



Manufacturing & Service Operations Management

Publication details, including instructions for authors and subscription information:
<http://pubsonline.informs.org>

An Empirical Analysis of Price, Quality, and Incumbency in Procurement Auctions

Tunay I. Tunca, D. J. Wu, Fang (Vivian) Zhong

To cite this article:

Tunay I. Tunca, D. J. Wu, Fang (Vivian) Zhong (2014) An Empirical Analysis of Price, Quality, and Incumbency in Procurement Auctions. *Manufacturing & Service Operations Management* 16(3):346-364. <http://dx.doi.org/10.1287/msom.2014.0485>

Full terms and conditions of use: <http://pubsonline.informs.org/page/terms-and-conditions>

This article may be used only for the purposes of research, teaching, and/or private study. Commercial use or systematic downloading (by robots or other automatic processes) is prohibited without explicit Publisher approval, unless otherwise noted. For more information, contact permissions@informs.org.

The Publisher does not warrant or guarantee the article's accuracy, completeness, merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications, or inclusion of an advertisement in this article, neither constitutes nor implies a guarantee, endorsement, or support of claims made of that product, publication, or service.

Copyright © 2014, INFORMS

Please scroll down for article—it is on subsequent pages



INFORMS is the largest professional society in the world for professionals in the fields of operations research, management science, and analytics.

For more information on INFORMS, its publications, membership, or meetings visit <http://www.informs.org>

An Empirical Analysis of Price, Quality, and Incumbency in Procurement Auctions

Tunay I. Tunca

Robert H. Smith School of Business, University of Maryland, College Park, Maryland 20742, ttunca@rhsmith.umd.edu

D. J. Wu

Georgia Institute of Technology, Scheller College of Business, Atlanta, Georgia 30308, dj.wu@scheller.gatech.edu

Fang (Vivian) Zhong

Zurich Financial Services Group, 8002 Zurich, Switzerland, fang.zhong@zurich.com

The use of multiattribute auctions for procurement of products and services when both price and quality matter is becoming more frequent. Such auctions often employ scoring rules and are open ended in winner determination. Yet there is a significant gap in the literature on the efficiency of these procurement mechanisms. In this paper, providing a theoretical model and utilizing data from legal service procurement auctions, we study how open-ended scoring auctions can be used effectively in procurement and demonstrate the roles supplier quality and incumbency play in this process. We demonstrate that open-ended auctions can generate substantial savings to a buyer without compromising quality. We study the underlying mechanism and show how the auction format can work to achieve such performance. We find that the buyer's revealed preferences significantly differ from her stated preferences. Finally, we contribute to the understanding of the role of incumbency in procurement auctions by providing evidence that what may be perceived as incumbency bias can in fact be a revelation of preference for quality.

Keywords: supply chain management; service operations; operations strategy; auctions and mechanism design; econometric analysis

History: Received: August 18, 2010; accepted: January 31, 2014. Published online in *Articles in Advance* May 28, 2014.

1. Introduction

The use of online auctions for procurement has grown tremendously in the last decade (Bartolini and Checketts 2007), extending initially from manufacturing goods to more complex products and services such as transportation, software, and professional services. Procuring more complex goods and services, however, comes with new challenges, such as accurate assessment of the value of offerings of different suppliers, subjective valuations, and control for quality. Critics argue that when less tangible attributes are important for the procured product or the service, auctions traditionally designed to extract price benefits can fail badly, since supplier selection based merely on price can result in a significant loss of quality. To address these challenges, in many practical industrial auction implementations, buyers often employ scoring rules in conjunction with open-ended award structures—buyers reserve the right to deviate from the scoring rules when making the actual winner selection.

One good example of a business category where quality considerations cause challenges is professional services. Professional services is a vast area with many subcategories such as marketing, consulting, insurance,

and legal services. The nature of these services and the associated costs are less structured with more variability in quality, and the value each provider offers is more subjective and buyer specific than for many other products. Coupled with the sensitivity of the provision and execution of these services for the buyer, it is evident that running auctions for these services is a difficult task. Increasingly, however, a number of large companies now use online reverse auctions to procure such services (A.T. Kearney 2006). A good example is General Electric's (GE) legal services sourcing. GE's Commercial Finance (GECF) division employs law firms and annually spends more than \$300 million. GECF's use of auctions for legal service procurement initiated in 2003, with a focus on increasing the value of legal services by reducing service costs and keeping its strategic relationship with law firms through a carefully executed "competitive bidding process" (Morgan 2003). This process covers procurement for a broad spectrum of legal services ranging from litigation to transactional matters.

An important part of GE's bidding process is its winner selection procedure. Law firms are informed that the selection will be based on quality considerations,

such as specific personnel, relevant experience, and availability, as well as economic considerations, such as suppliers' bid price and capability to comply with GE's transaction-related policies. In this process GE announces a nominal scoring rule but does not commit to necessarily abide by the scoring outcome of the bidding. It also reserves the right to award contracts to suppliers it finds more suitable among the participants after observing the bidding outcome; i.e., it employs an "open-ended" award structure. Given the large contract value of business services to be procured, and the complexity of the sourcing process, it is crucial for firms like GE to understand the effect of the bidding process on both cost reduction and supplier/service quality management.

A second important issue is maintaining the fairness of the process. Successful implementation of online procurement auctions hinges on the willing participation of the suppliers. Many large companies have been in strong relationships with their long-term suppliers, and the effect of introduction of procurement auctions on these relationships with incumbent suppliers is unclear. The existence of an "incumbency advantage" in procurement auctions has been the subject of many studies. There is strong evidence in the literature suggesting that incumbent suppliers have advantages in government procurement (Greenstein 1993, De Silva et al. 2003). Specifically, incumbents are awarded production contracts more often and receive a premium compared to nonincumbent winners. Indeed, there are strong incentives for industrial buyers to award incumbent suppliers, since this would provide minimal disruption in their processes and allow them to do business with a known partner. However, this inclination may create a perception of unfairness for nonincumbent suppliers invited to participate in the bidding and may lead them to see their chances of winning a contract against incumbents as low. This issue is especially important considering that reasonably broad supplier participation in the process is crucial for success of online procurement auctions. Therefore, a number of critical concerns for all parties involved rest on the handling of incumbent suppliers in an award process. A better understanding of the role of incumbency in procurement auctions is needed.

In this study, centered around the critical issues discussed above, we explore the usage and the impact of reverse auctions in services procurement. Specifically, we study the following questions: (1) Can reverse auctions be successfully implemented for supply categories where quality assessments can be subjective and play an important role, such as services? In particular, can cost savings be achieved without sacrificing service quality? (2) How does the contract award structure affect the buyer's expected utility? Does an open-ended award structure increase savings for the buyer? (3) What is

the impact and the role of incumbency on the auction outcome? Developing a theory and utilizing data from GE's bidding events for legal services, we aim to shed light on the value of using online reverse auctions in services procurement and the underlying determinants of the outcome of bidding events.

2. Literature Review

Despite a rich literature on multidimensional procurement auctions (see, e.g., Bichler and Steinberg 2007 and Elmaghraby 2000, 2007 for good overviews), studies that explicitly consider quality have been relatively limited (cf. Tunca and Zenios 2006). One common way of employing auctions for procurement in cases with multiple supplier attributes is through scoring rules, which are employed in the auctions we study in this paper. In such cases, a combined score rule to evaluate multiple attributes is announced and suppliers bid on these attributes together with price and compete to get the best score. There is ample evidence in the literature that demonstrates the desirability of scoring auctions. Engelbrecht-Wiggans et al. (2007) show that when quality is taken into consideration along with the bid price, provided there is a large number of bidders, a format that makes contract awards based on a combined price-quality score is preferable to the buyer compared to a price-only format. Asker and Cantillon (2008, 2010) demonstrate that such auctions perform better than several other common procurement procedures for buying differentiated products such as menu auctions, "beauty contests" (where the buyer does not reveal her type and the suppliers make a single bid), and price-only auctions with minimum quality thresholds and bargaining procedures. Lewis and Bajari (2011) show that in highway procurement contract awards, switching to a scoring auction format from traditional contracts results in efficiency gains for the buyer.

Given the established benefits of scoring auctions, an open question is still what the best ways are of implementing such mechanisms. In experimental settings, a number of studies examined various aspects of design of running scoring auctions such as multiattribute versus price-only auctions (Chen-Ritzo et al. 2005), rank feedback versus price feedback (Elmaghraby et al. 2012), and sealed-bid versus dynamic auctions (Haruvy and Katok 2013). Of particular interest to our study is understanding the best way to share the buyer's utility (true score) and to run the subsequent auction. Kostamis et al. (2009) theoretically examine the buyer's best auction format decision between sealed-bid and dynamic auctions for differentiated products when the buyer communicates her individual preferences (as price adjustments) to the suppliers before the auction and identify the conditions under which sealed-bid auctions perform better than dynamic auctions. We study

open-bid scoring auctions and focus on the question of whether the buyer should reveal her utility (scoring) function to the suppliers. In a two-supplier setting and known scoring rule auction, Colucci et al. (2012) compare various quality disclosure policies and identify conditions under which the buyer should reveal or conceal the qualities of the suppliers. In contrast, we examine a case where the suppliers know their quality but not the scoring function of the buyer.

Another design concern is whether the buyer should commit to the price outcomes from the auction or employ a two-stage process, in which the auction is followed by a price-negotiation process between the buyer and the winning suppliers. With suppliers of equal quality, Tunca and Wu (2009) study the question of when to commit to the auction outcome and derive conditions under which the buyer would be better off employing a two-stage process that alters the first-stage auction outcome in awarding contracts. Rezende (2009) studies the postauction price negotiation problem when there are quality differences between the sellers. He finds that if the buyer can commit to the auction price outcome, then the buyer has incentives to distort her taste for quality. However, if the buyer cannot commit to the auction price and there are postauction negotiations, her best strategy is to reveal her true preferences. In this paper, we do not examine auctions with postbidding negotiations. We study auctions where the price is final, but *award decisions* are open ended and not necessarily bound by the stated scoring rule (as employed by many companies such as GE). For this auction structure, we find theoretical conditions under which the buyer is better off not revealing its true preference for quality, i.e., deviating from its stated auction outcome, and empirically demonstrate that that was indeed the case using the GECF legal auctions data set.

Despite the frequent use of open-ended auctions in the industry, studies that focus on such auctions are rare. One main reason for this is the lack of direct observability of buyers' preferences. Krasnokutskaya et al. (2012) is another study that explores this type of auction. They develop a (noisy) identification strategy when quality and the buyer's preferences are not directly observable and apply it to an Internet market for programming services; they show that quality accounts for a large portion of the variation in buyer choices. Utilizing our unique data set that includes all bids and quality scores for all participating suppliers, we contribute to this nascent line of literature by directly measuring and testing the difference of the buyer's stated versus revealed preferences.

Our paper is also related to the literature on the role of incumbency in procurement auctions. It is well documented that incumbents have an advantage in being

awarded contracts when competing with nonincumbent suppliers. Incumbent entrenchment is the most common reason for buyers awarding contracts more frequently and with higher contract prices to incumbents (Demske et al. 1987, Riordan and Sappington 1989, Cabral and Greenstein 1990, Bajari et al. 2014). Utilizing data from federal computer procurement, Greenstein (1993) finds that incumbents are more likely to be selected as the winners of supply contracts. De Silva et al. (2003) compare the bidding behavior of incumbent and new entrant firms in government road construction auctions, and find that incumbents bid less aggressively than new entrants. Elmaghraby and Oh (2006) demonstrate that when learning by doing takes place, incumbents can have an inherent advantage in procurement auctions. Zhong and Wu (2006) empirically demonstrate that incumbents are three times more likely to win manufacturing contracts than nonincumbent suppliers, despite enjoying price premia. Wan et al. (2012) find that under postauction supplier qualification, incumbent suppliers bid less aggressively and hold back their bids—and may even boycott the auctions. All this theory and evidence suggests that nonincumbent suppliers may perceive that they are facing unfair odds in winning supply contracts. In fact, Snir and Hitt (2003) suggest that many buyers might use auctions to gather price information in order to negotiate with their incumbent suppliers. However, our unique data set allows us to explicitly control for supplier quality and test and demonstrate that the incumbency per se does not necessarily constitute an advantage. We show that when one takes quality into account, what may look like incumbency advantage may disappear. Further, we show that when the buyer has flexibility to alter the auction outcome, it does not use it to favor incumbents over nonincumbents. Rather, our results suggest that incumbent advantage in procurement auctions may in many cases stem from an implicit statement of preference for quality.

3. Theory

We first develop a theoretical model to discuss and demonstrate the contract award structure and the role of nonincumbent suppliers in service procurement auctions, where the buyer's preferences not only depend on price but also on quality of service. The results we derive in this section will help lay out the theoretical base for our empirical results and provide insights into *how* auction contract award structure and the inclusion of nonincumbent suppliers affect bidder behavior and expected buyer utility.

3.1. The Model Setting

Consider a firm (the buyer) that is procuring services. The buyer's utility for the service is given by $U(q, p) = \kappa + \theta q - p$, where q is the quality of the work, p is

the price paid for the service, and θ is the buyer's preference parameter for quality versus price. The buyer has two long-term suppliers (the incumbents), labeled A and B , who have been providing services to the buyer at different times depending on their cost realizations and the supplier's varying preferences, θ , that change over time and from case to case. This has been the common industry practice before the employment of online auctions as a procurement tool. The main reason for this practice has been the cost and time required for negotiating and contracting with each supplier (Holloway and Higuera 2002). Because of such costs, conventionally, with the lack of online bidding as a tool of price discovery, companies have carried out procurement with a small number of suppliers. Usually, large buyers choose these providers from among the high-quality suppliers in the industry and keep them on their stable supplier list. They get quotes from this selected group of suppliers when they need to procure products and services and negotiate with them to award procurement contracts.

The buyer's preference substitution rate of quality for price, θ , is her private information. Suppliers, in contrast, have a prior probability distribution on θ . For simplicity, assume that for the suppliers, the distribution of θ is uniform on $[\theta, \bar{\theta}]$. The quality of service provided by suppliers A and B are q_A and q_B , respectively, where $q_A > q_B$. Normalizing the difference between the quality assessments given to each firm by the buyer, we have $q_A - q_B = 1$. The two suppliers have random costs, c_A and c_B , with supports $[\underline{c}_A, \bar{c}_A]$ and $[\underline{c}_B, \bar{c}_B]$, and continuous distributions with densities f_A and f_B , respectively. We assume the higher-quality supplier incurs a higher cost, i.e., $\underline{c}_A > \bar{c}_B$ for simplicity and to eliminate long complex subcases that would not add to the main insights. We also assume $\kappa > \bar{c}_A + 1$ to guarantee that the supplier's service is always attractive to the buyer.

3.2. Bidding Format, Information Structure, and the Equilibrium Concept

To reduce price discovery and process costs, the buyer is considering using a bidding process for awarding contracts. The bidding format employed is a simple reverse English auction, where the suppliers (bidders) lower their prices until all bidders stop. When the bidding stops, the buyer calculates its utility for each bidder, $U(q_i, p_i) = \kappa + \theta q_i - p_i$, $i \in \{A, B\}$, and awards the contract to the supplier that offers the highest utility.

Switching to the bidding process does not necessarily change the equilibrium outcome. In fact, one can think of the traditional award process as a slow bidding process that the two suppliers are engaged in until neither is willing to change its bid. In this process, the buyer essentially carries out the mechanism by providing the implicit communication process between

the bidders. Therefore, and to maintain the simplicity of the analysis, the structure of the game and equilibrium in the traditional process can be viewed as essentially the same except that it will be reached through a longer and costlier process for the buyer. In the bidding, we assume that the prices are common knowledge to all participants. In practice, in many cases (including the bidding process GECF employs), during bidding, only his rank and the current winning bid are made available to each bidder. We make this assumption also for simplicity. Assuming the availability of bid rank and winning bid instead of the visibility of prices would make the model much more complex, without significantly affecting the insights. Further, we assume that each firm's quality is common knowledge to each participant. In practice, the quality scores of the firms, or those of their competitors, are not usually shared with them. Without this simplification, the model becomes analytically intractable. This assumption helps avoid complexity and keep the analysis reasonably simple and tractable while demonstrating the main arguments. Again to keep the model simple, we assume that there is only one winner. In practice, as in the case of GE, often times multiple suppliers are awarded contracts. This assumption does not change the gist of the economic dynamics for the purpose of our results or the main insights we derive from our propositions in this section.

The bidders' information about the buyer's preference for quality, θ , at the time of the bidding depends on the award rule process the buyer employs. If the buyer reveals its utility to the bidders and announces that it will stick with this scoring rule to award contracts, the bidders will know θ and bid accordingly. If the buyer does not reveal her true preferences and states that the auction results are not binding and she can award suppliers in the end according to her hidden preferences, the bidders only know the prior distribution of θ and bid using this coarser information. The latter reflects a common method employed in practice, including by GECF legal procurement auctions. The details of the two cases are given in the next section.

Note that in our setting each supplier's cost is random and private information to that supplier. In addition, the buyer's quality preference parameter θ is also private information, and if she does not reveal it (see below for more), this parameter is also uncertain for the suppliers. Therefore, we study the subgame perfect Bayesian Nash Equilibrium in the bidding game. An equilibrium of the bidding game is defined as a pair of prices for the bidders, such that given the other bidder's price and his information about the distribution of θ , each bidder does not want to change (reduce) his price. The formal equilibrium definition is given in §A of the online supplement (available at <http://dx.doi.org/10.1287/msom.2014.0485>).

3.3. Open-Ended vs. Closed-Ended Auction Award Structures

There are two auction structures that are potentially employed by the buyer. First, if the buyer reveals her true utility to the suppliers and announces that the winning selection will be made according to this rule, this is a *closed-ended* auction award structure. In this case, the bidders will compete knowing θ and set their bids accordingly. We denote this award structure with the superscript c .

In contrast, if the auction the buyer employs is nonbinding or open ended, then she does not have to award the contract to the lowest bidder. Rather, after observing the bidding outcome, she can choose to award the contract to a supplier that is not the lowest bidder. From our model's perspective, this is equivalent to the buyer *not* revealing her preference parameter θ , since if the buyer reveals her *true* preferences to the suppliers, they would bid knowing that the buyer would choose the winner based on the score precisely reflecting her preferences. She may announce a nominal scoring rule here (such as GECF does), which would be her *stated* preferences, but with no commitment to this scoring rule per se she can make the contract awards according to her real θ , which is hidden and can deviate from her stated one. With the true θ hidden, the suppliers bid according to their distributional estimates of θ . We call this structure the *open-ended* award structure and denote it with the superscript o .

The technical equilibrium outcomes for the open-ended and closed-ended auction formats are given in §A of the online supplement. We next present the buyer's choice between the two alternative award structures. The following proposition states that the buyer may be better off employing an open-ended auction format.

PROPOSITION 1. *If $\theta > (\bar{\theta} + \bar{c}_A - c_B)/2$, then for all $\theta \in [\theta, \bar{\theta}]$, in equilibrium, the buyer will choose the open-ended auction award structure over the closed-ended structure, and her contract award decisions (i.e., revealed preferences) will almost surely deviate from those that would follow from her stated preferences.*

If the buyer's preference for quality is strong enough, even in the worst case scenario, i.e., if θ is sufficiently high, in the closed-ended auction scenario, the high-quality bidder has an advantage and can keep his bid very high and still guarantee winning the contract. However, with the open-ended award structure, he still has to balance his desire for a higher margin with maximizing his probability of winning and hence cannot increase his bid as much as he would with the closed-ended auction. So he ends up bidding more aggressively than in the closed-ended auction case. This bidding behavior increases the buyer's expected utility and makes the open-ended structure attractive to her.

3.4. Inclusion of Nonincumbent Suppliers

With the introduction of the bidding process, the price discovery costs go down and the buyer can now include a larger supplier base in the price discovery process. Suppose that after switching to the auction, in addition to the incumbent bidders, the buyer is considering including $n \geq 2$ nonincumbent suppliers, each with service quality q_N , in the bidding process. The incumbents' service quality is higher than the service quality of nonincumbent suppliers; i.e., $q_N < q_B$. Nonincumbent suppliers' costs c_{Li} , $1 \leq \dots \leq n$ are independent and identically distributed random variables with support $[c_L, \bar{c}_L]$, where $\bar{c}_L < c_B$, and density f_L . For convenience in notation, we define $\Delta = q_B - q_N$, $\rho = 1/\Delta$, $\delta = c_B - c_L$, and let $\bar{c}_A - c_B = k \cdot \delta$, for a $k > 0$. We also denote the equilibrium bid price for each low-quality supplier by p_{Li} , $1 \leq \dots \leq n$, and let (i) denote the i th order statistic of a corresponding random variable.

To assess the effect of increased ability of price discovery with nonincumbent suppliers, we compare two procurement scenarios: (1) the base case, where the buyer interacts only with its two high-quality incumbent suppliers; and (2) the procurement auction, where the buyer includes the nonincumbent suppliers. We denote the former scenario with the superscript b and the latter with the superscript a . We use this notation in conjunction with our notation for closed- and open-ended auction structures. For instance, a scenario with open-ended award structure and only two incumbent suppliers bidding will be denoted by oa and so forth. In each scenario, the buyer will award the contract to one supplier whose offer maximizes the buyer's utility. We denote the price the buyer pays to the winning supplier by p_w and the quality of the service for the winning supplier by q_w . We next analyze the characteristics of the outcome and compare the two scenarios.

PROPOSITION 2. *Under an open-ended auction structure, with the inclusion of nonincumbent suppliers, there exists a $\bar{\delta} > 0$, such that if $\delta < \bar{\delta}$, in equilibrium:*

(i) *There are cost savings from both incumbent and nonincumbent suppliers. Technically, we denote the event that an incumbent wins the auction by I (the event that a nonincumbent wins the auction is then I'). Then, $E[p_w^{oa} | I] < E[p_w^{ob}]$, and $E[p_{L(1)}^{oa} | I'] < E[p_{L(1)}^{ob}]$.*

(ii) *There exists a $\bar{k} > 0$ such that for $k < \bar{k}$, conditional on an incumbent supplier winning the auction, the expected quality of the winning incumbent supplier is higher. That is $E[q_w^{oa} | I] > E[q_w^{ob}]$.*

Part (i) of Proposition 2 states that the introduction of nonincumbent suppliers not only provides cost savings from these suppliers but also forces the incumbent suppliers to bid lower. Furthermore, part (ii) of Proposition 2 states that, given that the cost efficiency difference between the incumbents is not very

large, introduction of nonincumbent suppliers in fact increases the expected quality of the winner, if the winner is an incumbent. In other words, higher-quality incumbents become more likely to win than lower-quality incumbents. This is an important benefit the buyer sees from the open-ended structure of the auction. We discuss this further below, after the next proposition that shows the effect of the inclusion of the nonincumbent suppliers on price and buyer's expected utility.

PROPOSITION 3. (i) *Under a closed-ended auction structure, the cost savings and expected utility gains for the buyer with the inclusion of the nonincumbent suppliers vanish if the cost advantage of the low-quality, nonincumbent suppliers vanishes. Specifically, if the nonincumbent suppliers are arbitrarily close to being dominated in both price and quality, i.e., as $\Pr\{c_j - c_{Li} < \epsilon\} \rightarrow 0$, for $j \in \{A, B\}$ and all i , then (a) $E[p_w^{cb}] - E[p_w^{ca}] \rightarrow 0$ and (b) $E[U(q_w^{ca}, p_w^{ca})] - E[U(q_w^{cb}, p_w^{cb})] \rightarrow 0$.*

(ii) *Under an open-ended auction structure, there are cost savings and expected utility gains for the buyer with the inclusion of the nonincumbent suppliers even if these nonincumbent suppliers are arbitrarily close to being dominated in both price and quality. Technically, as $\Pr\{c_j - c_{Li} < \epsilon\} \rightarrow 0$, for $j \in \{A, B\}$ and all i , there exist constants $\tau_p, \tau_u > 0$, such that (a) $E[p_w^{ob}] - E[p_w^{oa}] > \tau_p$ and (b) $E[U(q_w^{oa}, p_w^{oa})] - E[U(q_w^{ob}, p_w^{ob})] > \tau_u$.*

Proposition 3 demonstrates an important difference between open-ended and closed-ended auctions. The contrast between parts (i)(a) and (ii)(a) of the proposition illustrates that when a buyer employs an open-ended auction format, much larger gains can be generated than in a closed-ended auction. More precisely, the proposition looks at the worst case scenario, where the added benefits of including the new lower-cost suppliers is extremely small in that their cost advantage over the incumbent ones is vanishing. Denoting ϵ as the cost difference between the lower-cost suppliers and the higher-cost incumbents as $\epsilon \rightarrow 0$ —i.e., even when the cost advantage of the nonincumbent firms is infinitesimal—the expected cost savings for the buyer from inclusion of these suppliers in an open-ended auction is large (converges to a constant), as stated in part (ii)(a). However, for a closed-ended auction, as the cost advantage becomes infinitesimal, the expected cost savings would also have become infinitesimal, as part (i)(a) states. Consequently, as the nonincumbent suppliers become inefficient, though by part (i)(b) the gains for the closed-ended auction vanish, part (ii)(b) states that the overall effect of introducing the nonincumbent suppliers into the process on the buyer's utility is still significant for the open-ended auction.

It is important to note that the insights from our theoretical analysis do *not* focus on the direct effect of

reduced prices with increased competition through addition of new suppliers to bidding. Rather, the analysis aims to demonstrate the strong indirect *quality-related* effects of the inclusion of new suppliers that go over and beyond the simple effect of increased price competition. More specifically, the results indicate that in an open-ended auction, the addition of new low-cost, low-quality suppliers can generate significant and amplified utility improvement for the buyer compared to a closed-ended auction. Propositions 1–3 together reveal how the auction structure works to generate significant value for the buyer. Because of their overall quality disadvantage, nonincumbent suppliers bid aggressively to win contracts. Incumbents, in contrast, can counter the nonincumbents' low bids with their high quality and normally do not have to bid very aggressively. However, the uncertainty in the buyer's final award decision in an open-ended format makes it suboptimal for the incumbents to keep their prices high: they bid more aggressively than they would in a closed-ended auction to minimize the risk of losing to low-price nonincumbents. The highest quality incumbents hold on to winning spots, and lower-quality incumbents lose out. Consequently, the average quality of winning incumbents increases. The result is that prices fall with a relatively low impact on quality, and the buyer's expected utility increases—even when the nonincumbents are very inefficient. This is an important advantage that the open-ended structure of the auction brings to the buyer and would not happen with the closed-ended format.

4. Hypothesis Development

In this section, utilizing the findings and conclusions of the theoretical model we presented in §3, we develop hypotheses to test. We start by exploring the price savings the buyer accrues through the bidding events. Surveys on industry practice consistently report industrial buyers' cost reduction in the range of 5%–25% after applying dynamic bidding events to industrial parts sourcing processes (Jap 2002, Beall et al. 2003, Elmaghraby 2007). Therefore, as is also predicted in §3, we would expect the buyer to accrue overall savings from implementing the auction. One question is whether these savings originate from both incumbent and nonincumbent winners. As mentioned earlier, empirical studies show that incumbent suppliers often have advantages in procurement auctions. This advantage shows itself in a higher probability of winning contracts as well as enjoying a price premium compared to the nonincumbent winners (Greenstein 1993, De Silva et al. 2003). Hence, another question is whether the incumbents are even forced to reduce their bids significantly compared to their preauction prices. Our results in Proposition 2(i) showed that, after the introduction

of the nonincumbent suppliers, in an open-ended auction, in equilibrium, higher-quality incumbents bid significantly more aggressively to increase their probability of winning in case the buyer's actual preference for the quality is low, which would mean that the nonincumbent suppliers' lower price-lower quality bids are more attractive to the buyer. As a result, the final bids of the winning incumbent suppliers should be significantly lower compared to their bids before the auction. Further, Proposition 2(i) also predicts that the average winning bid by a nonincumbent supplier should be significantly lower than the prices before the auction. Thus, we have:

HYPOTHESIS 1. *Compared to the average price of incumbent suppliers before the auctions,*

- (a) *The average final bid of the winning incumbent suppliers is lower.*
- (b) *The average final bid of the winning nonincumbent suppliers is lower.*

Second, the introduction of the auction changes the bidding behavior of the incumbents and the composition of the winning incumbents. As we have shown in §3, more aggressive bidding by the higher-quality incumbent suppliers, together with the presence of the lower-quality, lower-cost nonincumbent suppliers in the bidding, narrows the lower-quality incumbents' winning prospects. Therefore, as stated in Proposition 2(ii), the expected quality of winning incumbent suppliers increases. Thus, we have:

HYPOTHESIS 2. *Compared to the average quality of incumbent suppliers before the auctions, average quality of the winning incumbent suppliers is higher.*

Existing literature on procurement auctions provides evidence that incumbency is an important advantage for winning contracts (Greenstein 1993, 1995; Elmaghraby and Oh 2006). The phenomenon is mainly attributed to incumbents' entrenchment. For example, in manufacturing and product development, entrenchment can be a result of incompatibility of the future systems with the established ones (Greenstein 1993, Chen and Forman 2006) or strategic investment in capacity and technology of incumbent firms (Farrel and Gallini 1988, Farrel and Shapiro 1989, Riordan and Sappington 1989). Our theory from §3 indicates that one factor that can contribute to more frequent selection of incumbents could be higher average quality of incumbent suppliers. In fact, from our analysis throughout §3, one can see that quality plays a significant role in winner selection regardless of the incumbency status. If the incumbents in fact have higher average quality, and if one does not observe a buyer's explicit quality assessments but just the incumbency status, our analysis indicates that one could conclude that incumbency results in higher frequency of winning. In fact, most previous studies

on incumbency do not have explicit independent quantitative measurements to account for the differences in buyer's quality assessments between incumbents and nonincumbents. In contrast, our theory indicates that if one could observe supplier quality and account for it in determining the factors for winner selection, it could emerge that quality is the factor that leads to incumbents having a higher winning rate rather than pure incumbency status. With explicit quantitative supplier quality assessments, the data set we use in this paper provides a unique opportunity to control for supplier quality when testing for incumbent effect. In particular, to sift out the effects of incumbency and quality and pinpoint the preferences for quality in supplier selection we will test the following hypotheses.

HYPOTHESIS 3. (a) *Without controlling for quality measures, incumbency is a significant factor in determining the probability of a contract award.*

(b) *When included as a control, quality is a significant factor in determining the probability of a contract award and incumbency is not.*

As we have shown in Propositions 1–3, when the buyer is likely to have strong preferences toward quality, as in the case with service procurement auctions, the buyer prefers to employ an open-ended award structure. Further, in an open-ended auction, both the buyer's cost savings and overall utility increases significantly compared to a closed-ended auction. Therefore, in service procurement auctions, the buyer is likely to hold an open-ended auction rather than a closed-ended one. In particular, this means that if a buyer announces a scoring rule without commitment to award the contracts according to that rule, her true preferences (revealed preferences from her winner selection) will almost surely differ from her announced scoring rule. To put it in the notation of our model, let the buyer's stated preferences (or scoring rule) be $U(q, p | \theta_s) = \theta_s q - p$, and her true preferences are characterized by $U(q, p | \theta_r) = \theta_r q - p$. (We can drop the constant κ in the utility function without loss of generality as it does not affect the relative supplier selection.) The buyer will make her decisions based on her true preferences, using her true quality-price substitution rate θ_r , and her true preferences can be revealed from her supplier selection at the end of the auction. Then we expect $\theta_r \neq \theta_s$. Further, again based on Proposition 3, the buyer's average utility based on her revealed preferences should also be improved compared to her utility before. In other words, our last hypothesis can be stated as

HYPOTHESIS 4. (a) *The buyer's revealed substitution rate between quality and price is different than her announced rate.*

(b) *The average utility of the buyer is higher than her average utility before the auctions.*

5. Data and Analysis

5.1. Dynamic Bidding for Legal Services

Our data on service procurement auctions come from GECF's large scale auctions for awarding legal services contracts. In 2003, GECF decided to switch the method for its legal services procurement. Previously, it used a traditional contract award process for legal services, where incumbent suppliers were awarded contracts after traditional negotiation processes. Our data come from the first online auctions after this switch. Note that each area of legal services was procured separately with a disjoint set of suppliers corresponding to the related department of a given law firm. For each type of legal service, a unique set of bidders participate in bidding that participate only in the process for that particular type of service. All these stipulations allow a highly controlled comparison on the outcomes before and after the auction process.

GECF has an innovative online procurement process for legal services. The procurement team and the lead internal lawyers first specify the expertise levels for each legal service category, such as real estate or bankruptcy. An auction is organized for each category. All incumbent law firms participated in the new online procurement process. In addition, a large number of nonincumbent firms (specifically their corresponding units) were invited as well. All bidding units were informed that they would be evaluated based on both economic and quality considerations. Therefore, being the lowest bidder did not ensure being selected as a winner. Suppliers were also informed that multiple winners would be selected for GE's list of contracted suppliers for that category. The suppliers from the selected winners list for each category would provide legal services to GE for three years after the auction.

GE uses a dynamic reverse auction mechanism to induce competitive bidding for legal services. Suppliers are required to bid the hourly rates for predefined expertise levels for their employees (e.g., associate, junior and senior partners, etc.). The total bid, or the "blended rate" as referred by GE, of a law firm is the sum of the hourly rates for different expertise levels that law firm submits. The final total bid is used to compare and rank the suppliers' prices. During an auction a supplier observes its current bid rank and the lowest bid at any given time. Each auction starts with a short initial period of about 30 minutes with unlimited two-minute extension periods. This period is automatically extended as long as there are new bids submitted within the last five minutes. The auction ends when there are no new bids arriving for any expertise level from any supplier. The lowest bid of the auction is revealed to all suppliers, though the identity of the lowest bidder is not. Suppliers also know their final standing in the bidding process.

GE employs a scoring approach to quantify its preferences for "cost" and "quality" factors. Each bidder is assigned an *Economic Score* and a *Legal Score*, respectively. *Economic Score* has two components: *Bid Rank* and *Sourcing Rate*. *Bid Rank* is the rank of a supplier's final bid. Prior to an auction, GE conducts a request for information, which essentially captures various transaction-related issues, such as payment terms, pricing policy, and invoice policy. Based on suppliers' self-reported answers to the request for information, GECF assigns a score between 1 and 10, 1 being the best and 10 being the worst. This score is called the *Sourcing Rate* of each qualified law firm. The *Economic Score* is the weighted average of *Bid Rank* (95%) and *Sourcing Rate* (5%), with lower scores being better. *Legal Score* also consists of two elements: *Expertise, Efficiency, and Capacity (EEC)* and *Legal Rating*. *EEC* captures a law firm's experience, market knowledge, expertise and efficiency of specific personnel, depth and support resources with respect to such personnel, capacity to handle volume of work for the relevant business units, and ability to interface well with GE customers and GE. The score is assigned by GE's in-house counsels based mainly on GE's past experience with a given law firm, considering the firm's reputation, historical performance, internal stakeholder recommendation and experience, transaction experience, and firm resume. *Legal Rating*, on the other hand, captures considerations such as the law firm's ability to represent GE without numerous potential conflict situations and their full compliance with the GE Company Outside Counsel Policy. *Legal Score* is the weighted average of *EEC* (85%) and *Legal Rating* (15%), with a lower score being better.

Finally, the *Composite Score* is the sum of the *Economic Score* and the *Legal Score*. That is,

Composite Score

$$\begin{aligned} &= \text{Economic Score} + \text{Legal Score} \\ &= (0.95 \times \text{Bid Rank} + 0.05 \times \text{Sourcing Rate}) \\ &\quad + (0.85 \times \text{EEC} + 0.15 \times \text{Legal Rating}). \end{aligned} \quad (1)$$

Note that by construction, a lower *Composite Score* is better for a supplier. Also note that each firm has a single quality score that does not change before or after auctions. What changes is the price competitiveness behavior of the suppliers under each method (i.e., traditional negotiation process before the auctions versus the auction process). Therefore, the *Composite Score*, which is the main quantitative benchmark that reflects the buyer's utility, controls for quality for the before and after cases.

Suppliers are fully informed of the content, assignment, and structure of the scores. However, they do not know their individual scores or the scores of their competitors at any moment during the procurement

process. Although suppliers' *Composite Scores* determine the ranking of the suppliers and help in selecting the winners, it is also important to note that the suppliers with lower *Composite Scores* are *not* guaranteed to be awarded the contract. That is, after the auction outcome is determined, GE can select a supplier with a higher (i.e., worse) *Composite Score* than one with a lower (i.e., better) one. *Composite Score* defines a preference curve for the buyer between price and quality at equal weights. However, that does not necessarily reflect the buyer's true preferences. The buyer's true relative preference ratio (which is a proxy for θ in the perspective of the model we presented in §3) can be different from these *stated* preferences. We will explore this aspect of the setting later in §5.6.

5.2. Data

The online bidding events for legal services in our data set were conducted by GE at the end of 2003. There are 33 different "rooms" or legal categories that the preapproved law firms bid in our data set. The winning suppliers will collectively handle 95% of GECF's legal work for a two-year period starting in January 2004, which may be extended to a third year. All auctions were conducted simultaneously. Even if representatives from the same law firm are present as bidders in two different auctions, they belong to different divisions of the firm and make their bids as completely independent decision makers with their independent objective functions and with no information about the auctions in the other rooms. In other words, no decision maker simultaneously participates in multiple auctions.

Before switching to online bidding events, GECF has traditionally procured legal services through bilateral contracts with a subset of the suppliers that participate in the online bidding. This is the common industry practice, as discussed in §3. In this data set, those suppliers GE was working with in 2003 for a given category are the *incumbent* suppliers for that category, and the remaining suppliers are the *nonincumbents*. The incumbent suppliers have substantially higher quality than the nonincumbents on average (average legal score for incumbents is 3.37 compared to 10.26 for nonincumbents) and there are fewer incumbents (with an average of 4.61 incumbent suppliers versus 8.70 nonincumbents per auction).

The data set includes the final bid for all suppliers participating in all auctions in addition to the score components, including the individual values of *Sourcing Rate*, *EEC*, and *Legal Rating*, as well as the identity of the winners in each bidding room. Table B.1 in the online supplement displays brief descriptive statistics for the auctions. In addition to the auction data, the data set covers the hourly rates GECF was paying to incumbent suppliers at each expertise level for all legal service

categories defined by GE before the bidding events. The award process for GE's legal contracts (both before and after auctions) does not prespecify the percentage of the work that will be given to each winner. Rather, it only specifies winners, and the contracts are awarded as the legal work materializes in the future while the contract is valid. Therefore, there is no way of knowing beforehand, what percentage of contracts will be awarded to each winner. Since it is not possible to know the exact percentage shares beforehand, GECF uses the average of the winners' prices as the estimate of the average winners' price both before and after auctions. This is an unbiased estimate of the average price given the information set at the time of the award decisions, and we also use this average price measure throughout the paper.

5.3. Tests for Cost Savings

We start by exploring the cost savings the buyer achieves by implementing the auctions and the source of the savings. To do this we compare the hourly rates before and after the bidding events in each room to estimate the cost savings. It needs to be taken into account that the contract prices will be valid for three years after the auction. Based on GE's historical records on legal fee growth, the legal service industry annual price growth rate is between 7% to 15%. If nothing had changed, we would expect, on average, the contract prices to increase by 7% and 15% annually. So to make a correct present value comparison, we need to bring hourly rate dollars for the next three years to the 2003 values. A conservative assumption would take the legal fee growth rate as 7% and bring all prices to year 2003 dollars. Alternatively, we can make an even more conservative estimate, and using the historical U.S. inflation rates from U.S. Department of Labor, Bureau of Labor Statistics Consumer Price Index data, we can calculate the average compounded inflation rate from 2000 to 2003 and use this rate as the discount rate for the present value calculations. (The raw data for these rates can be found at <ftp://ftp.bls.gov/pub/special.requests/cpi/cpi.txt>.) Using these data, the average compounded annual inflation between 2000 and 2003 is 2.597%.

We first look at the overall savings. For this, we use nonparametric estimation for hypothesis testing and statistical inference when the sample size is small (Wooldridge 2001). Two sample *t*-tests are applied to the three-year average hourly rate and the auction rate to evaluate whether the difference between before and after auction hourly rates is significant. Before we get into the discounted rates, first, even without taking the present value adjustments of before- and after-auction rates, there are significant savings even with the nominal dollar values. Comparing the nominal after auction winning hourly rates to the before auction

2003 rates, we find that there is a 4.1% average annual savings, which is significant with a p -value of 0.08. (See Table B.2 in the online supplement for a detailed breakdown.) Further, the present value based analysis, as summarized above, strengthens this finding. Using the annualized compound inflation rate of 2.597%, and controlling for the type of legal services provided, procurement through auctions achieved an overall three-year average 9.6% cost reduction. The savings sum up to \$17.91 million per year in total in 2003 dollars. Moreover, t -test for paired observations shows that the difference between the three-year average hourly rate before the auctions and the hourly rate after the auctions has a t -value of 4.443 and is significant at the 0.01% level. This establishes that there are significant (inflation-adjusted) savings from using the auctions. In addition, we performed a Wilcoxon sign-rank test to confirm robustness. The z -value for that test is 3.565 with a p -value of 0.0004. Therefore, we can conclude that there are significant overall savings after the auctions. Detailed computation of cost savings at the bidding-room level can be found in Table B.2 in the online supplement.

Next, to test Hypothesis 1, we separately calculated the average hourly rates of the incumbent and the nonincumbent winners to assess whether the buyer accrues savings from each type of bidder as stated in parts (a) and (b) of Hypothesis 1. For the auctions with at least one incumbent winner, the average before auction hourly rate was \$326.48. The average present (2003) value of the incumbent winner's hourly rates (using the annual inflation rate implied by the Bureau of Labor Statistics historical data) was \$293.65. Performing a paired t -test on these two samples, the t -value is 2.404 with a p -value of 0.0123. We further perform a Wilcoxon sign-rank test to confirm robustness. The z -value for that test is 2.971 with a p -value of 0.0030. Therefore, we can conclude that Hypothesis 1(a) is supported.

For the auctions where there was at least one nonincumbent supplier winner, the average before-auction hourly rate was \$320.73; the average present value of the nonincumbent winner's hourly rates in contrast was \$286.06. Running a paired t -test on these two samples yields a t -value of 3.630 with a p -value of less

than 0.0011. Again running a Wilcoxon sign-rank test to confirm robustness yields a z -value of 3.053 with a p -value of 0.0023, which means that Hypothesis 1(b) is also supported.

Our tests indicate that there are significant savings to the buyer from the employment of online bidding events. The question then becomes whether these cost savings were achieved at the expense of quality. We explore the answer to that question in §5.4. Further, our result on the buyer's savings from the incumbents suggests that incumbents may not necessarily enjoy the advantages found in previous studies. We investigate this issue in depth in §5.5.

5.4. Tests for the Effect on Service Quality

Direct and explicit measurement of supplier quality has been a challenge in research studies on auctions. The main reason for this is the rarity of explicit quantitative measures of "quality" of the product or service procured. Further, even if one could somehow have a measurement of the quality of each supplier, the relative "value" of quality versus price according to the buyer's preferences is seldom, if ever, explicitly known by the researcher. Our data set offers a unique opportunity to address these challenges. Recall that according to GE's scoring rule, each law firm's service quality is measured by three scores, namely, *Legal Rating*, *EEC*, and their combination, the *Legal Score*. That is, our data set provides *direct* quantitative measurements of supplier quality. Further, in our case, the buyer's explicit stated weights for the *Economic Score* and the *Legal Score* in the calculation of the *Composite Score* are known. This allows us to make an assessment on the buyer's overall utility change before and after the auctions.

Armed with these data, we can first check whether the average winning supplier quality suffered after the auctions. The average values of the quality measures before and after auctions are presented in Table 1. The table is organized in three panels: (a) all auctions (31 bidding rooms), (b) the auctions where there are incumbent winners (26 bidding rooms), and (c) the auctions where there are nonincumbent winners (17 bidding rooms). Two of the 33 auctions in our data set do not have *Legal Scores* reported for the nonincumbents and are therefore removed from the analysis in this section. For the tests, we employ a one-sided

Table 1 Quality Measures of the Supplier Base Before and After Auctions

	(a) All auctions ($N = 31$)		(b) Auctions with incumbent winners ($N = 26$)		(c) Auctions with nonincumbent winners ($N = 17$)	
Average scores	Before auctions	After auctions	Before auctions	Incumbent winners	Before auctions	Nonincumbent winners
<i>Legal Rating</i>	3.38	3.49	3.01	2.93	3.84	3.95
<i>EEC Score</i>	3.50	3.66	3.63	3.25*	3.41	4.69**
<i>Legal Score</i>	3.37	3.39	3.42	2.98*	3.51	4.51**
<i>Composite Score</i>	9.57	8.09***	9.44	7.70***	10.08	9.39

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

t -test to detect any changes in average supplier quality. (Wilcoxon sign-rank tests of equality of the means of the average scores also yield the same results.) For all auctions—dependent two-sample t -tests on the two sets of average scores—the changes in each of the three individual quality measures are small and insignificant, as shown in panel (a) of Table 1. Note that the improvement in the *Composite Score* is significant (from 9.57 to 8.09, $p = 0.000$). This is because the *Composite Score* is the sum of *Economic* and *Legal Scores* and thereby reflects the price savings established in §5.3. In short, it could be possible to effectively employ auctions for service procurement *without* (significantly) compromising the average quality—and gain significant price savings at the same time.

When we separate the average scores of incumbent winners from nonincumbent winners as shown in panels (b) and (c) in Table 1 and compare them with the average scores before the auctions, the differences in supplier quality become significant. As shown in panel (b), the average *Legal Score* of incumbent winners is significantly reduced after the auctions (from 3.42 to 2.98, $p = 0.057$). That is, conditional on winning the auction, average supplier quality increases for incumbents, which means that Hypothesis 2 is supported. However, note that the average *Legal Score* of nonincumbent winners is significantly higher than that of the incumbent firms before the auctions (4.51 compared to 3.51, $p = 0.048$) as shown in panel (c). The average *EEC Score*, the key measurement of supplier quality, is significantly lower for incumbent winners than it was before the auctions (3.25 compared to 3.63, $p = 0.097$). In contrast, the average *EEC Score* of nonincumbent winners is significantly higher than the level before the auctions (4.69 compared to 3.41, $p = 0.026$).

Importantly, these findings provide insights and evidence for how the auctions work for the buyer, i.e., how it is possible for the buyer to lower the prices while maintaining the service quality. In particular, note that there is no significant difference between the average *Composite Score* of nonincumbent winners and the level before the auctions (9.39 compared to 10.08, $p = 0.291$). That is, there is no significant *direct* overall benefit for the buyer from the nonincumbent suppliers, as the price benefit they bring is negated overall (as measured by the *Composite Score*) by the loss in quality of service when they win the contracts. However, there are *indirect* benefits from the inclusion of low-quality suppliers enabled by the auctions, as this causes higher-quality *incumbent* suppliers to lower their bids significantly: The incumbent winners' *Composite Scores* are significantly better than the average *Composite Scores* before the auctions (7.70 compared to 9.44, $p < 0.01$), significantly improving the overall *Composite Score* for all auctions. As demonstrated theoretically in §3, in particular part (ii) of Proposition 2, with

the introduction of nonincumbent suppliers, since the buyer's true utility function is not known and since the auctions are open ended, higher-quality incumbents reduce their bids significantly to reduce the risk of losing to low-quality but also low-price nonincumbent suppliers. In the process, incumbent suppliers with relatively lower quality are squeezed out, and as a result, the average quality of incumbent winners increases, with a significant drop in the incumbent winners' bids.

5.5. Incumbency and Winner Selection

To test Hypothesis 3, we conduct a series of logit regressions, controlling for the relevant factors *including* the buyer's assessment of supplier service quality. Specifically, we estimate the probability (p) of a law firm being selected as a winner conditional on its incumbent status (IC) and a vector of performance scores (S). To control for the competitiveness of different bidding rooms, we include number of winners (*NumofWinners*), number of bidders (*NumofBidders*), and the percentage of nonincumbent bidders (*NonIncPerc*) for each bidding room j , as well as the final bid of each supplier i in each bidding room j (*FinalBid*). We define P_{ij} as firm i 's probability of winning a contract in auction j . Altogether, P_{ij} can be estimated through the following logit model:

$$\log \frac{P_{ij}}{1 - P_{ij}} = \beta_0 + \beta_I IC_{ij} + \sum_k \beta_k S_{kij} + \beta_w \text{NumofWinners}_j + \beta_b \text{NumofBidders}_j + \beta_n \text{NonIncPerc}_j + \beta_f \text{FinalBid}_{ij}. \quad (2)$$

In (2), the variable IC_{ij} is an indicator variable for incumbency (i.e., equals 1 if supplier i is an incumbent in auction j , and 0 otherwise). The S_{kij} variables denote the score variables for supplier i and auction j , for the score component k that keeps track of price competitiveness and quality assessments of the suppliers (e.g., *Bid Rank*, *EEC*, *Economic*, and *Legal Scores*).

Table 2 presents our results. Panel (a) presents the results of a sequence of logit models with increasing level of detail for the "score" variables. Model I is a simple benchmark model, where supplier quality is ignored. We study this model to have a level comparison with previous studies that examine incumbency but do not have explicit quality measurements. In this model, in addition to auction control variables, only the *Bid Rank* ($S_{ij} = (\text{Rank}_{ij})$) and the incumbent indicator are present. Model II includes the *Composite Score* ($S_{ij} = (\text{Composite}_{ij})$), Model III separates the *Composite Score* into *Economic* and *Legal Scores* ($S_{ij} = (\text{Economic}_{ij}, \text{Legal}_{ij})$), and finally, Model IV gives the full decomposition into basic score variables, $S_{ij} = (\text{Rank}_{ij}, \text{Sourcing Rate}_{ij}, \text{EEC}_{ij}, \text{Legal Rate}_{ij})$.

As shown in Model I, when one only considers the final *Bid Rank* and *Incumbency* as the determinants of

Table 2 Tests of Incumbency Advantage with Control for Service Quality Assessments

	(a) Pooled logit models				(b) Auction fixed-effects models			
	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model VIII
<i>Incumbency</i>	1.051*** (2.69)	0.382 (0.92)	0.444 (1.03)	0.368 (0.84)	0.978** (2.56)	0.285 (0.70)	0.205 (0.47)	0.103 (0.23)
<i>Composite Score</i>		−0.456*** (−6.15)				−0.455*** (−6.09)		
<i>Economic Score</i>			−0.480*** (−5.80)				−0.446*** (5.84)	
<i>Legal Score</i>			−0.417*** (−4.57)				−0.499*** (4.59)	
<i>Bid Rank</i>	−0.346*** (−5.16)			−0.417*** (−5.78)	−0.289*** (−5.15)			−0.453*** (5.81)
<i>Sourcing Rate</i>				0.036 (0.36)				0.072 (0.71)
<i>EEC</i>				−0.328*** (−3.91)				−0.383*** (3.74)
<i>Legal Rating</i>				−0.133* (−1.15)				−0.244* (1.66)
<i>NumofWinners</i>	0.328* (1.77)	0.479** (2.42)	0.452** (2.23)	0.392* (1.77)				
<i>NumofBidders</i>	0.056 (1.67)	0.162*** (3.51)	0.159*** (3.45)	0.174*** (3.36)				
<i>NonIncPerc</i>	0.338 (0.41)	0.498 (0.58)	0.550 (0.63)	0.587 (0.67)				
<i>FinalBid</i>	0.003 (1.17)	0.003 (1.29)	0.004 (1.45)	0.004 (1.27)				
<i>Constant</i>	−1.654 (−1.24)	−0.893 (−0.68)	−1.027 (−0.77)	−0.852 (−0.59)				
<i>N</i>	198	198	198	198	198	198	198	198
χ^2	65.27	91.06	91.52	91.45	44.22	74.18	74.52	76.56
<i>Pseudo R</i> ²	0.228	0.332	0.333	0.333				
Log likelihood	−104.61	−91.714	−91.481	−91.516				

Note. The values in parentheses are corresponding z-statistics.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

winning, the coefficient of the incumbency indicator is positive and highly significant ($\beta = 1.051$, $p = 0.007$); i.e., the results suggest a strong incumbency advantage in selecting winners. Therefore, Hypothesis 3(a) is supported. Given the coefficient of incumbency in this model, incumbent firms seem significantly more likely to be selected as the winners—in fact, incumbency seems to give an advantage to a supplier equivalent to about three places improvement in *Bid Rank* on average. However, once we include variables that contain information about the quality of the suppliers, the story changes: As shown in Table 2, for Model II, the coefficient of *Composite Score* is negative and significant ($\beta = -0.456$, $p = 0.000$), whereas the incumbency indicator becomes insignificant ($\beta = 0.382$, $p = 0.360$). The same observation is supported by Model III by separating the *Composite Score* into *Economic* and *Legal Scores*, both with negative and highly significant coefficients; and finally, by the full decomposition given in Model IV, where the coefficients for *Bid Rank* ($\beta = -0.417$, $p = 0.000$) and *EEC Score* ($\beta = -0.318$, $p = 0.000$)

are both negative and significant, while the incumbent indicator remains insignificant ($\beta = 0.368$, $p = 0.402$).

For the control variables we employ, the number of winners is positive and significant for all models and the number of bidders is positive and significant for models II, III, and IV. The former reflects the fact that a higher number of awards increases winning probability. The latter points to the strength of the relative value of having a better score based on the size of the candidate competitor population: e.g., all else being equal, the same bid rank is a stronger indicator of supplier fitness in a larger supplier pool than a smaller supplier pool. The results suggest that this effect is sufficiently strong to overcome increased competitiveness that a higher number of bidders brings to bidding. In contrast, percentage of nonincumbent bidders and the final bid are not significant, meaning they do not add any additional explanatory power to the regression given the other independent variables.

One potential issue here is multicollinearity. For instance, GE may be giving better legal scores

to incumbent bidders, which may result in *EEC*, *Legal Rating*, the *Legal Score* and ultimately the *Composite Score* already capturing the effect of incumbency. Similarly, incumbents may bid less aggressively simply due to their status. Checking for this potential problem, first, a correlation analysis of the independent variables demonstrates that collinearity on a single-pair base is not present. Further, we calculated the Variance Inflation Factors (VIFs) for the independent variables. The VIF values for all independent variables are well below 10—in fact, all VIF values are below 3, with an average of 1.65, suggesting that there is no significant multicollinearity among the independent variables. (The correlation and VIF tables are given in §C in the online supplement.)

Another potential problem that can arise is endogeneity. One source of endogeneity in our regression is that the winner determination as well as some variables such as Number of Winners may depend on the full bidding profile (price bids and qualities) of all bidders; i.e., there may be some omitted variables. However, attempting to include the profile of all bidders in the regression would pose serious data and structural problems, such as the introduction of a very large number of additional independent variables to the regression, an unequal number of bidders (and hence independent variables) among auctions, and complex structural relationships. Therefore, including the entire bidding profile for each auction would likely not be feasible to implement and not produce reliable estimates. By assigning auction-specific fixed adjustments, a fixed-effects model largely compensates for this missing variables problem and takes the combined effects of the auction-based variables into account. Therefore, we test fixed-effects models of P_{ij} to account for this issue as well as other potential dependencies within each auction. The results are presented in panel (b) of Table 2. Parallel to Models I–IV, we employ a gradually increasing score decomposition in Models V–VIII. As shown in the table, the conclusions are consistent with those of Models I–IV: incumbency advantage is strong and significant when the quality measurements are excluded but becomes insignificant when one takes quality measures into account.

Another source of endogeneity could be unobserved idiosyncratic buyer tastes that affect the supplier selection. If there are idiosyncratic tastes at the bidder level, i.e., if the buyer's idiosyncratic tastes change from bidder to bidder with no systematic pattern that can be captured by an explicit separately observable variable, and the buyer had made decisions according to those, a regression would not be able to pick this up. However, in our case, if such an idiosyncratic preference exists, we do have a proxy in the data to account for it. Specifically, if the buyer has a certain preference that she believes should affect her decision,

this is a rational choice, given the buyer's preferences, and she can and should incorporate that preference in the quality score, i.e., the *Legal Score* and its components *EEC* and *Legal Rating*. The buyer uses it in her own decision making by weighing the benefits from it versus the price offered by the suppliers using its internal substitution rate (θ). Therefore, such possible bidder-level idiosyncratic preferences are likely already included in GE's choices, since the *Legal Score* controls for it; they would also be included in our regression analysis above. Similarly, certain suppliers may bid less aggressively since they may believe they have a better chance to win because of the buyer's idiosyncratic preferences toward them. Therefore, these two types of variables (i.e., quality-related scores and bid rank) that are determined by buyer and bidder behavior may be endogenous to other variables in our regression in a way that may affect the accuracy of our results. To address such endogeneity issues, we employ the Probit models with instrumental variables. (As a robustness check, we also estimate the Probit models parallel to the Logit models given in Table 2, and the results are consistent; see §D of the online supplement.)

For the quality-based variables, a good instrumental variable is the standard posted hourly rates of the law firms before the auctions. This is because (1) the posted rates outside of the auctions should not affect the buyer's bidder selection in the auctions; and (2) firms' standard posted rates relative to the other firms in the same room can be good predictors of an objective quality assessment for the firm, which should be correlated with GE's quality assessments and the scores. Therefore, for each supplier in each room, we include that supplier's posted hourly rate rank among all the suppliers participating in the same room, *StrRank*, and, as a control among different legal areas, the mean standard posted rate for the suppliers in a given room *StrMean*. For *Bid Rank*, in addition to the standard posted rate, we also use the deviation from the median winning bid as an instrument. Let $MedWinBid_j$ be the median of the bids of the winning suppliers in auction j ; define $\Delta Bid_{ij} = FinalBid_{ij} - MedWinBid_j$, where $FinalBid_{ij}$ is the last bid of supplier i in auction j . ΔBid_{ij} is a good instrument because (1) the magnitude of this deviation should not affect a rational buyer's award decision and in the presence of *FinalBid* and *Bid Rank* as an estimator, ΔBid_{ij} does not provide any additional estimation power for a bidder's winning probability; and (2) it is a reasonably good estimator for *Bid Rank*, as it is correlated with the relative final bid position of the bidder among other bidders in the end of the auction.

The equations for the regressions with instrumental variables and the regression results including the first-stage regressions are given in §E in the online supplement. The results of the Probit estimations with

instrumental variables of Models I–IV support our conclusions. For each instrumental variable endogeneity corrected model, the Wald test of exogeneity reveals no detected endogeneity, and χ^2 tests show that each model has explanatory power at the 1% significance level. Further, *F*-tests for all first-stage regressions show that they all have explanatory power at 1% significance level and the instruments—i.e., *StrRank*, *StrMean*, and ΔBid —are significant estimators of the potentially endogenous variables, *Bid Rank*, *Composite Score*, *Economic Score*, *Legal Score*, and *EEC*. Therefore, as we had expected, the instruments worked well to estimate the potentially endogenous variables and corrected any potential endogeneity from the Probit regressions. The results of the endogeneity corrected regressions support Hypothesis 3. *Incumbency* is significant in Model I, which does not have quality measures, supporting Hypothesis 3(a). However, when measures that involve firm quality are included in Models II and III, such as the *Composite Score* and the *Legal Score*, these measures turn out to be significant and incumbency immediately loses its significance, supporting Hypothesis 3(b). Only in Model IV, the quality measure *EEC* barely misses being significant (*p*-value is 0.108). However, incumbency is again far from being significant (*p*-value is 0.427). Note that instrumental variable models are known to be very slow in convergence—especially when there are many explanatory variables and instrumental variables, as in Model IV. In our sample, we have approximately 200 observations, which has been adequate to demonstrate significance in Models I–III. We believe with a higher number of observations, *EEC* would also become easily significant, whereas incumbency would still stay far from being significant.

To summarize, Hypothesis 3 is supported. If one explicitly takes quality into consideration, what may look like an incumbency advantage may disappear. In most studies that explore incumbent bias, no explicit quantitative measurement for quality has been present. However, there is ample reason for incumbents to have higher quality than nonincumbents, and this is the case for our data set. Interestingly, a restricted analysis of our data also supports an incumbency advantage on the surface. However, as demonstrated above, inclusion of quality as an explanatory variable may show otherwise. That is, what one may consider as incumbent bias may actually be a statement of preference for quality. This point is important for the success of the auction process. Our results state that, as long as a participant has desirable service or product quality, being a nonincumbent is not necessarily a handicap in winning contracts. That is, procurement auctions can in fact be run in a fair manner for all participants.

5.6. Incumbency and Revealed Preferences

In an open-ended auction such as GECF employs to purchase legal services, the buyer can reverse the auction outcome. If a buyer has incumbent bias, then she could use this flexibility to award contracts to incumbent suppliers over nonincumbent ones even when the latter are ranked better based purely on the auction outcome. In our data set, this would mean that in the end of the bidding, the buyer selects an incumbent with a *higher* (worse) *Composite Score* over a nonincumbent with a *lower* (better) *Composite Score*, breaking her *stated* scoring rule. If the buyer treats incumbents and nonincumbents equally, her winner selection when she breaks her scoring rule should be consistent, given any pair of suppliers, regardless of whether the suppliers are both nonincumbents, both incumbents, or a mixed pair of a nonincumbent and an incumbent. But if the buyer favors incumbents by breaking the stated score ordering, there would be an imbalance to the incumbents' advantage when such rule-breaking winner selections occur in the data.

There are three possible ways a reversal of stated ranking rule can occur between a pair of suppliers. Specifically, the winning supplier has (i) a worse *Economic Score* but a better *Legal Score*; (ii) a better *Economic Score* but a worse *Legal Score*; or (iii) both worse *Economic* and *Legal Scores*, compared to the losing supplier. Table 3 gives a summary of such observations of supplier pairs in our data. To detect the differences among the cases where the buyer may be separating the suppliers in a pair based on their incumbency status, we divide the observations into four groups based on the status of suppliers included in each pair: Group A consists of pairs where both suppliers are nonincumbents; Group B is of pairs where both suppliers are incumbents; Group C is where the preference is reversed favoring an incumbent, i.e., the winning supplier of the pair is an incumbent and the losing supplier is a nonincumbent; and finally, Group D is where the opposite happens—the winning supplier is a nonincumbent and the losing one is an incumbent. For each group, we identify the cases where the buyer in fact violates her stated scoring rule in selecting the winner, i.e., those cases where the winner's *Composite Score* is *higher* (worse) than that of the losing supplier.

Table 3 Buyer Reversals of Stated Preferences

	Group A: Nonincumbent	Group B: Incumbent	Group C: Mixed pairs (incumbent wins)	Group D: Mixed pairs (nonincumbent wins)
Number of pairs	28	31	54	16
Number of violations	15	16	27	9
Percentage (%)	53.6	51.6	50.0	56.3

As shown in Table 3, the highest number of violations of stated preferences is from nonincumbents to incumbents, with 27 occurrences—three times as much as that from incumbents to nonincumbents. Therefore, on the surface it may look like the buyer is violating her stated winner rule in favor of incumbents. However, this argument neglects to control for the differences in quality in supplier populations. To account for the significant quality difference between the incumbent and nonincumbent supplier groups, we need to evaluate the frequency of rule violations by controlling for the type of the switch among the two classes of suppliers, i.e., by comparing the frequency of violations *within* Groups A–D, which are organized to provide this control. With this control in place, from Table 3, we can see that Group C (nonincumbent to incumbent switch) in fact has the lowest percentage (50.0%), followed by Groups B (51.6%) and A (53.6%). Interestingly, when a nonincumbent is selected over an incumbent supplier, the buyer violates the scoring rule even more frequently (with a high percentage of 56.3%). We test the significance of the differences among these ratios by the Pearson chi-square test for proportion. These tests do not show significant difference between any two groups. In other words, we do not find evidence that the buyer violates the scoring rule more often when choosing incumbents over nonincumbents.

Then what causes the large number of decision reversals in favor of incumbents? Recall from our discussion in §§3 and 5.1 that in an open-ended auction as GE employs, suppliers have uncertainty about the buyer's true preferences, which plays an important role in the effectiveness of the process for the buyer. However, the buyer's selection decisions at the end of the auction may partially reveal her true preferences. Thus, the buyer's *revealed preferences* (Samuelson 1938) can differ from her *stated preferences*. In our case, the buyer's stated preferences are captured by the *Composite Score*, as described in §5.1. However, examining the data for the cases where the buyer violates her own preference rule, we can get more information about her actual preferences.

For each pair of suppliers with the buyer's preference reversal, the two *Economic* and *Legal Score* "bundles" of the suppliers involved offer information about the price-quality trade off the buyer makes when selecting winners. Figure 1 plots the *Economic Score* on the x -axis and the *Legal Score* on the y -axis of the paired suppliers where there is a violation of stated preference from the four groups as given in Table 3. The two ends of each line indicate the paired suppliers, with the end marked by "+" as the winner. The lines that travel from upper left to bottom right indicate that the winner is selected because of better quality; i.e., the winner has lower *Legal Score* but higher *Economic Score*. These pairs indicate a stronger preference for *quality over price*. In contrast,

the lines that travel from bottom right to upper left indicate stronger preference for *price over quality*. Note that we exclude the few cases where the buyer awards a contract to a supplier with both worse quality and price over one that is better in both attributes. This is because such cases clearly occur for reasons other than price and quality considerations and therefore do not provide any information about the buyer's preferences related to the price-quality trade off.

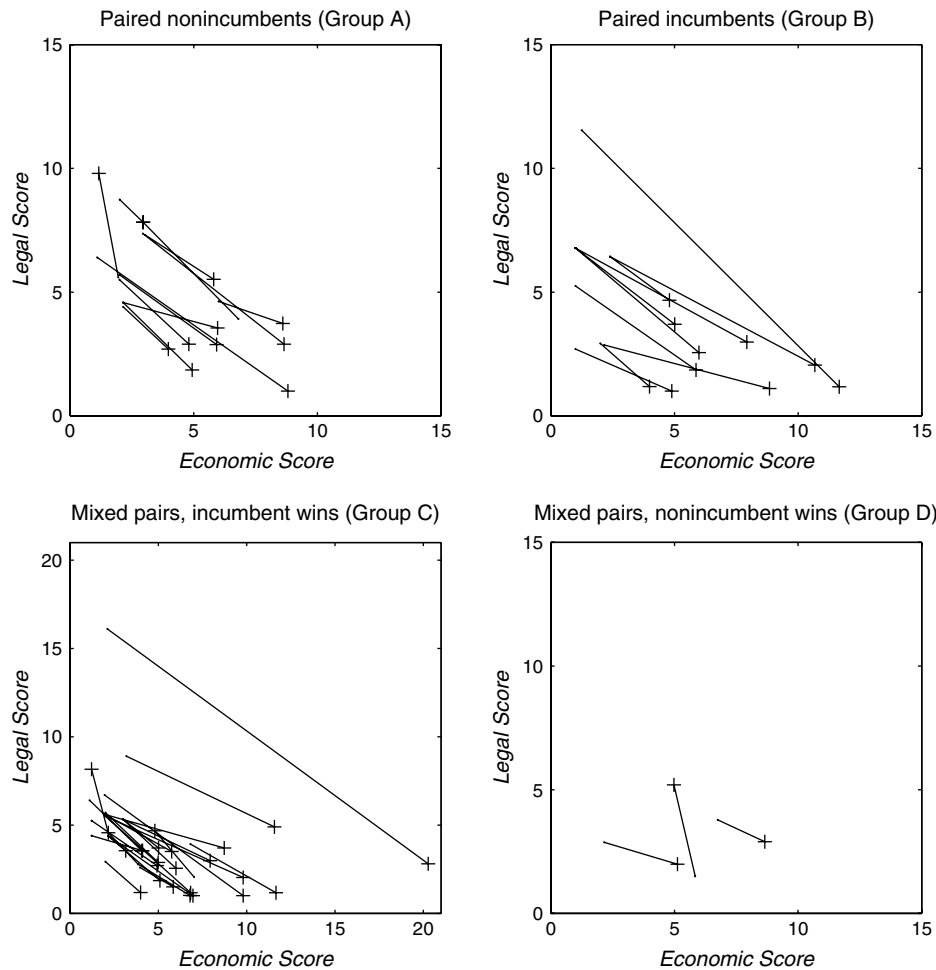
From Figure 1, it is apparent that "quality over price" choices dominate "price over quality" choices. To formalize this observation, we use a binomial test to determine the statistical significance of the proportion of "quality over price" cases for Groups A, B and C. (Group D is excluded because of insufficient sample size.) The results are shown in Table 4. As can be seen from the table, in an overwhelming majority of the cases where the buyer violates her stated preferences, she makes a decision in favor of "higher quality" (*Legal Score*) over "better price" (*Economic Score*), and this separation is statistically significant. Specifically, we can reject the hypothesis that there is no preference for "quality" over "price" at a 2% confidence level for Group A and a 0.1% confidence level for Groups B and C, as well as for the combined sample. Therefore, we can conclude that the buyer's true preferences favor the *Legal Score* over the *Economic Score*. Hence, in determining the buyer's revealed preference curves, we focus on cases where she favors quality over price.

Given a pair of suppliers, the slope of the line connecting the *Economic* and *Legal Score* points corresponding to the two suppliers represents an explicit preference substitution rate between *Economic* and *Legal Scores* of the suppliers. Specifically, the buyer's stated preferences, summarized by the fact that *Composite Score* = *Economic Score* + *Legal Score*, weigh these two scores equally. This means that the buyer's *indifference curves* implied by her stated preferences have a slope of -1 . Any nonpreference reversal pair, i.e., one with a line-slope in $(-\infty, -1)$, is supported by this preference statement and does not provide any additional information on buyer preferences. Yet with the pairs where the buyer reversed her stated preferences in favor of higher quality have a line slope $s > -1$, and any such line is a (noisy) indicator that the slope of the buyer's true indifference curve is in $(s, 0)$. Therefore, by analyzing the slopes of these lines, we can predict a lower bound for the slope of the buyer's true indifference curve.

Table 4 Binomial Test for the Proportion of "Quality over Price" Choices

Group	N	Quality over price	p -value
A	12	10	0.019
B	10	10	0.000
C	24	21	0.000
A–C combined	46	41	0.000

Figure 1 Depiction of the Relative Measurement of Attributes for Each Pair of Suppliers, Where the Buyer Violates Her Stated Preference Rule in Awarding Contracts



Notes. Each point indicates the *Economic–Legal Score* coordinates of a supplier, and each line connects two suppliers in a pair where preferences are reversed. For each pair, “+” indicates the winning supplier. Groups A–D are as given in Table 3.

Formally, we denote the buyer’s indifference curve for the service auctioned in bidding room j as

$$\text{Utility Score} = \text{Economic Score} + \theta_j \times \text{Legal Score}, \quad (3)$$

where $\theta_j = \theta_0 + \varepsilon_j$. θ_0 represents the constant component of the buyer’s price-quality substitution rate, and ε_j is the component specific to the service auction in the j th bidding room, where, without loss of generality, $E[\varepsilon_j] = 0$. From (3), $\text{Legal Score} = (\text{Utility Score}) / \theta_j - (\text{Economic Score}) / \theta_j$; i.e., the slope of the true indifference curve is $s_j^t = -1/\theta_j$. One immediate question is whether the slopes of the indifference curves significantly differ from -1 , i.e., whether the buyer’s true utility (or indifference curves) is different than stated. Another question is whether the buyer reveals an incumbent bias by using different substitution rates depending on the incumbency status of the two suppliers in a given pair where there is a preference reversal. This can be detected by testing whether the slopes of

the indifference curves differ among the supplier pair groups A–C, separated based on suppliers’ incumbency status.

Table 5 presents the results of the analysis of these questions. There are two main conclusions coming out of this table: first, all three groups have slopes that differ significantly from -1 . (All three slopes are also significantly different from 0.) This means that the buyer’s real preferences are significantly different from

Table 5 Slopes of Revealed Preference Curves for “Quality over Price” Selections

	Mean	Std. dev.	Min	Max	N
A: Nonincumbents	−0.73***	0.25	−0.98	−0.27	10
B: Incumbents	−0.67***	0.22	−0.99	−0.26	10
C: Mixed pairs (incumbent wins)	−0.68***	0.21	−0.96	−0.28	21

Note. Significance of the slope difference from -1 .

*** $p < 0.01$.

her stated preferences and that the true preferences give *higher* weight to quality over price than the stated preferences. Therefore, Hypothesis 4(a) is supported. Second, based on the Mann-Whitney test results, there is no statistically significant difference among the slopes corresponding to the three groups. This means that when reversing stated preferences to award an incumbent supplier over a nonincumbent supplier, there is no evidence that the buyer shows any difference in preference (such as applying a more relaxed price-quantity trade off when awarding incumbents over nonincumbents) compared to the cases where she reverses her preferences to award an incumbent over another incumbent, or a nonincumbent over another nonincumbent. In summary, the buyer's preference reversals do not necessarily arise from the incumbency status of the suppliers. Rather, such reversals indicate a significant deviation from her stated preferences in favor of service quality.

Finally, utilizing the observations with the buyer's preference reversals, we can estimate the buyer's revealed utility function. Since there is no significant difference in the slope of revealed preference curves among Groups A–C, we can pool the three groups and calculate the average observed slope of the pooled sample. This calculation gives an estimator for the expected observed slope, $E[s_j^o]$ as -0.69 . Now, by Jensen's inequality,

$$E[s_j^t] = E\left[-\frac{1}{\theta_j}\right] \leq -\frac{1}{\theta_0}. \quad (4)$$

Since $E[s_j^o] \leq E[s_j^t]$, by (4) we then have $E[s_j^o] \leq -1/\theta_0$, which implies $-1/E[s_j^o] \leq \theta_0$. It follows that $E[\theta_j] = \theta_0 \geq -1/(-0.69) = 1.449$, and the buyer's (expected) revealed preference curve lies above

Revealed Utility Score

$$= \text{Economic Score} + 1.449 \times \text{Legal Score}. \quad (5)$$

That is, the buyer in fact values improvements in supplier quality scores at least at a rate about 45% higher than implied by her stated preferences. As demonstrated, this fact is reflected strongly in the buyer's final contract award decisions, overshadowing factors like incumbency. Further, using the buyer's revealed preferences derived in (5), we can test whether there is indeed a utility increase for the buyer as a result of the auctions. Calculating the buyer's expected utility using the updated preferences for *Composite Score*, a dependent *t*-test shows that the *Composite Score* across all auctions improves from 10.95 to 10.13 ($p = 0.017$); i.e., the buyer's utility increase is significant. Therefore, we can conclude that Hypothesis 4(b) is also supported.

6. Concluding Remarks

GECF's legal service procurement auctions were viewed as a success within the company. The division followed up with an internal voice of customer survey, as well as reviews for preferred providers during Quarter 4 of 2004 and Quarter 1 of 2005. Overall, GECF's general counsels were very happy with the outcome and "lawyers were more pleased than anyone else" (from our interview with Charles Kirol). GECF's successful initiative was followed up by use of the same blueprint for procurement by other GE divisions and units. For instance, GE Capital Solutions (GECS), a different unit of GE, revised its internal process for selecting outside counsel to include a competitive bidding process to select the law firms in various regions and states that must be considered for all bankruptcy and litigation legal work starting June 2006 for a minimum contract term of one year. Similar process changes were made in other categories of legal services, such as litigation and tax in GECS as well.

Our results suggest that utilizing an open-ended award structure in procurement auctions can significantly improve a buyer's expected utility compared to a traditional closed-ended award structure, where the buyer announces its true scoring rule and commits to award the contracts accordingly. Our theoretical analysis demonstrates that this policy recommendation can be generalized to other markets for services or products, where quality plays a major role in the buyer's purchasing decisions. In particular, in service or product markets where the buyer's preference for quality is strong (even at its lowest possible value on its support) and the cost differences among suppliers are relatively low, open-ended auctions should be successful for the buyers, and with the mix of new suppliers and incumbent suppliers, open-ended auctions could reduce prices while maintaining quality. Other than legal services, service market examples include consulting, outsourced projects in information technology, and marketing and advertising. Examples of suitable product markets include contract manufacturing, specialty or customized parts, or critical parts for an end product. Simpler closed-ended auctions would more likely be desirable for more generic and less critical parts of a product for which quality may carry a relatively lower weight than cost savings and where the suppliers are relatively similar and none of them exhibits strong quality-based advantages over others. Further research could be helpful in confirming and extending our findings.

One concern about higher-quality suppliers winning more frequently could be increased concentration of the supplier base. Increased supplier base concentration over time can lead to worse prices for the buyer. To prevent this potential problem, it is important that the auction-based procurement process keep in check and maintain supplier diversification. GE's process by

its nature is inclined toward this purpose. First, note that maintaining supplier base diversity is an issue for both offline and online procurement processes. GE's new online process in fact is more helpful in this aspect by allowing the active involvement of a large number of suppliers to keep the incumbents in check. Therefore, if the incumbent suppliers over time start charging higher than competitive rates, it is more likely that they will be losing against a higher number of nonincumbent competing suppliers. Second, GE's award process has multiple awards, with an average number of 4.15 contracts awarded per auction. Hence the incumbent supplier base is kept large, which forces a certain level of diversity and maintains competition even among the winning suppliers. Further, on average, 30.9% of the winners are nonincumbents and therefore, sufficient fresh blood is provided to the supplier base through auctions. Another concern with the auction process could be intensified price competition, which might hurt the quality of the service in the longer term. GE's process counters that by choosing the winning suppliers with a quality-price balanced approach. As presented in this paper, empirical evidence suggests that GE managed to keep the quality levels about the same before and after the auctions. In the long term, this can be maintained, especially by keeping the historical quality scores and checking that service quality levels are maintained after each award process.

As is typical in procurement auctions, we do not directly observe bidders' actual private costs. In fact, bidders have incentives not to reveal them during or after the auction. If one had that information, it could be possible to compare their actual bids to their predicted equilibrium bids using their cost information. This remains an interesting future study.

Supplemental Material

Supplemental material to this paper is available at <http://dx.doi.org/10.1287/msom.2014.0485>.

Acknowledgments

The authors are grateful to Charles Kirol from General Electric Commercial Finance for providing the data used in this study and for valuable discussions. For helpful comments and discussions, the authors thank Steve Graves (the editor), the associate editor, the anonymous referees, Sanjeev Dewan, Ernan Haruvy, Elena Katok, Hau Lee, Haim Mendelson, Jim Patell, Harvey Wagner, Bob Wilson, and Stefanos Zenios, as well as seminar participants at Dartmouth College, Duke University, Emory University, George Mason University, Georgia Tech, Indiana University, INSEAD, London Business School, Penn State University, Purdue University, New York University, Southern Methodist University, Stanford University, University of British Columbia, University of California at Davis, University of California at San Diego, University of North Carolina Chapel Hill, University of Maryland, University of Texas at Dallas, University of Rochester, University of Virginia, University of Wisconsin at Madison, Washington University at St. Louis, and Yale University.

References

- Asker J, Cantillon E (2008) Properties of scoring auctions. *RAND J. Econom.* 39(1):69–85.
- Asker J, Cantillon E (2010) Procurement when price and quality matter. *RAND J. Econom.* 41(1):1–34.
- A.T. Kearney (2006) Sourcing complex business services. Technical report, A.T. Kearney Analysis, Stanford, CA.
- Bajari P, Houghton S, Tadelis S (2014) Bidding for incomplete contracts: An empirical analysis of adaptation costs. *Amer. Econom. Rev.* 104(4):1288–1319.
- Bartolini A, Checketts V (2007) The advanced sourcing and negotiation benchmark report: The art and science of the deal. Technical report, Aberdeen Research Group, Boston, MA.
- Bichler M, Steinberg R (2007) Introduction to the special issue on e-auctions for procurement operations. *Production Oper. Management* 16(4):401–403.
- Cabral L, Greenstein S (1990) Switching costs and bidding parity in government procurement of computer systems. *J. Law, Econom., Organ.* 6(2):453–469.
- Beall S, Carter C, Carter PL, Germer T, Hendrick T, Jap S, Kaufmann L, et al. (2003) The role of reverse auctions in strategic sourcing. Report, CAPS Research, Tempe, AZ.
- Chen P, Forman C (2006) Switching costs, network effects, and buyer behavior in IT markets. Working paper, Georgia Institute of Technology, Atlanta.
- Chen-Ritzo C-H, Harrison TP, Kwasnica AM, Thomas DJ (2005) Better, faster, cheaper: An experimental analysis of multiattribute reverse auction mechanism with restricted information feedback. *Management Sci.* 51(12):1753–1762.
- Colucci D, Doni N, Valori V (2012) Preferential treatment in procurement auctions through information revelation. *Econom. Lett.* 117(3):883–886.
- Demski JS, Sappington D, Spiller PT (1987) Managing supplier switching. *RAND J. Econom.* 18(1):77–97.
- De Silva DG, Dunne T, Kosmopoulou G (2003) An empirical analysis of entrant and incumbent bidding in road construction auctions. *J. Indust. Econom.* 51(3):295–316.
- Elmaghraby WJ (2000) Supply contract competition and sourcing policies. *Manufacturing Service Oper. Management* 2(4):350–371.
- Elmaghraby WJ (2007) Auctions within e-sourcing events. *Production Oper. Management* 16(4):409–422.
- Elmaghraby WJ, Oh S-K (2006) Procurement auctions and eroding price contracts in the presence of learning by doing. Working paper, University of Maryland, College Park.
- Elmaghraby WJ, Katok E, Santamaria N (2012) A laboratory investigation of rank feedback in procurement auctions. *Manufacturing Service Oper. Management* 14(1):128–144.
- Engelbrecht-Wiggans R, Haruvy E, Katok E (2007) A comparison of buyer-determined and price-based multiattribute mechanisms. *Marketing Sci.* 26(5):629–641.
- Farrel J, Gallini NT (1988) Second-sourcing as a commitment: Monopoly incentives to attract competition. *Quart. J. Econom.* 103(4):673–694.
- Farrel J, Shapiro C (1989) Optimal contracts with lock-in. *Amer. Econom. Rev.* 79(1):51–68.
- Greenstein SM (1993) Did installed base give an incumbent any measureable advantages in federal computer procurement? *RAND J. Econom.* 24(1):19–39.
- Greenstein SM (1995) Lock-in and the costs of switching mainframe computer vendors in the U.S. federal government in the 1970s. *IEEE Ann. History Comput.* 17(3):58–66.
- Haruvy E, Katok E (2013) Increasing revenue by decreasing information in procurement auctions. *Production Oper. Management* 22(1):19–35.
- Holloway CA, Higuera A (2002) eSourcing Strategy at Sun Microsystems. Case No. OIT34, Stanford University, Graduate School of Business.
- Jap SD (2002) Online reverse auctions: Issues, themes and prospects for the future. *Acad. Marketing Sci.* 30(4):506–525.

- Kostamis D, Beil DR, Duenyas I (2009) Total-cost procurement auctions: Impact of suppliers' cost adjustments on auction format choice. *Management Sci.* 55(12):1985–1999.
- Krasnokutskaya E, Song K, Tang X (2012) The role of quality in service markets organized as multi-attribute auctions. Working paper, Johns Hopkins University, Baltimore, MD.
- Lewis G, Bajari P (2011) Procurement contracting with time incentives: Theory and evidence. *Quart. J. Econom.* 126(3):1173–1211.
- Morgan JK (2003) COMFIN external communication to law firms. GE Commercial Finance.
- Rezende L (2009) Biased procurement auctions. *Econom. Theory* 38(1):169–185.
- Riordan MH, Sappington D (1989) Second sourcing. *RAND J. Econom.* 20(1):41–58.
- Samuelson P (1938) A note on the pure theory of consumer's behaviour. *Economica* 5(17):61–71.
- Snir EM, Hitt L (2003) Costly bidding in online markets for IT services. *Management Sci.* 49(11):1504–1520.
- Tunca TI, Wu Q (2009) Multiple sourcing and procurement process selection with bidding events. *Management Sci.* 55(5):763–780.
- Tunca TI, Zenios SA (2006) Supply auctions and relational contracts for procurement. *Manufacturing Service Oper. Management* 8(1):43–67.
- Wan Z, Beil DR, Katok E (2012) When does it pay to delay supplier qualification? Theory and experiments. *Management Sci.* 58(11):2057–2075.
- Wooldridge JM (2001) *Econometric Analysis of Cross Section and Panel Data*, 1st ed. (MIT Press, Cambridge).
- Zhong FV, Wu DJ (2006) E-sourcing: Impact of bidding behavior and non-price attributes. *Proc. 27th Internat. Conf. Inform. Systems (ICIS)*, Milwaukee, 1979–1998.