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Charles J. Thomas
Chapman University

Bart J. Wilson
Chapman University, bjwilson@chapman.edu

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A comparison of auctions and multilateral negotiations

Charles J. Thomas*

and

Bart J. Wilson**

We compare first-price auctions to an exchange process that we term "multilateral negotiations." In multilateral negotiations, a buyer solicits price offers for a homogeneous product from sellers with privately known costs, and then plays the sellers off one another to obtain additional price concessions. Using the experimental method, we find that with four sellers, transaction prices are statistically indistinguishable in the two institutions, but with two sellers, prices are higher in multilateral negotiations than in first-price auctions. The institutions are equally efficient with two sellers, but multilateral negotiations are slightly more efficient with four sellers.

1. Introduction

■ In this article we use the experimental method to study an exchange process that combines features from auctions and bilateral bargaining. Specifically, we study a setting in which a buyer solicits price offers from sellers and then confronts each seller with claims about his rivals' price offers to elicit a more favorable offer. The buyer plays the sellers off one another until he either accepts one of the offers or breaks off the negotiations. This process is pervasive in industrial procurement, with buyers extending formal requests for proposal (RFPs) and then haggling with suppliers after receiving the initial offers. It is also common to many other transactions, including the securing of job offers and the purchasing of computers, contractors' services, and automobiles. We refer to this exchange institution as "multilateral negotiation" to distinguish it from multilateral bargaining, in which more than two agents bargain over the division of common surplus (see Krishna and Serrano, 1996). We are interested in such issues as the efficiency of multilateral negotiations, the effect of the number of sellers on the transaction price, and the effect of the agents' and the institution's characteristics on the agents' bargaining positions.

* Federal Trade Commission; cjthomas@ftc.gov.

** George Mason University; bwilson3@gmu.edu.

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We are also interested in the relationship between the outcomes of multilateral negotiations and various auction formats, for two reasons. First, this relationship has important implications for institutional design. The fact that some buyers in an industry use multilateral negotiations, while others use one-shot sealed-bid auctions, suggests either that the processes are outcome-equivalent or that there are factors that make one process preferable to the other. Concerns about institutional design are particularly important in the emerging e-commerce field, where buyers and sellers are developing software agents to handle the procurement process online. For example, Su, Huang, and Hammer (2000) have implemented a prototype server for automated, Web-based negotiations between buyers and sellers. Other researchers and practitioners in computer science and management information systems are creating artificially intelligent mechanisms for negotiations and auctions, but there is no empirical and little theoretical economic research comparing these institutions to guide their work. This article provides a first step in such a research agenda.

Second, the relationship between the outcomes of multilateral negotiations and auctions has important implications for antitrust analysis. Recently, U.S. competition authorities and private parties have used auction models to evaluate the impact of proposed mergers.[1] Even if transactions resemble multilateral negotiations, an analyst might use auction models to evaluate market behavior because such models have been extensively studied, while there are no formal multilateral negotiation models. If the outcomes of auctions and multilateral negotiations are similar, then there should be less concern about using a modelling approach that does not precisely fit the market's institutional characteristics. Otherwise, caution should be used in applying auction models when transactions more closely resemble multilateral negotiations.

We study the relationship between first-price auctions and multilateral negotiations by permitting fairly unstructured negotiation between a buyer and several sellers. Each experimental session anonymously matches a buyer with either two or four sellers, and consists of several periods of negotiations and first-price auctions. In the multilateral negotiations, the buyer can communicate electronically in real time with the sellers, but the sellers cannot communicate with each other.[2] In the auctions, the buyer plays a passive role, and none of the players can communicate with each other. We match sellers' costs across groups and institutions to study whether outcomes depend on which institution is used. Similarly, we vary the number of sellers to see how the outcomes change within an institution.

We find that the number of sellers has an economically significant effect on the relationship between first-price auctions and multilateral negotiations. With two sellers who have no prior experience with either institution, transaction prices in multilateral negotiations are significantly higher than transaction prices in first-price auctions. With four sellers, however, we cannot distinguish between the transaction prices. In fact, with four sellers we cannot distinguish between the institutions' prices at any point in the experiment.

We also find a sequencing effect in the two-seller treatment. First, sellers first exposed to multilateral negotiations set higher prices in first-price auctions than do sellers first exposed to first-price auctions. Second, those sellers first exposed to multilateral negotiations subsequently set higher prices in first-price auctions than the other sellers set in multilateral negotiations, in contrast to our findings in the initial institutional regime. We attribute these results to the influence of institutional experience, though there are alternative explanations.

The article is structured as follows. Section 2 describes the existing theory most relevant to multilateral negotiations and explains the basis for our hypothesis that the outcomes of first-price auctions and multilateral negotiations will be similar. Section 3 describes the experimental design and procedures. Section 4 presents our results, and Section 5 concludes.

2. Related theoretical background

■ The exchange mechanism we study has not been formally modelled in the bargaining literature, presumably due to its strategic complexity. Hence, our analysis is driven by our intuition

[1] For example, auction results were used to evaluate the recent merger between Rite-Aid and Revco (Baker, 1997).

[2] The Appendix contains selections from the communication transcripts.

about how first-price auctions and multilateral negotiations should be related. To begin, we describe first-price auction theory and our conception of how multilateral negotiations are executed. Next we describe existing work related to multilateral negotiations, and finally we explain our intuition about the relationship between auctions and multilateral negotiations.

Consider a setting in which T risk-neutral sellers producing homogeneous products compete to fulfill a contract for a single risk-neutral buyer. V_B is the buyer's commonly known value of having the contract fulfilled. Each seller's cost c is a privately known independent draw from the continuous distribution function G with density g that is strictly positive over the support $[\underline{c}, \overline{c}]$. In the auction literature, this is referred to as a symmetric independent private value (IPV) setting.

The first-price auction proceeds with each seller simultaneously submitting a secret price offer. The seller offering the lowest price is awarded the contract at its offered price, provided that price is less than V_B. All other sellers receive nothing. If a sale is made, then the winning seller's profit is $p - c_w$, where p is the transaction price and c_w is the winning seller's cost. The buyer's profit is $V_B - p$, total surplus is $V_B - c_w$, and efficiency is $(V_B - c_w)/(V_B - c_1)$, where c_1 is the lowest realized cost.

The multilateral negotiation proceeds with each seller simultaneously submitting a secret price offer. The buyer can accept one of the offers or reject them all. If the buyer accepts an offer, then the game concludes and the transaction price is the price p offered by the winning seller. As in the auction setting, the winning seller's profit is $p - c_w$, where c_w is the winning seller's cost, and the buyer's profit is $V_B - p$. If the buyer rejects all offers, then the buyer can announce to each seller a (possibly different and not necessarily true) competing offer that is better than the seller's standing offer. The sellers can respond to these communications by making additional secret price offers, the buyer can accept or reject these new offers, and so on. The game continues in this fashion until a transaction occurs.

Although we are not aware of any formal models of multilateral negotiations, there is research that examines related exchange mechanisms. One approach incorporates multiple sellers into a bilateral bargaining framework. For example, Shaked and Sutton (1984) model an alternating offer setting in which the buyer can switch to a different seller at some commonly known cost. The buyer can bargain with only one seller at a time, and offers from one seller are void upon the buyer's switching to the other seller. Assuming that both sellers are commonly known to have the same cost, the authors find that the second seller's presence creates a credible threat that permits the buyer to obtain more surplus than if switching were impossible.[3] Our approach differs from Shaked and Sutton (1984) in that we do not assume that the sellers' costs are common knowledge. We also relax their alternating offer structure. In our setting, we envision the buyer not proposing a price at which he is willing to buy, but instead obtaining price concessions by presenting a seller with claims about the discounts offered by rival sellers. Moreover, multilateral negotiations permit the buyer to hold multiple offers simultaneously, a feature distinct from the alternating offer setting.

Another approach incorporates dynamic aspects of a buyer's ability to decline all offers in a procurement auction. For example, McAfee and Vincent (1997) model a buyer's selection of a reserve price, when the buyer cannot commit not to solicit offers in the future if he declines all offers made today. Our approach differs from McAfee and Vincent (1997) in that we do not assume that offers are made public. More important, we do not assume that the buyer commits to an announced reserve price. While the buyer in a multilateral negotiation probably uses a "reservation offer" to decide whether to accept an offer, the reservation offer may be based on the entire set of received offers. This decision structure lets the buyer use current offers to forecast future ones.

It has been hypothesized that the negotiations we describe are related to second-price or English auctions (see Waehrer and Perry, 1999). The argument is that the buyer should be able to obtain concessions from a seller until the seller's offer is just equal to his cost. While we

[3] Fudenberg, Levine, and Tirole (1987) examine an alternative model in which the buyers' values are private information and the seller makes all of the offers.

agree partly with this characterization, our intuition is that the relationship between multilateral negotiations and various auction formats depends critically on the buyer's ability to credibly reveal to a seller his rivals' offers. In particular, if the offers cannot be credibly revealed, then the multilateral negotiation should be similar to a first-price auction.[4] When the buyer tries to use a rival's offer to elicit a better offer from the seller, the seller must be concerned that the buyer is not being truthful about the terms or existence of the rival's offer. Consequently, the seller must be aware that he could end up bidding against himself by offering price reductions that are undercut by fictitious discounts from a rival.

Just as in multilateral negotiations, in many auction settings a seller must be concerned about bidding against himself. For example, consider a variant of the "button auction" described by Milgrom and Weber (1982) in which the contract price starts at a high level, each potential seller depresses a button to signal its willingness to fulfill the contract at the current price, and the price decreases in continuous fashion. A seller signals its lowest offer by releasing its button at that price. A firm cannot depress its button after releasing it, so a firm cannot exit and then re-enter the bidding. The winning firm is the last to release its button, and it is paid the price at which it released its button.

Suppose that sellers do not see the identity or price of firms that drop out, so they do not know if other firms are currently participating.[5] A seller must be concerned that it is continuing to depress its button after all other sellers have dropped out. The informational structure suggests that the outcome of this game should be related to the outcome of a multilateral negotiation without credible revelation. However, this game is strategically equivalent to a Dutch clock procurement auction, in which the price starts at zero and increases in continuous fashion, and the winner is the first firm to depress its button. Moreover, the Dutch auction is strategically equivalent to a sealed-bid first-price auction. Thus, from a theoretical perspective there should exist a relationship between first-price auctions and multilateral negotiations in which rival sellers' offers are not verifiable.

The preceding relationship may not be exact for several reasons. First, Coppinger, Smith, and Titus (1980) and Cox, Roberson, and Smith (1982) report that in buying auctions, prices are higher in first-price auctions than in Dutch clock auctions in which the price clock starts at a high level. Cox, Smith, and Walker (1983) conclude that the real-time nature of the Dutch clock auction matters because as the clock ticks down, bidders mistakenly lower their expectations of their rivals' values. If nonverifiable multilateral negotiations are isomorphic to Dutch auctions, then in a procurement auction we might expect multilateral negotiation prices to exceed first-price auction prices.

Second, the outcomes of multilateral negotiations most likely depend on the players' ability to haggle. For example, suppose that one seller has a low-cost draw relative to his rivals, and that all the sellers begin with high offers that they reduce in the course of the negotiations. When the high-cost rivals stop offering discounts, the low-cost seller may do the same if the buyer fails to report (i.e., does not lie about) further competing discounts from the other sellers. The buyer may not lie about competing offers if he fears the long-term consequences of purchasing from a seller who refused to lower his price in the face of an alleged offer made by a rival. Thus, negotiated prices may exceed one-shot first-price auction prices. However, a skilled buyer may be able to keep a seller offering discounts below his equilibrium first-price auction offer, because an *ex post* losing seller in a first-price auction would lower his price offer to win the contract. Hence, the buyer might be able to extract more favorable offers in a multilateral negotiation.

Third, the outcomes may differ because in multilateral negotiations sellers must have incentives to make serious offers. That is, there is no reason for sellers to make an offer until the last possible moment, particularly if there are no delay costs and if they think that serious initial offers

[4] If the offers can be credibly revealed, then the multilateral negotiation should be similar to a second-price or English auction, because sellers should be willing to make concessions until the price reaches their cost.

[5] If sellers see when their rivals drop out, then the auction is equivalent to the version of the button auction described by Milgrom and Weber in which the last active seller wins and is paid the price at which its final rival exits.

will be used against them later in the negotiation.[6] This effect would tend to make negotiated prices exceed first-price auction prices. In our experimental framework there is a time limit on each negotiation period, and the buyer cannot receive infinitely many offers. Consequently, a seller might be concerned that he will be left out of the communication process if he does not make serious offers. Moreover, if the seller does not stay current with the state of play, then even if he tries to come in late in the negotiations he will not have a good sense of what the market price is. These market frictions would tend to reduce negotiated prices, but not necessarily below the level of first-price auction prices.

3. Experimental design and procedures

■ Because there are no models of multilateral negotiations, we conducted a heuristic experiment (see Smith, 1982) to compare first-price auctions and multilateral negotiations. We focus on the case without credible revelation of rivals' offers because it seems to be more empirically relevant. Moreover, the relationship between auctions and multilateral negotiations seems less likely to be exact in this setting than with credible revelation of offers.

Using "F" to denote a sequence of first-price auctions and "N" to denote a sequence of multilateral negotiations, we pair two treatments, one with the pattern *NFFN* of sequences and one with the pattern *FFNF* of sequences.[7] The first and third sequences consist of 12 transactions, the second consists of 16, and the fourth consists of 6.[8] We vary these two treatments by changing the number of sellers. One has two sellers per buyer, while the other has four sellers per buyer.

For each of the four treatments, $\{2 \text{ sellers}, 4 \text{ sellers}\} \times \{NFFN, FFNF\}$, we have four groups of subjects. Each subject is assigned a specific role in a specific group for the duration of the session. A seller's characteristics consist of 46 random cost draws from the uniform distribution on the support [0, 6.00], one for each period of play. Of the eight groups with four sellers, seller i ($i = 1, 2, 3, 4$) has the same cost draws across groups. Of the eight groups with two sellers, seller i ($i = 1, 2$) has the same cost draws across groups. Moreover, the costs of sellers 1 and 2 in the two-seller treatment are the same as the costs of sellers 1 and 2 in the four-seller treatment.

Our experiment consists of a total of 736 first-price auctions or rounds of multilateral negotiation using 64 undergraduate student volunteers (48 sellers and 16 buyers). Some students had participated previously in market experiments, but with different trading institutions. No subject participated in more than one of the sessions reported in this experiment.

In addition to reading self-paced instructions displayed by the software, the subjects followed along as the experiment monitor read aloud from a handout with both additional and review information.[9] The public instructions explained (and made common knowledge) that the sellers' costs were assigned randomly each period and that the distribution of the draws was $U[0, 6.00]$. The instructions also revealed that the buyer's value was 6.00. Revealing the buyer's value is consistent with prior experiments that use buying auctions in which bids are constrained to be nonnegative, which informs the subjects that bids below zero have no chance of being accepted.

The random cost draw for a given period was disclosed to the subject at the beginning of the period. In the first-price auction environment, after learning his cost each seller had a maximum of four minutes to submit his private offer to sell, though this limit was never binding. The computer automatically awarded the contract to the seller who submitted the lowest offer once all the offers had been submitted, provided that the lowest offer was less than 6.00. At the end of the auction,

[6] Multilateral negotiation will be equivalent to a first-price auction if the buyer's cost of obtaining additional offers exceeds the maximum possible gain from obtaining those offers, or if the discount factor is zero (so that future transactions have no value). In both cases the buyer will accept one of the initial offers.

[7] Our initial intent was to use the more standard *FNF* and *NFN* sequences of treatments. However, our pilot session indicated that the *NFN* treatment would have taken too much time for the number of paired auctions we initially wished to conduct.

[8] Six trailing periods of negotiation were the most that could be comfortably run within a two-hour experiment.

[9] The instructions for the first-price auction are based upon those used by Cox, Roberson, and Smith (1982) and Cox, Smith, and Walker (1983, 1988). The instructions for the multilateral negotiation are newly developed.

the final market price was announced electronically to all market participants, after which the session proceeded to the next period.

In the multilateral negotiation environment, after learning his cost each seller had a maximum of 30 seconds in the first phase of the period to submit his initial offer to the buyer. The instructions indicated that the seller would be able to lower his offer at any time in the second phase of the period. Once the buyer received all initial offers, the clock was reset to four minutes for the negotiation phase. At any time during the negotiation phase, a seller could (only) lower his offer, and the buyer could accept the offer of a single seller. Furthermore, a buyer and a specific seller could use text messaging over the computer network to engage in nonbinding discussions concerning a deal. The sellers could communicate only with their buyer. However, the buyer could negotiate individually with any seller, but only one at a time, while retaining standing offers from the other sellers. This process is meant to parallel the process of a buyer soliciting RFPs and then negotiating in person, over the phone, or online until a transaction price is agreed upon. A transcript of the discussions between the buyer and the seller remained on the screen for the duration of the period. The subjects only knew the laboratory identification numbers of the parties with whom they were communicating. Once the buyer accepted an offer, the final market price was announced electronically to all market participants,[10] after which the session proceeded to the next period. Each seller had no information on the initial offers or the subsequent discounts made by the other sellers, unless the buyer revealed it in their discussions. However, the sellers could not verify this information.

The subjects were not told the number of trading periods in the session or in any institutional regime within the session. Moreover, the subjects did not know the nature of any future trading institution, as the instructions for an institution were displayed only prior to commencing trade. It was public information that the same set of sellers was matched with the same buyer for the experiment's duration. Such repeated auction play is a common feature of naturally occurring markets and the previous auction experiments discussed above.

Participants received \$5 for showing up on time, plus their salient earnings. In the four-seller sessions, the buyers' exchange rate was US\$1 for 8 experimental dollars, and the sellers' exchange rate was US\$1 for .25 experimental dollars. In the two-seller sessions, the exchange amounts were 6 and 2 experimental dollars for each US\$1, respectively.[11] To equalize all subjects' earnings expectations, the exchange rates are more favorable to the sellers because a buyer receives a payoff every period, but a seller only expects to win every two or four periods, depending on the number of sellers in the treatment. The average subject's earnings (in addition to the \$5 show-up fee) for the experiment were \$17.12. The *FFNF* four-seller sessions and all two-seller sessions lasted one hour on average, while the *NFFN* four-seller sessions lasted almost two hours.

4. Experimental results

■ For each period of play, our data include the institution used, the transaction price, each seller's cost, the buyer's value, and each seller's initial and subsequent offers in the multilateral negotiations. We also have a verbatim record of the communications between buyers and sellers. While not used in the statistical analysis, the transcripts provide insights about the players' strategies and their beliefs about their rivals' strategies.

We summarize our results in a series of four findings. In addition to the qualitative results displayed in tables and figures, we analyze the data using a linear mixed-effects model for repeated measures.[12] The results from estimating this model by the four regimes of 46 periods are reported in Table 2 below. The dependent variable is the observed market price. The treatment effects (*Two*

[10] There were two cases in which the buyer did not accept any offer, both in the two-seller treatment.

[11] The subjects in the two-seller and four-seller treatments were given different exchange rates imputed from the US\$ payoffs of subjects in the IPV first-price auction experiments of Cox, Roberson, and Smith (1982). Given their outcomes, we tried to increase the saliency of the four-seller treatment by lowering the exchange rate further.

[12] See Laird and Ware (1982) and Longford (1993) for a description of this technique.

versus *Four* sellers, and *Negotiation* versus *First-Price Auction*) and an interaction effect from the 2 × 2 design are modelled as (zero-one) fixed effects, whereas the 16 independent sessions are modelled as random effects, e_i. To control for the across-period cost variation, we include the deviations of the lowest and second-lowest costs from their theoretical expected values, and the interactions of those deviations with the treatment variables. The expected values of the lowest and second-lowest costs are 2 and 4 in the two-seller treatment, and 1.2 and 2.4 in the four-seller treatment. Evaluating the costs' deviations from their mean values, denoted c_{1ij} and c_{2ij}, rather than their levels, permits us to capture each treatment's expected price solely in the treatment coefficient. Specifically, we estimate the model

$$\begin{aligned} Price_{ij} = \mu &+ e_i + \beta_1 Two_i + \beta_2 Negotiation_i + \beta_3 Two_i \times Negotiation_i \\ &+ \beta_4 c_{1ij} + \beta_5 c_{1ij} \times Two_i + \beta_6 c_{1ij} \times Negotiation_i + \beta_7 c_{1ij} \times Two_i \times Negotiation_i \\ &+ \beta_8 c_{2ij} + \beta_9 c_{2ij} \times Two_i + \beta_{10} c_{2ij} \times Negotiation_i + \beta_{11} c_{2ij} \times Two_i \times Negotiation_i \\ &+ \varepsilon_{ij}, \end{aligned}$$

where the sessions are indexed by i and the periods by j (e.g., $j = 1, 2, \ldots, 12$, for the first regime of twelve periods).[13] We accommodate heteroskedastic errors by session when estimating the model via maximum likelihood.

We first assess the effect of changing the number of sellers within a specific institution. This baseline result establishes that changing the number of sellers affects transaction prices in a manner consistent with the predictions of standard oligopoly models.

Finding 1. For all regimes, the primary effect of reducing the number of sellers from four to two significantly increases transaction prices.

Evidence. Table 1 reports the average transaction price for the first 12 periods, by institutional regime and number of sellers. The average price in the first-price auctions is 1.87 with four sellers and 3.10 with two sellers, a 66% increase. This percentage increase nearly matches the predicted theoretical increase of 65%, though the transaction prices are much lower than the predicted theoretical levels also reported in Table 1. The average price in the multilateral negotiations is 1.88 with four sellers and 3.69 with two sellers, a 97% increase. Similar price comparisons can be made for the remaining periods.

To formally test these conclusions, we refer to the estimates in Table 2. The coefficient on the *Two* dummy variable measures the primary effect of the two-seller treatment. It is significant in all four regimes, raising transaction prices by $\hat{\beta}_1 = 1.03, 1.24, 2.32$, and .99 experimental dollars, respectively. *Q.E.D.*

We now compare the transaction prices and the efficiency of first-price auctions and multilateral negotiations in the initial institutional regime, when subjects have no prior experience with either institution.

Finding 2a. In Regime 1, multilateral negotiation prices and first-price auction prices are statistically indistinguishable with four sellers. However, multilateral negotiation prices are significantly higher than first-price auction prices with two sellers.

Evidence. The average prices for the first 12 periods are reported in Table 1. With four sellers, the average price is 1.87 in the first-price auctions and 1.88 in the multilateral negotiations. With two sellers, the average price is 3.10 in the first-price auctions and 3.69 in the multilateral negotiations.

The estimate of the *Negotiation* coefficient ($\hat{\beta}_2$) in Table 2 represents the amount by which the negotiation treatment changes transaction prices relative to first-price auctions, holding the number of sellers constant at four. The point estimate is nearly zero and is insignificant (p-value

[13] The linear mixed-effects model for repeated measures treats each session as one degree of freedom with respect to the treatments. Hence, with four parameters, there are 12 degrees of freedom for the estimates of the treatment fixed effects (16 sessions−4 parameters).

TABLE 1 **Average Transaction and Predicted Nash Prices by Regime**

Sequence	Two Sellers Observed	Two Sellers Nash Prediction	Four Sellers Observed	Four Sellers Nash Prediction
FFNF				
Periods 1–12: *F*	3.10	4.12	1.87	2.49
Periods 13–28: *F*	3.01	4.01	2.01	2.79
Periods 29–40: *N*	3.22	4.11	1.69	2.43
Periods 41–46: *F*	3.01	4.07	1.60	2.31
NFFN				
Periods 1–12: *N*	3.69	4.12	1.88	2.49
Periods 13–28: *F*	4.01	4.01	2.12	2.79
Periods 29–40: *F*	4.07	4.11	1.74	2.43
Periods 41–46: *N*	3.52	4.07	1.54	2.31

Note: The predicted Nash prices are conditional on the draws and the assumption of risk-neutral price-setting. The *ex ante* Nash predictions are 4.00 with two sellers and 2.40 with four sellers.

= .8708). However, for two sellers the negotiation treatment significantly raises transaction prices by $\hat{\beta}_2 + \hat{\beta}_3 = .99$ experimental dollars above the level in first-price auctions (p-value = .0004).

Finding 2b. In Regime 1, the primary effect of changing the number of sellers does not significantly change the level of efficiency. The primary effect of changing from auctions to multilateral negotiations slightly increases the level of efficiency. However, with two sellers, the total effect of changing from auctions to multilateral negotiations does not significantly change the level of efficiency.

Evidence. Table 3 reports the average efficiency for the first 12 periods, by institutional regime and number of sellers. The high efficiency levels are consistent with those reported in previous auction experiments.[14] Table 4 reports the results from a linear mixed-effects model for the efficiency levels, for which the baseline treatment is four sellers in first-price auctions. We do not control for across-period cost variation like we did in the pricing analysis, because cost variation theoretically should not influence efficiency. In the auction treatment, reducing the number of sellers from four to two has no effect on efficiency ($\hat{\gamma}_1 = 1.57$, p-value = .2154). With four sellers the negotiation treatment significantly raises efficiency levels by $\hat{\gamma}_2 = 2.98$ percentage points (p-value = .0134). However, with two sellers the *Negotiation* primary effect is offset by the *Two* × *Negotiation* interaction effect ($\hat{\gamma}_2 + \hat{\gamma}_3 = -.39$, p-value = .6539).

Findings 2a and 2b report that transaction prices with two sellers are higher in multilateral negotiations than in first-price auctions, but that efficiency is the same. We infer that the trading rules affect the transfer of surplus from the buyer to the more efficient of the two sellers. With four sellers, transaction prices are the same across institutions, but the level of efficiency increases slightly when using multilateral negotiations (3 percentage points).

One explanation for the price differential is that multilateral negotiations may foster tacit collusion. However, this explanation is weak because (a) there is no evidence of bid rotation, (b) the negotiation transcripts indicate that the sellers are concerned about how competitive their offers are, and (c) efficiency is high. McAfee and McMillan (1992) show that collusion without side payments in first-price auctions requires inefficient allocation of contracts. It seems reasonable

[14] For example, see Cox, Roberson, and Smith (1982) and Cox, Smith, and Walker (1983).

TABLE 2 Estimates of the Linear Mixed-Effects Model for Price[a]

	Estimate	Standard Error	Degrees of Freedom	p-value	Estimate	Standard Error	Degrees of Freedom	p-value
	Regime 1: Periods 1–12				**Regime 2: Periods 13–28**			
μ	1.75	.13	166	.0000	1.53	.12	232	.0000
Two	***1.03***	***.20***	***12***	***.0001****	***1.24***	***.17***	***12***	***.0000****
Negotiation**	***.03***	***.19***	***12***	***.8708***	***.13***	***.17***	***12***	***.4354***
Two* x *Negotiation	***.96***	***.28***	***12***	***.0047***	***1.10***	***.24***	***12***	***.0007***
c_1	.98	.16	166	.0000	.88	.03	232	.0000
$c_1 \times$ *Two*	−.22	.17	166	.1829	−.01	.05	232	.8760
$c_1 \times$ *Negotiation*	.10	.23	166	.6560	−.03	.06	232	.5966
$c_1 \times$ *Two* $\times$ *Negotiation*	−.63	.24	166	.0094	−.54	.08	232	.0000
c_2	−.04	.12	166	.7667	.08	.03	232	.0150
$c_2 \times$ *Two*	.13	.13	166	.3089	−.06	.05	232	.3010
$c_2 \times$ *Negotiation*	−.16	.17	166	.3609	−.04	.06	232	.5061
$c_2 \times$ *Two* $\times$ *Negotiation*	.10	.19	166	.5780	.01	.08	232	.8977
Number of observations			190				256	
H_a:		$\beta_2 + \beta_3 \neq 0$		.0004		$\beta_2 + \beta_3 > 0$		.0000
	Regime 3: Periods 29–40				**Regime 4: Periods 41–46**			
μ	1.71	.13	168	.0000	1.66	.03	72	.0000
Two	***2.32***	***.19***	***12***	***.0000****	***.99***	***.09***	***12***	***.0000****
Negotiation	***−.05***	***.18***	***12***	***.8088***	***.10***	***.07***	***12***	***.1404***
Two* x *Negotiation	***−1.27***	***.28***	***12***	***.0007***	***1.01***	***.11***	***12***	***.0000***
c_1	.91	.04	168	.0000	.78	.04	72	.0000
$c_1 \times$ *Two*	−.50	.06	168	.0000	−.08	.08	72	.3579
$c_1 \times$ *Negotiation*	.00	.05	168	.9397	−.12	.08	72	.1603
$c_1 \times$ *Two* $\times$ *Negotiation*	.43	.09	168	.0000	−.49	.12	72	.0001
c_2	.00	.04	168	.9750	−.10	.04	72	.0231
$c_2 \times$ *Two*	−.03	.07	168	.6879	.11	.08	72	.1744
$c_2 \times$ *Negotiation*	−.02	.05	168	.6679	.18	.10	72	.0705
$c_2 \times$ *Two* $\times$ *Negotiation*	.04	.10	168	.7064	−.12	.12	72	.3388
Number of observations			192				96	
H_a:		$\beta_2 + \beta_3 \neq 0$		.0000		$\beta_2 + \beta_3 > 0$		.0000

Note: For brevity, the session random effects are not included in the table.

[a] $Price_{ij} = \mu + e_i + \beta_1 Two_i + \beta_2 Negotiation_i + \beta_3 Two_i \times Negotiation_i + \beta_4 c_{1ij} + \beta_5 c_{1ij} \times Two_i + \beta_6 c_{1ij} \times Negotiation_i + \beta_7 c_{1ij} \times Two_i \times Negotiation_i + \beta_8 c_{2ij} + \beta_9 c_{2ij} \times Two_i + \beta_{10} c_{2ij} \times Negotiation_i + \beta_{11} c_{2ij} \times Two_i \times Negotiation_i + \varepsilon_{ij}$, where $e_i \sim N(0, \sigma_1^2)$ and $\varepsilon_{ij} \sim N(0, \sigma_{2,i}^2)$.

* One-sided test.

** For Regime 2, *Negotiation* is a dummy variable denoting a history of multilateral negotiations in the previous regime.

that collusion in multilateral negotiations also requires inefficiency. Therefore, because the two institutions are equally efficient, it is unlikely that the higher transaction prices in the multilateral negotiations can be attributed to collusion.

In Section 2 we claimed that auctions and negotiations might differ because the buyer may be unable to keep low-cost sellers offering additional discounts in those instances in which rival sellers have high costs. Figure 1 illustrates how behavior consistent with that hypothesis influences the difference in the transaction prices of first-price auctions and multilateral negotiations with two sellers. When the lowest cost is high (in which case the gap between the lowest and second-lowest cost is likely to be small), negotiated prices and first-price auction prices are similar. When the lowest cost is low (in which case the gap between the lowest and second-lowest cost is likely to be large), negotiated prices exceed first-price auction prices. With four sellers this result does not

TABLE 3 **Average Efficency by Regime**

Sequence	Two Sellers (%)	Four Sellers (%)
FFNF		
Periods 1–12: *F*	96.4	96.0
Periods 13–28: *F*	99.5	98.8
Periods 29–40: *N*	97.1	96.8
Periods 41–46: *F*	98.3	98.6
NFFN		
Periods 1–12: *N*	94.3*	96.8
Periods 13–28: *F*	96.1	98.7
Periods 29–40: *F*	92.5	98.9
Periods 41–46: *N*	97.6	98.6

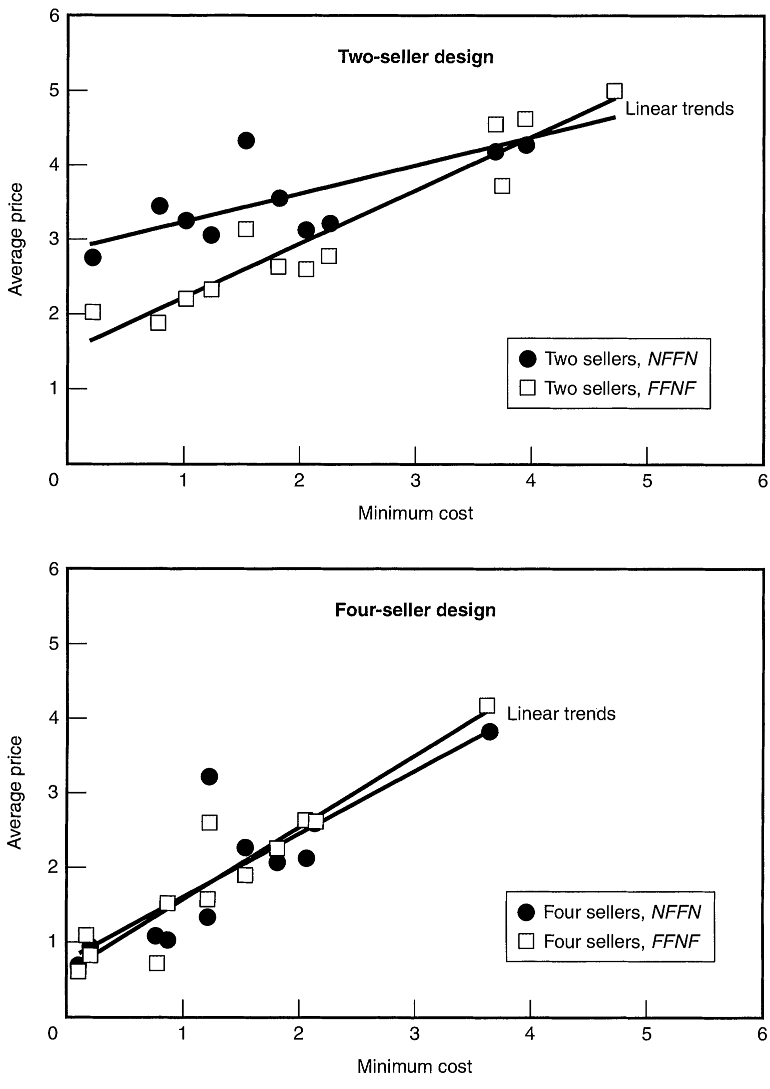
Note: Efficiency is defined to be 100% × (6 − winner's cost)/(6 − lowest cost draw).
*This average includes two observations for which the buyer rejected both final offers and purchased nothing in those periods, resulting in 0% efficiency. The statistical tests in Finding 2b include these two observations. Excluding these two observations, the average efficiency is 98.5%.

TABLE 4 **Estimates of the Linear Mixed-Effects Model for Efficiency**[a]

	Estimate	Standard Error	Degrees of Freedom	p-value
Regime 1: Periods 1–12				
μ	97.02	1.03	176	.0000
Two	1.57	1.20	12	.2154
Negotiation	2.98	1.03	12	.0134
Two × *Negotiation*	−3.36	1.58	12	.0552
Number of observations	192			
Regime 2: Periods 13–28				
μ	98.74	.53	240	.0000
Two	1.26	.53	12	.0342
Negotiation History	.55	.65	12	.4201
Two × *Negotiation History*	−5.95	1.38	12	.0010
Number of observations	256			
Regime 3: Periods 29–40				
μ	99.99	.002	176	.0000
Two	−7.64	1.51	12	.0003
Negotiation	−1.47	.44	12	.0056
Two × *Negotiation*	9.10	1.57	12	.0001
Number of observations	192			

Note: There is insufficient variation in the level of efficiency across and within treatments to estimate the model for Regime 4.
[a] $Efficiency_{ij} = \mu + e_i + \gamma_1 Two_i + \gamma_2 Negotiation_i + \gamma_3 Two_i \times Negotiation_i + \varepsilon_{ij}$, where $e_i \sim N(0, \sigma_1^2)$ and $\varepsilon_{ij} \sim N(0, \sigma_{2,i}^2)$.

FIGURE 1
AVERAGE PERIOD PRICES VERSUS MINIMUM COST IN REGIME 1



emerge, plausibly because the difference between the lowest and second-lowest costs is smaller than when there are only two sellers.

Our third finding illustrates how trading sequence affects market performance. We report this finding in three parts, the first of which compares the common 16 periods of first-price auctions in periods 13 through 28. The second part compares the behavior for periods 29 through 40, and the third part assesses the return to the original institution in periods 41 through 46, just prior to which all subjects have equal experience with the institutions.

Finding 3a. In Regime 2, first-price auction prices are significantly higher for the sellers in the *NFFN* treatment than for the sellers in the *FFNF* treatment, with two sellers. There is no across-treatment difference in transaction prices with four sellers.

Evidence. Table 1 reports the average prices for periods 13 through 28. With two sellers, the average price is 3.01 for those sellers in the *FFNF* treatment and 4.01 for those sellers in the *NFFN* treatment, a 33% increase. With four sellers, there is only a 5% increase.

The alternative to the null hypothesis that the transaction prices are identical is that prices may be higher for those who negotiated initially. This difference could be an experience effect caused by first participating in multilateral negotiations, or it could be because the subjects randomly assigned to the *NFFN* two-seller treatment tend to set higher prices.[15] We employ a one-sided test for the two-seller treatment because we have already observed that negotiated prices are higher than first-price auction prices in the initial 12 periods, but we employ a two-sided test for the four-seller treatment. Referring to Table 2, with two sellers the first-price auction prices are $\hat{\beta}_2 + \hat{\beta}_3 = 1.23$ experimental dollars higher in the *NFFN* treatment than in the *FFNF* treatment (p-value = .0000). However, with four sellers we find no across-treatment difference in transaction prices ($\hat{\beta}_2 = .13$, p-value = .4354). *Q.E.D.*

Finding 3b. In Regime 3, first-price auction prices in the *NFFN* treatment exceed negotiated prices in the *FFNF* treatment, with two sellers. There is no across-institution difference in transaction prices with four sellers.

Evidence. Table 1 reports the average prices for periods 29 through 40. With two sellers, the average multilateral negotiation price is 3.22 for those sellers in the *FFNF* treatment, and the average first-price auction price is 4.07 for those sellers in the *NFFN* treatment. With four sellers, the average prices are 1.69 and 1.74.

We have no clear prediction of how prices might differ across the two institutions, so we employ a two-sided test for equivalence of transaction prices. Referring to Table 2, for two sellers first-price auction prices are $-(\hat{\beta}_2+\hat{\beta}_3) = 1.32$ experimental dollars above the prices for two sellers in multilateral negotiations (p-value = .0000). However, for four sellers we find no difference in transaction prices ($\hat{\beta}_2 = -.05$, p-value = .8088). *Q.E.D.*

Finding 3c. In Regime 4, the original ranking of the institutions' transaction prices returns when the subjects return to their original institution. That is, multilateral negotiation prices are statistically indistinguishable from first-price auction prices with four sellers, but multilateral negotiation prices are significantly higher than first-price auction prices with two sellers.

Evidence. Table 1 reports the average prices for the final six periods. With four sellers, the average price is 1.60 in the first-price auctions and 1.54 in the multilateral negotiations. With two sellers, the average price is 3.01 in the first-price auctions and 3.52 in the multilateral negotiations.

At the start of period 41, each subject has experience with 12 multilateral negotiations and 28 first-price auctions, though in a different order. We employ a one-sided test for the two-seller treatment because negotiated prices were statistically higher than first-price auction prices in the initial 12 periods, but we employ a two-sided test for the four-seller treatment. Referring to Table 2, for two sellers the negotiation treatment significantly raises transaction prices by $\hat{\beta}_2+\hat{\beta}_3 = 1.11$ experimental dollars above the level in first-price auctions (p-value = .0000). However, for four sellers we find no difference in transaction prices ($\hat{\beta} = .10$, p-value = .1404). *Q.E.D.*

The three parts of Finding 3 indicate that with two sellers there is an across-treatment difference that affects transaction prices throughout the experiment. We infer that initial exposure to multilateral negotiations leads to higher prices throughout the session than does initial exposure to first-price auctions. One explanation for this result is that the nature of the competition induced by the initial institution may permanently affect how sellers formulate their bidding/negotiating strategies. For example, the competition induced by the one binding offer of the first-price auction may overwhelm the opportunity for the sellers later to keep prices higher with multilateral negotiations. We also admit the possibility that the subjects randomly assigned to the *NFFN* and *FFNF* two-seller treatments may differ in their propensity to set high prices. Regardless of the reason, the sequence effect in the two-seller treatment has a nontrivial effect on the subjects' earnings. Sellers first exposed to two-seller multilateral negotiations earn on average US$7.82 (or

[15] We thank a referee for pointing out this alternative hypothesis.

85%) more than their counterparts first exposed to first-price auctions. This difference comes at a cost to the buyers, who earn US$6 less when first exposed to multilateral negotiations.

Our final examination of across-treatment differences tests our hypothesis that multilateral negotiations without credible revelation of rivals' offers should look more like first-price auctions than second-price or English auctions.[16] While we do not have experimental data for second-price or English auctions, we generate simulated English auction data by appealing to Coppinger, Smith, and Titus (1980) and Kagel, Harstad, and Levin (1987), who showed that bidders follow their dominant strategies in English auctions. Therefore, the simulated English auction price is the second-lowest cost.

Finding 4. With both two and four sellers, multilateral negotiation prices are not explained by the second-lowest cost, but they are explained by the lowest cost. Hence, multilateral negotiations without credible revelation of rivals' offers more closely resemble first-price auctions than English auctions.

Evidence. Table 2 reports by regime the influence of the lowest and second-lowest costs on both negotiated prices and first-price auction prices. We focus on Regimes 1, 3, and 4, for which there are paired first-price auctions and multilateral negotiations. In each regime, the lowest cost significantly influences the market price in both institutions directly through the c_1 term ($\hat{\beta}_4$ = .98, .91, .78, Regimes 1, 3, and 4, respectively). Of the cost interaction coefficients, only the $c_1 \times$ *Two* $\times$ *Negotiation* coefficient is consistently significant (p-values = .0094, .0000, and .0001) and roughly half the magnitude of the c_1 and *Two* $\times$ *Negotiation* coefficients. In contrast, the second-lowest cost has no influence on negotiated prices, except marginally in Regime 4. *Q.E.D.*

Finally, we comment on the within-subject effects of the multilateral negotiation and first-price auction institutions. We focus on the two-seller treatment because Findings 2 and 3 indicate that the four-seller treatment yields very similar pricing and efficiency levels across institutions. In our working paper, Thomas and Wilson (2000), we report that winning multilateral negotiation prices are not greater than the confidence and prediction intervals of the seller's first-price offer function for either the *NFFN* or *FFNF* sessions. Thus, there appears to be no across-institution difference at the subject level. In addition, the first-price offer function at low-cost draws is closer to the risk-neutral prediction in the *NFFN* sessions than in the *FFNF* sessions. One explanation for the latter finding is that the subjects' institutional experience influences their risk preferences in the first-price auctions.[17] An alternative explanation is that initial exposure to an institution affects the subjects' formulation of their strategies in both institutions. This is similar to the model proposed in Crawford and Broseta (1998) to explain how whether or not subjects were exposed to one institution affects how they behave in a second. These within-subject conclusions, however, must be tempered by the observation that these experience effects cannot necessarily be disentangled from session effects.

5. Conclusion

■ In this article we study a common exchange process that we term "multilateral negotiations," in which a buyer plays sellers off one another to obtain concessions on their initial price offers. Using experimental techniques, we evaluate subject behavior in multilateral negotiations without credible revelation of rivals' offers, and we compare the outcomes of multilateral negotiations and first-price auctions.

When subjects have no experience with either institution, we find that transaction prices are statistically higher in multilateral negotiations than in first-price auctions with two sellers, but that the institutions are equally efficient. We also find that prices are indistinguishable in the

[16] We thank a referee for suggesting this analysis.

[17] See Berg, Dickhaut, and McCabe (1996) for an experiment that finds that individuals' risk preferences are not stable across institutions.

two institutions with four sellers, but that multilateral negotiations are slightly more efficient. Moreover, with four sellers we cannot distinguish between the two institutions' transaction prices at any point in the experiment, which suggests that the institutions are outcome-equivalent with four sellers. Finally, we find that nonverifiable multilateral negotiations more closely resemble first-price auctions than English auctions.

Our results have implications for institutional design and for antitrust analysis. First, buyers in our setting should prefer to employ first-price auctions rather than multilateral negotiations, assuming that multilateral negotiations are more costly in terms of the time spent determining the transaction price. Second, caution should be used in applying auction models in merger analyses in which transactions more closely resemble multilateral negotiations. Not only do we find that the price level can differ substantially across the institutions for certain numbers of sellers, but the percentage price change associated with changing the number of sellers also can differ.

The implications of our results are limited by the scope of our experiment and would benefit from further research. First, it would be useful to extend our analysis to settings with different numbers of sellers. At this point, we do not know for what number of sellers multilateral negotiations and first-price auctions become indistinguishable, or whether the price-concentration relationship is actually linear. Second, from the perspective of merger policy, it would be useful to extend our analysis to settings with changes both in the number of sellers *and* in the sellers' postmerger cost distributions. To date, these issues have not been explored fully in the auction setting, and clearly not in our multilateral negotiation setting. Finally, it would be interesting to let the buyer select his preferred institution, or be unable to commit not to haggle upon receiving the sellers' initial offers.

Appendix

■ The following selections are taken from the real-time ordered transcript for the four two-seller *NFFN* discussions (bold added for emphasis).

Session 1, period 11 (Seller 1's cost is .20 with an initial offer of 3.50. Seller 2's cost is .41 with an initial offer of 4.15).

[Buyer to Seller 1]: can you go down to 3.00?
[Seller 1]: yes
[Buyer to Seller 2]: they are lower onceagain....is it possible to go down quite a bit?
[Seller 1]: will that work best for you?
[Seller 2]: tell me a price? [Buyer to Seller 2]: what's the lowest you can possibly go?
[Seller 2]: Tell me there price
[Buyer to Seller 2]: can you beat 3.00?
[Seller 1]: if not I can sacrafice 2.94
[Buyer to Seller 2]: actually...they just went below that..can u go any lower?
[Seller 1]: do you have a better offer?
[Seller 2]: If we don't deal wuicker then we lose money. you arem aking money everytime so don't barter so much
[Buyer to Seller 1]: woah...they just went down a lot...can you go any lower? you are both real close.

The buyer accepted Seller 1's offer of 2.00.

Session 2, period 1 (Seller 1's cost is 1.23 with an initial offer of 5.00. Seller 2's cost is 2.81 with an initial offer of 7.50).

[Buyer to Seller 1]:
[Seller 1]: yes??
[Seller 2]: hi there
[Buyer to Seller 1]: seller 2 has offered me $3. Can you beat that?
[Seller 1]: 2.90
[Seller 2]: is my price too high?
[Seller 1]: so?
[Buyer to Seller 2]: seller 1 just offered me 2.50 can you beat that
[Seller 1]: i give u 2.90
[Seller 2]: ha, nope. I'd lose a ton of money!
[Seller 2]: maybe next time
[Buyer to Seller 1]: seller 2 just countered with 2.25, can you beat that

(Note: The buyer is lying. Seller 2 never lowered his initial offer of 7.50.)

[Seller 1]: ok??

The buyer accepted Seller 1's offer of 2.20.

Session 3, period 7 (Seller 1's cost is 2.37 with an initial offer of 3.75. Seller 2's cost is 2.25 with an initial offer of 4.50).

[Seller 2]: give me an offer
[Buyer to Seller 2]: How about 3.50
[Seller 2]: make it 4.00
[Seller 2]: how is that
[Buyer to Seller 2]: sorry

The buyer accepted Seller 1's offer of 3.75.

Session 4, period 11 (Seller 1's cost is .20 with an initial offer of 5.75. Seller 2's cost is .41 with an initial offer of 3.82).

[Seller 1]: This is ridiculous...
[Seller 2]: This is a low price for ya
[Buyer to Seller 2]: sold at 2.75
[Buyer to Seller 1]: don't think you can do this round
[Seller 1]: where you at
[Buyer to Seller 1]: goota show me 3.25
[Seller 2]: How's 3.50
[Seller 1]: I'll show 4
[Buyer to Seller 2]: 3.0 is a deal
[Buyer to Seller 1]: down to 3.2
[Seller 2]: 3.15?
[Buyer to Seller 1]: 3.0 sells
[Buyer to Seller 2]: gotta compete
[Buyer to Seller 2]: show me 3.0
[Seller 1]: where you at
[Buyer to Seller 1]: i'm at 2.8
[Seller 2]: it's only 5 cents
[Seller 1]: what happened to 3
[Buyer to Seller 2]: gotta beat 3.0 now
[Buyer to Seller 1]: competition
[Seller 2]: 2.98
[Seller 1]: competition, hahahahhaha
[Buyer to Seller 2]: show me 2.75 and i buy
[Buyer to Seller 1]: gotta beat 2.8
[Buyer to Seller 2]: gotta buy from the lowest bed
[Buyer to Seller 2]: beat 2.7

The buyer accepted Seller 2's offer of 2.65.
Seller 1's submitted offers were: 5.75, 5.50, 4.00, 3.50, 3.29, 3.00, 2.80, and 2.75.
Seller 2's submitted offers were: 3.82, 3.50, 3.25, 3.05, 2.98, 2.85, and 2.65.

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