a mean price similar to NSNs that never had automated auctions, but those that had sealed auctions had a lower mean price (rows 3 and 21).

- A large number of purchases, even when open and sealed bid auctions may have been possible, are still manual purchases. For example, in FSC 2530 in NSNs that had at least one open auction, 10,000 out of 15,000 procurements were manual (row 2 vs rows 6 and 11). Though those NSNs qualified for automated procurements, they were manual.

- About 75 percent of open-bid solicitations were open-bid purchases (compare rows 6 in table 1 with row 6 in table 2). The remainder of those converted to manual purchases. We note also that a few NSNs that never had open-bid auctions at least started out as open-bid auctions, because the cells in the second and third columns in row 6, Table 2 for each FSC are not empty.

Table 1. Auction purchase summary data

			2530			4730			5930			5961		
			NSNs that had open bid purchases	NSNs that had automated but no open purchases	NSNs that had no sealed or open purchases	NSNs that had open bid purchases	NSNs that had automated but no open purchases	NSNs that had no sealed or open purchases	NSNs that had open bid purchases	NSNs that had automated but no open purchases	NSNs that had no sealed or open purchases	NSNs that had open bid purchases	NSNs that had automated but no open purchases	NSNs that had no sealed or open purchases
1		Number of purchases	23,361	20,266	26,190	5,873	142,770	77,845	3,186	99,458	49,549	8,007	19,870	18,442
2	Open-bid era	Number of purchases	15,090	11,021	11,221	749	2,928	1,409	405	2,155	934	4,697	10,195	4,327
3		Mean price	271.81	104.39	234.18	164.35	122.82	232.87	283.38	216.41	279.8	156.53	44.61	138.98
4		Mean quantity	254.5	148.84	359.17	346.28	373.86	133.97	52.61	47.09	78.63	117.48	220.71	279.83
5		Mean cost	8,178.42	1,766.72	16,461.05	1,973.52	2,075.19	3,062.12	2,801.42	2,682.24	5,575.29	4,902.04	1,534.76	5,241.44
6	Open-bid era, open purchases	Number of purchases	4,217			598			292			1,666		
7		Mean price	313.48			149.12			286.55			170.96		
8		Mean quantity	260.62			416.4			57.28			112.78		
9		Mean cost	6,330.49			1,924.02			2,950.50			4,409.45		
10		Mean number of bidders	5.46			5.98			7.29			4.63		
11	Open-bid era, sealed-bid purchases	Number of purchases	264	678		79	849		39	419		129	1,480	
12		Mean price	297.11	149.49		153.46	141.05		335.68	324.28		183.5	45.71	
13		Mean quantity	105.77	48.34		64.08	461.06		32.33	44.21		100.36	321.41	
14		Mean cost	3,520.35	1,217.19		1,856.31	1,864.48		2,902.08	2,781.36		3,128.99	1,770.51	
15		Mean number of bidders	6.36	5.36								4.94	6.13	
16	Open-bid era, sealed-bid purchases, cost <$2500	Number of purchases	102	542		53	586		13	204		74	1049	
17		Mean price	157.64	99.06		68.01	60.79		367.06	184.36		80.34	35.25	
18		Mean quantity	56.4	27.39		58.28	404.39		2.54	14.22		56.32	95.4	
19		Mean cost	1,143.94	429.71		557.33	710.75		679.49	651.22		815.21	427.31	
20	Automated purchase era	Number of purchases	16,951	12,599	12,809	4,026	90,502	36,538	2,068	65,569	18,051	5,448	12,116	5,675
21		Mean price	266.37	106.34	233.6	159.11	133.67	234.3	274.24	223.62	321.83	155.81	46.08	126.31
22		Mean quantity	244.99	165.21	355.67	960.99	393.98	3,161.78	78.02	628.56	2,210.45	113.58	217.11	252.18
23		Mean cost	7,815.63	1,787.66	15,470.78	3,007.92	2,214.25	3,541.99	4,463.16	3,305.55	8,157.66	4,791.62	1,505.81	4,633.44
24	Automated era, open purchases	Number of purchases	4,218			605			296			1,671		
25		Mean price	313.42			147.65			286.05			170.56		
26		Mean quantity	260.66			528.33			56.75			113.36		
27		Mean cost	6,334.87			1,931.09			2,923.74			4,405.16		
28	Automated era, sealed-bid purchases	Number of purchases	818	1,071		1,019	20,444		597	15,893		328	2,170	
29		Mean price	214.24	150.87		193.04	233.28		315.31	324.46		157.44	49.87	
30		Mean quantity	129.95	105.23		1,057.89	466.75		86.88	76.46		88.56	281.9	
31		Mean cost	3,464.19	1,353.97		4,219.35	3,466.48		5,579.03	4,526.46		3,236.30	1,662.10	
32		Mean number of bidders	6.36	5.36		8.24	7.41		8.46	7.97		4.94	6.13	
33	Automated era, sealed-bid purchases, cost <$2500	Number of purchases	311	840		285	9,394		73	5,267		157	1,573	
34		Mean price	143.82	106.93		78.76	70.64		283.7	156.75		76.96	34.92	
35		Mean quantity	75.09	89.05		366.28	290.97		36.55	25.05		48.73	116.64	
36		Mean cost	1,030.79	492.88		774.03	683.19		1,007	665.67		825.66	486.43	
37		Mean number of bidders	5.91	5.46		9.07	7.33		8.4	7.32		5.36	5.86	

Table 2. Auction solicitation summary data

			2530			4730			5930			5961		
			NSNs that had open bid pur-chases	NSNs that had auto-mated but no open purchases	NSNs that had no sealed or open pur-chases	NSNs that had open bid pur-chases	NSNs that had auto-mated but no open pur-chases	NSNs that had no sealed or open purchases	NSNs that had open bid pur-chases	NSNs that had auto-mated but no open purchases	NSNs that had no sealed or open purchases	NSNs that had open bid pur-chases	NSNs that had auto-mated but no open purchases	NSNs that had no sealed or open purchases
1	Open-bid era	Number of purchases	15,090	11,021	11,221	749	2,928	1,409	405	2,155	934	4,697	10,195	138.98
2		Mean price	271.81	104.39	234.18	164.35	122.82	232.87	283.38	216.41	279.8	156.53	44.61	279.83
3		Mean quantity	254.5	148.84	359.17	346.28	373.86	133.97	52.61	47.09	78.63	117.48	220.71	5,241.44
4		Mean cost	8,178.42	1,766.72	16,461.05	1,973.52	2,075.19	3,062.12	2,801.42	2,682.24	5,575.29	4,902.04	1,534.76	211
5	Open-bid era, open solicitations	Number of purchases	5,241	130	230	604	42	15	293	31	13	2,046	182	254.35
6		Mean price	319.9	225.84	750.09	148.18	90.18	498.59	287.4	304.23	330.63	179.58	265.35	82.08
7		Mean quantity	276.43	201.75	113.95	412.95	2,430.40	45.2	57.14	18.03	10.46	117.21	95.92	7,182.22
8		Mean cost	7,021.85	4,889.15	12,862.85	1,913.23	2,366.47	4,107.62	2,967.85	3,506.81	2,600.56	5,047.28	3,513.48	3.35
9		Mean number of bidders	5.53	6.91	4.45	5.96	5.5	5.27	7.28	4.9	4	4.73	4.75	1,139
10	Open-bid era, sealed-bid solicita-tions	Number of purchases	1,354	957	696	79	916	72	40	434	24	475	2,297	206.11
11		Mean price	282.06	150.5	406.35	153.46	153.24	502.84	329.31	326.38	690.31	245.68	59.43	125.17
12		Mean quantity	288.58	91.75	83.6	64.08	433.3	61.99	42.77	43.42	40	151.1	418.84	4,509.23
13		Mean cost	7,330.05	1,777.31	5,827.88	1,856.31	2,092.88	4,605.66	3,738.43	2,855.00	13,967.10	7,394.02	2,963.32	
14		Mean number of bidders	6.36	5.36								4.94	6.13	
15	Open-bid era, sealed-bid solicita-tions , cost <$2500	Number of purchases	168	702	344	53	603	32	13	213	10	122	1,260	661
16		Mean price	173.67	103.16	173.1	68.01	63.23	102.07	367.06	179.89	186.22	135.27	37.44	81.26
17		Mean quantity	103.72	33.21	20.13	58.28	394.03	41.59	2.54	13.84	34.2	56.05	91.32	47.03
18		Mean cost	1,172.34	426.48	499.57	557.33	714.21	755.59	679.49	638.58	536.09	922.96	445.29	513.36
19	Automated purchase era	Number of purchases	16,951	12,599	12,809	4,026	90,502	36,538	2,068	65,569	18,051	5,448	12,116	5,675
20		Mean price	266.37	106.34	233.6	159.11	133.67	234.3	274.24	223.62	321.83	155.81	46.08	126.31
21		Mean quantity	244.99	165.21	355.67	960.99	393.98	3,161.78	78.02	628.56	2,210.45	113.58	217.11	252.18
22		Mean cost	7,815.63	1,787.66	15,470.78	3,007.92	2,214.25	3,541.99	4,463.16	3,305.55	8,157.66	4,791.62	1,505.81	4,633.44
23	Automated era, open solicitations	Number of purchases	5,242	130	230	615	124	41	300	93	49	2,051	182	211
24		Mean price	319.85	225.84	750.09	146.02	167.55	375.4	286.33	241.62	324.23	179.24	265.35	254.35
25		Mean quantity	276.45	201.75	113.95	521.63	909.77	52.8	56.1	27.65	17.39	117.67	95.92	82.08
26		Mean cost	7,025.24	4,889.15	12,862.85	1,925.08	2,881.97	2,756.44	2,923.32	3,078.39	3,531.51	5,042.22	3,513.48	7,182.22
27	Automated era, sealed-bid solicita-tions	Number of purchases	1,908	1,351	699	1,347	27,099	4,800	821	21,824	3,811	687	3,001	1,161
28		Mean price	250.9	151.26	406.16	182.51	236.9	498.45	317.77	333.34	513.32	215.06	61.66	204.47
29		Mean quantity	245.87	124.23	83.3	1,629.74	547.82	372.47	97.98	87.76	51.03	131.66	367.32	125.68
30		Mean cost	6,199.80	1,723.00	5,821.29	4,807.30	4,036.52	5,259.10	6,423.72	5,334.47	6,569.69	6,198.70	2,628.84	4,495.15
31		Mean number of bidders	6.36	5.36		8.24	7.41		8.46	7.97		4.94	6.13	
32	Automated era, sealed-bid solicita-tions , cost <$2500	Number of purchases	377	1,000	344	302	10,780	2,209	79	6,067	1,551	205	1,788	673
33		Mean price	153.38	108.55	173.1	78.96	72.59	135.62	271.22	162.13	181.59	110.44	36.55	50.1
34		Mean quantity	92.91	83.27	20.13	417.52	284.9	58.46	37.58	25.52	11.7	50.34	111.16	509.78
35		Mean cost	1,063.26	480.5	499.57	799.79	697.9	575.12	1,037.19	688.65	610.83	887.34	492.04	
36		Mean number of bidders	5.91	5.46		9.07	7.33		8.4	7.32		5.36	5.86	

Figures 1 and 2 present the number of bidders for each FSC based on the solicitation type. All bids over 15 are grouped with the 15 bidders. The mean number of bidders is added as a line. The mean number of bidders is statistically different between the types of solicitations for all the FSCs except 2530, vehicle parts. In particular, for the other three FSCs, the observed number of bids per auction is higher under the sealed bid format than under the open format. It may be the case that bidders with the highest costs decided not to enter a bid after observing the standing low bid. It may also suggest asymmetric bidders, where the high-cost bidder decides not to compete in the open auction.

To examine this further, future analysis can look at the bidder identities to see if it was a subset of firms that bid in sealed but not in open auctions. In particular, we can calculate differences in the percentage of sealed auctions in which a firm bid compared to the percentage of open auctions in which it bid. If a histogram of these differences over all firms shows them to be tightly clustered around a mean difference, it suggests symmetric bidders, because all bidders occasionally draw a high cost from the same distribution and decide not to bid in a given open auction. If differences are bimodal, then we may have an environment of asymmetric bidders, because some bidders would be bidding just as actively under both formats, but weaker bidders would show a large drop off in bidding under the open format.

Figure 1. Distributions and means of number of bidders in sealed bid solicitations

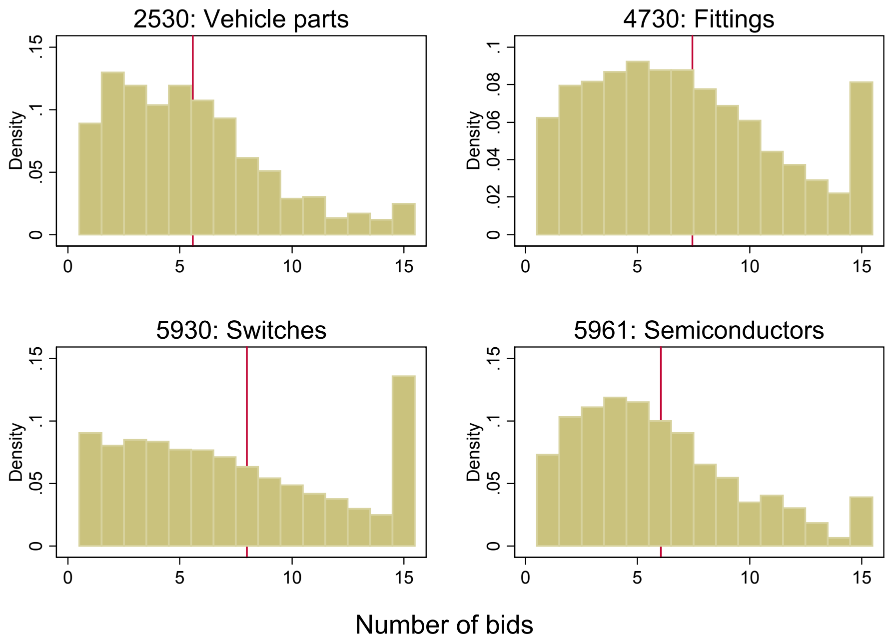
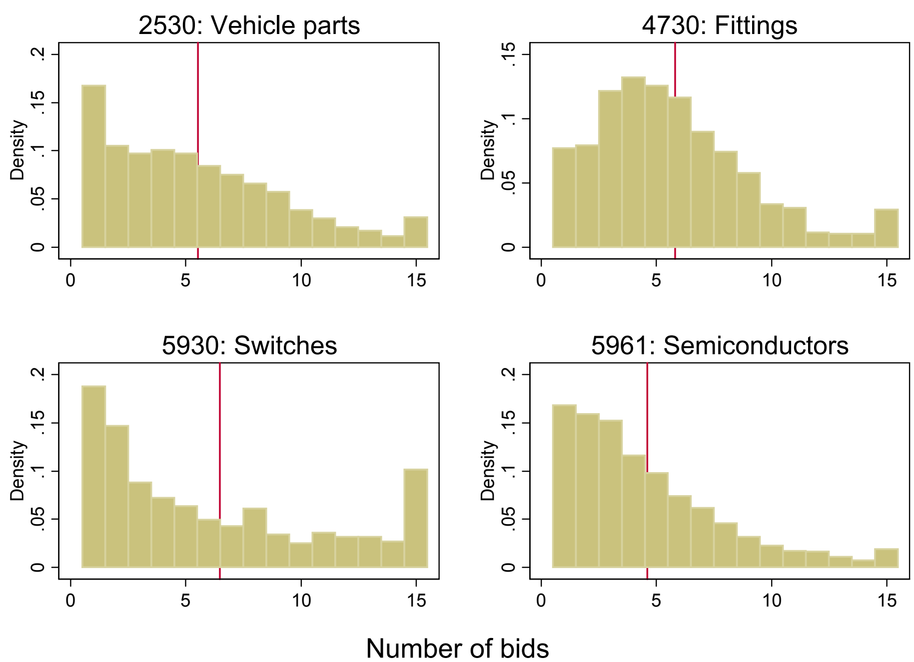


Figure 2. Distribution (and means) of number of bidders for open bid solicitations



Reduced form estimation

In this section we provide estimates of the effects of open and automated bidding on the winning bid, by FSC. We first discuss our empirical strategy and then present estimation results.

Identifying FAST eligible auctions

As discussed in the previous section, DIBBS auction rules declared certain sealed-bid auctions eligible to end early if (1) the total purchase cost did not exceed $2500 and (2) a hidden reserve price was met. According to the DSCC master solicitation:

> "Quotes $2500 or less may be awarded prior to the return date on solicitations that have not been designated for [open-bid] auctioning. Commencing at 3:00 p.m. four business days after the issue date, and continuing every day thereafter at 3:00 p.m. until the return date, all quotes $2500 or less will be evaluated by DSCC's automated contract evaluation program to determine whether an early micropurchase award can be made. Quotes $2500 or less should therefore be submitted as soon as possible on all non-auctioning T or U solicitations."[2]

We expect that bidders would likely bid differently (probably more aggressively) if a sealed-bid auction is eligible for a FAST award. This change in bidding behavior may be motivated by a number of factors, including the prospect of saving a fixed cost of monitoring the auction or realizing earlier payment. Because sealed-bid auctions with the FAST award feature have a meaningfully different structure than regular sealed-bid auctions, it is important to distin-

2. Excerpt from DSCC Master Solicitation, June 2006 version, posted on the internet: http://www.dscc.dla.mil/DownLoads/Documents/ MasterSol/PACE/DSCC_MasterSol_PACE_Current.html, last accessed 3/24/2008.

guish these two types of sealed-bid auctions. To test revenue equivalence, it is the latter type (those without the FAST feature) against which we want to compare open-bid auctions.

Unfortunately the data do not clearly identify which auctions were designated as eligible for FAST micropurchase award. FAST-eligible auctions simply appear as regular sealed-bid solicitations in our data. As a result, we have used information provided by DSCC on how they determined FAST eligibility in order to approximate the subset of sealed-bid auctions that were FAST eligible. We use three main indicators.

Our first FAST-eligible indicator uses the lowest purchase price within the previous 12 months, adjusted for inflation.[3] We multiply this inflated last purchase price by the current quantity to obtain the expected nominal minimum cost. The indicator for FAST-eligible awards is then defined as those with an expected nominal adjusted cost under $2,500. Our next proxy for FAST-eligible awards is an indicator for any automated solicitation for which the bid data are missing. We were told by DIBBS representatives that bid information usually is not retained for FAST awards, but they could not confirm whether this was true for all cases or whether FAST is the only reason bid information might be missing. The third variable we use is an indicator of whether an automated award was made prior to the close of the solicitation period. Our hope is that the three indicators together provide a reasonable proxy for the awards that were actually eligible for FAST.

Estimation results and key findings

In this section, we present estimation results on the effect of open bidding on prices by modeling price as a function of the quantity purchased, the use of open bidding, certain indicators for FAST

3. We considered only purchases with "reasonable" prices (as coded by DSCC). If no such price was available from the previous year, we looked successively in the previous 2 years through 5 years, one year at a time until a prior purchase with a reasonable price was found. This method approximates our understanding of how DLA calculates "lowest price paid."

award eligibility and time (to control for time trends in price not captured by the Producer Price Index (PPI)). We estimate each FSC separately, because the underlying informational environment concerning the costs of production is likely to differ by type of product. Specifically, we estimate variants of the equation

$$\ln price_{it} = u_i + \alpha_1 \ln quantity_{it} + \alpha_2 auto + \alpha_3 open + \alpha_4 fast + \alpha_5 t + \alpha_6 t^2 + \varepsilon_{it}$$

where $\ln price_{it}$ is the price of good i at time t, $\ln quantity_{it}$ is the quantity of good i purchased at time t, u_t is a fixed effect for each NSN, *open* is an indicator equal to one when open bidding was used for the purchase/solicitation and zero otherwise, *fast* is one or more of the proxies for FAST-eligible sealed-bid purchases described above, and ε is an independently and identically distributed error term.

To distinguish FAST-eligible sealed-bid auctions from the traditional sealed-bid auctions we are interested in, we employ three estimation strategies. The first is to exclude entirely from the analysis any solicitation eligible for FAST according to any one of the three FAST proxies described above. The second approach does not exclude any observations, but includes the three FAST proxy variables described above directly in the specification. Finally, we limit the data to only those NSNs for which every purchase we observe is above $2,500.

Under the log specification, the coefficient on the *open* indicator can be interpreted as the percent price change resulting from using open bidding, relative to sealed bidding. Likewise, the coefficient on the *automated* explanatory variables can be interpreted as the percentage reduction in price resulting from an automated award relative to a manual award. Using the fixed effect term controls for the average price of each product.

We estimate this equation on the sample of solicitations and purchases for each FSC separately, using purchases of NSNs that ever had an open-bid purchase. We further limit the sample to definite-delivery, definite-quantity purchases that were "stand-alone" purchase orders. That is, they weren't part of a blanket purchasing agreement or basic ordering agreement.[4] To keep quantity data comparable, we also exclude any NSNs that had a unit-of-issue change during the period of analysis. In table 3 we present summary statistics for the largest sub sample studied in each FSC.

Table 3. Summary statistics of largest sub sample used in regressions

Covers purchase orders for NSNs that ever had an open-bid purchase [a]

FSC	Variable	Obs	Mean	Std. Dev.	Min	Max
2530: Vehicle parts	Nominal price	13,449	382.33	875.94	0.0	18,718
	Real price	13,449	281.98	644.75	0.0	13,071
	Quantity	13,449	231.72	1,080.80	1.0	36,683
	Nominal cost	13,449	8,043.45	17,045.60	0.0	981,742
	Real cost	13,449	5,882.41	11,909.35	0.0	619,396
	Ln (price)	13,447	4.47	1.65	-4.9	9
	Ln (quantity)	13,449	3.36	1.98	0.0	11
	Auto solicitation	13,449	0.65	0.48	0.0	1
	Open solicitation	13,449	0.38	0.49	0.0	1
	Auto purchase	13,449	0.51	0.50	0.0	1
	Open purchase	13,449	0.31	0.46	0.0	1
	Auto solicitation to manual purchase	13,449	0.14	0.35	0.0	1
	Early automated award	13,449	0.06	0.23	0.0	1
	Predicted cost< $2500	13,449	0.15	0.35	0.0	1
	Auto award with missing bids	13,449	0.04	0.21	0.0	1
	Auto award before PACE period	13,449	0.01	0.12	0.0	1
	Time (months since Jan 1960)	13,449	500.15	33.97	408.0	559
	Contract terminated	13,449	0.06	0.25	0.0	1
4730: Fittings	Nominal price	4,295	206.31	528.96	0.1	7,560
	Real price	4,295	155.84	399.27	0.0	5,608
	Quantity	4,295	856.40	6,998.50	1.0	383,100
	Nominal cost	4,295	3,994.82	6,400.14	10.0	89,464
	Real cost	4,295	2,996.76	4,691.16	7.6	67,032

[4] Specifically, we include only awards that were coded as contract type “V”, “P”, “M”, or “W”, which are automated or manual purchase orders. We also excluded cases in which multiple NSNs were purchased under a single purchase order.

Table 3. Summary statistics of largest sub sample used in regressions

Covers purchase orders for NSNs that ever had an open-bid purchase [a]

FSC	Variable	Obs	Mean	Std. Dev.	Min	Max
	Ln (price)	4,295	3.20	2.17	-3.1	9
	Ln (quantity)	4,295	3.97	2.25	0.0	13
	Auto solicitation	4,295	0.63	0.48	0.0	1
	Open solicitation	4,295	0.14	0.35	0.0	1
	Auto purchase	4,295	0.56	0.50	0.0	1
	Open purchase	4,295	0.14	0.35	0.0	1
	Auto solicitation to manual purchase	4,295	0.07	0.26	0.0	1
	Early automated award	4,295	0.06	0.23	0.0	1
	Predicted cost< $2500	4,295	0.18	0.38	0.0	1
	Auto award with missing bids	4,295	0.01	0.12	0.0	1
	Auto award before PACE period	4,295	0.05	0.22	0.0	1
	Time (months since Jan 1960)	4,295	483.74	33.60	408.0	558
	Contract terminated	4,295	0.07	0.25	0.0	1
5930: Switches	Nominal price	2,222	364.10	580.41	0.0	6,371
	Real price	2,222	273.25	427.49	0.0	4,660
	Quantity	2,222	94.42	263.21	1.0	3,599
	Nominal cost	2,222	6,383.47	9,487.33	0.0	145,704
	Real cost	2,222	4,809.73	7,025.77	0.0	104,597
	Ln (price)	2,221	4.79	1.42	0.3	8
	Ln (quantity)	2,222	2.97	1.76	0.0	8
	Auto solicitation	2,222	0.58	0.49	0.0	1
	Open solicitation	2,222	0.14	0.34	0.0	1
	Auto purchase	2,222	0.51	0.50	0.0	1
	Open purchase	2,222	0.13	0.34	0.0	1
	Auto solicitation to manual purchase	2,222	0.07	0.26	0.0	1
	Early automated award	2,222	0.03	0.18	0.0	1
	Predicted cost< $2500	2,222	0.12	0.33	0.0	1
	Auto award with missing bids	2,222	0.03	0.18	0.0	1
	Auto award before PACE period	2,222	0.01	0.10	0.0	1
	Time (months since Jan 1960)	2,222	484.20	33.38	408.0	558

Table 3. Summary statistics of largest sub sample used in regressions

Covers purchase orders for NSNs that ever had an open-bid purchase [a]

FSC	Variable	Obs	Mean	Std. Dev.	Min	Max
	Contract terminated	2,222	0.04	0.19	0.0	1
5961: Semi-conductors	Nominal price	6,372	197.35	620.88	0.0	16,408
	Real price	6,372	146.85	461.60	0.0	12,179
	Quantity	6,372	108.16	245.36	1.0	5,178
	Nominal cost	6,372	5,973.36	10,406.05	0.0	101,662
	Real cost	6,372	4,443.51	7,647.46	0.0	78,413
	Ln (price)	6,361	3.90	1.48	-7.2	9
	Ln (quantity)	6,372	3.58	1.58	0.0	9
	Auto solicitation	6,372	0.59	0.49	0.0	1
	Open solicitation	6,372	0.32	0.47	0.0	1
	Auto purchase	6,372	0.45	0.50	0.0	1
	Open purchase	6,372	0.26	0.44	0.0	1
	Auto solicitation to manual purchase	6,372	0.14	0.35	0.0	1
	Early automated award	6,372	0.04	0.20	0.0	1
	Predicted cost< $2500	6,372	0.16	0.37	0.0	1
	Auto award with missing bids	6,372	0.03	0.17	0.0	1
	Auto award before PACE period	6,372	0.01	0.09	0.0	1
	Time (months since Jan 1960)	6,372	492.05	36.82	408.0	560
	Contract terminated	6,372	0.08	0.27	0.0	1

a. Real prices and costs are expressed in 1984 dollars.

Some interesting observations from the samples we study are:

- Around 60 percent of solicitations in our sample were automated, with over half being open-bid for FSCs 2530 and 5961 and about one fourth open-bid for the other FSCs.
- When we exclude FAST-eligible purchases (defined as those with predicted cost under $2,500), open-bid solicitations account for about 75 percent of automated solicitations in FSCs 5961 and 2530.

- Between 11 and 25 percent of automated solicitations end up as manual awards, because the winning bid failed to satisfy some evaluation criterion.
- The average nominal cost per purchase ranges from about $4,000 to $8,000.
- Between 4 and 8 percent of contract awards are later terminated by one of the parties.

The results of estimating this equation are listed in tables 4-7. Columns (1) and (2) in each table limit the sample to awards that are not FAST eligible according to any one of our proxies. Column (1) uses solicitations as explanatory variables, while (2) uses purchases. Columns (3) (using solicitations) and (4) (using purchases) include all awards, but control for those that are FAST eligible using our three proxy variables. Columns (5) and (6) limit the sample the most, considering only NSNs that never had purchases below $2,500. While we believe this last sub sample excludes FAST eligible awards with greatest accuracy, the price for this accuracy is a greatly reduced sample size. We still report estimation results from this last sub sample to illustrate that coefficient estimates, though not statistically significant, are quantitatively not too different from estimates obtained from the first two sub-samples. Thus we feel more confident that our first two sub samples with results in columns (1)-(4) are controlling for FAST-eligible awards adequately.

Because automated solicitations that do not meet maximum price thresholds revert to manual evaluation, we get a censored picture by comparing only open-bid and sealed-bid automated *purchases*. In particular, open-bid purchases may result in lower prices than sealed-bid purchases, but open-bid solicitations may also revert to manual purchases more often than sealed-bid solicitations, making inference difficult. In the specification using purchases (columns (2), (4), and (6)), we therefore include an indicator of whether a manual award originated as an automated solicitation. As an alternative, we also examine the price effects of using sealed- vs. open-bid *solicitations* (which include purchases that were routed for manual execution because they did not meet price criteria). Regression results using solicitations are reported in columns (1), (3) and (5). By expanding the data to include solicitations, we capture outcomes of those that reverted to manual purchases.

Key results are:

- Examining the coefficients in the "Open solicitation" row in columns (1), (3) and (5) in all four tables, we see that the open bid format does as well as or better than the sealed bid format in all FSCs, consistent with the symmetric, affiliated values model of rational bidding.

- Using the coefficient estimates for "Open solicitation" in column (3) (the largest sub sample) in each table, we find revenue equivalence of sealed and open formats for FSC 2530 (Brake, steering, wheel, and axle components) and some evidence of revenue dominance of open auctions for the other FSCs: we estimate 7 percent savings for FSC 4730 (Hose, pipe, tube, lube, and railing fittings), 4 percent savings for 5930 (Switches) and 6 to 8 percent savings for FSC 5961 (Semiconductor devices and associated hardware).

- The coefficients on automated solicitations in column (3) reveal that automated solicitations yield no savings over manual, with the exception of FSC 4730, in which automated solicitations are associated with 5 percent savings over manual. However, as discussed earlier, this may be an artifact of the requirement that all high-priority purchases be manual.

- The Ln (quantity) coefficients in almost all columns in all tables indicate that higher quantity purchased has a statistically significant association with lower price. On average, doubling the quantity purchased result in a 15 to 20 percent drop in price.

- The FAST award feature appears to yield high savings. The three proxy variables all have statistically significant effects in nearly all tables, columns (3) and (4). Having a predicted lowest cost under $2,500 and having an early automated award are both associated with lower prices, ranging from 5 percent to 20 percent. Having missing bid data is associated with higher prices, perhaps because this variable captures the fast-eligible awards that neither met the reserve price nor ended early (most likely because the winning bid was too high). Because we have no observations of auctions with the FAST award feature for purchases above $2,500, it is unclear whether these savings would extend to higher-value awards.

Table 4. Fixed-effects estimates of sealed and open-bid automated auctions, compared to manual, NSNs that had open purchases, FSC 2530 (Brake, steering, axle, and wheel components)[a]

	Excludes potential FAST Awards		Includes FAST Proxies		Includes NSNs always >$2500	
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Ln (quantity)	-0.112**	-0.114**	-0.14**	-0.14**	-0.134**	-0.137**
Automated solicitation	-.014		-0.01		-0.03	
Open solicitation	-.003		0.01		-0.018	
Automated purchase		-0.04**		-0.04**		-0.06**
Open purchase		0.01		0.02		-0.01
Auto solicitation became manual purchase		0.036**		0.05**		0.02
FAST proxy 1: Predicted cost<$2500			-0.05**	-0.06**		
FAST proxy 2: Auto award with missing bid			0.11**	0.13**		
FAST proxy 3: Early automated award			-0.09**	-0.08**		
Time trend: Months since Jan 1960	.016**	.016**	0.015**	0.016**	0.019**	0.02**
Time trend squared	-.00002*	-0.00002**	-0.00002**	-0.00002**	-0.00002*	-0.00002*
Constant	1.10	0.92	1.09	0.90	0.69	0.52
Number of observations	7,190	7,190	13,447	13,447	1,952	1,952
Number of NSNs	1,435	1,435	1,686	1,686	268	268
R-squared	0.76	0.76	0.56	0.56	0.81	0.81

Dependent variable: Ln (Price)

a. ** statistically significant at the 1 percent level, *statistically significant at the 5 percent level

Table 5. Fixed-effects estimates of sealed and open-bid automated auctions, compared to manual, NSNs that had open purchases, FSC 4730 (Hose, pipe, tube, lube, and railing fittings)[a]

	Excludes potential FAST Awards		Includes FAST Proxies		Includes NSNs always >$2500	
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Ln (quantity)	-0.19**	-0.19**	-0.25**	-0.25**	-0.19**	-0.19**
Automated solicitation	-0.05		-0.05**		-0.05	
Open solicitation	-0.03		-0.07**		0.01	
Automated purchase		-0.04		-0.06**		-0.035
Open purchase		-0.03		-0.06**		-0.01
Auto solicitation became manual purchase		0.06		-0.03		-0.13
FAST proxy 1: Predicted cost<$2500			-0.15**	-0.16**		
FAST proxy 2: Auto award with missing bid			0.20**	0.21**		
FAST proxy 3: Early automated award			-0.10**	-0.09**		
Time trend: Months since Jan 1960	.03**	0.03**	0.03**	0.03**	0.03	0.03
Time trend squared	-.00003**	-0.00003**	-0.00003**	-0.00003**	-0.00002	-0.00003
Constant	-1.97		-2.46	-2.52	-1.18	-0.91
Number of observations	1,693	1,693	4,295	4,295	507	507
Number of NSNs	307	307	580	580	57	57
R-squared	0.89	0.89	0.66	0.66	0.87	0.87

a. ** statistically significant at the 1 percent level, *statistically significant at the 5 percent level

Table 6. Fixed-effects estimates of sealed and open-bid automated auctions, compared to manual, NSNs that had open purchases, FSC 5930 (Switches)[a]

	Excludes potential FAST Awards		Includes FAST Proxies		Includes NSNs always >$2500	
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Ln (quantity)	-0.18**	-0.18**	-0.20**	-0.20**	-0.15**	-0.15**
Automated solicitation	0.02		0.01		-0.004	
Open solicitation	-0.03		-0.04*		-0.019	
Automated purchase		0.02		0.003		-0.01
Open purchase		-0.02		-0.03		-0.01
Auto solicitation became manual purchase		0.03		0.04		0.03
FAST proxy 1: Predicted cost<$2500			-0.11**	-0.11**		
FAST proxy 2: Auto award with missing bid			0.06*	0.07*		
FAST proxy 3: Early automated award			-0.07*	-0.06		
Time trend: Months since Jan 1960	-0.01	-0.01	0.01	0.01	0.01	0.01
Time trend squared	0.00	0.00	0.00	-0.00	0.00	-0.00
Constant	6.62	6.63	2.49	2.39	2.94	2.99
Number of observations	1,242	1,242	2,221	2,221	642	642
Number of NSNs	197	197	293	293	72	72
R-squared	0.76	0.76	0.44	0.44	0.70	0.70

a. ** statistically significant at the 1 percent level, *statistically significant at the 5 percent level

Table 7. Fixed-effects estimates of sealed and open-bid automated auctions, compared to manual, NSNs that had open purchases, FSC 5961 (Semiconductor devices and associated hardware)[a]

Approach to isolate FAST	Excludes potential FAST Awards		Includes FAST proxies		Includes NSNs always >$2500	
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Ln (quantity)	-0.198**	-0.21**	-0.26**	-0.27**	-0.22**	-0.23**
Automated solicitation	-0.01		-0.02		-0.06	
Open solicitation	-0.08**		-0.06**		-0.06	
Automated purchase		-0.13**		-0.11**		-0.11
Open purchase		0.04		0.03		-0.02
Auto solicitation became manual purchase		0.06		0.08**		-0.04
FAST proxy 1: Predicted cost<$2500			-0.18**	-0.15**		
FAST proxy 2: Auto award with missing bid			0.09*	0.12**		
FAST proxy 3: Early automated award			-0.17**	-0.11**		
Time trend: Months since Jan 1960	0.03**	0.03**	0.03**	0.03**	0.03	0.04*
Time trend squared	-0.00003*	-0.00003**	-0.00003**	-0.00003**	-0.00*	-0.00003*
Constant (avg fixed effect)	-1.45	-2.78	-2.90	-3.85	-3.04	-3.43
Number of observations	2,876	2,876	6,361	6,361	938	938
Number of NSNs	727	727	1,007	1,007	143	143
R-squared	0.56	0.58	0.32	0.32	0.63	0.64

a. ** statistically significant at the 1 percent level, *statistically significant at the 5 percent level

Conclusion

In this paper we have examined repeated procurements of selected commodities conducted by DSCC under three different formats: (1) manual, sealed-bid, first-price auctions, (2) automated, sealed-bid first-price auctions and (3) automated, open-bid auctions.

We find that the ranking of the formats (in terms of lowest procurement cost obtained) varies by type of commodity. For vehicle parts we find automated open-bid auctions are equivalent to sealed-bid automated auctions in terms of the procurement cost obtained. For fittings, switches and semiconductors, we find some evidence that open bidding reduces procurement costs relative to sealed-bid auctions. We estimate the magnitude of this effect to be on the order of 4 to 8 percent.

These findings are broadly consistent with the revenue ranking results in the theoretical literature for symmetric, competitive, risk-neutral bidders in an affiliated private (or common) values framework.

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List of tables

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