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A Comparison of Auctions and Multilateral Negotiations

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with suppliers after receiving the initial offers. This process 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 the multilateral bargaining setting described above.

Due to the prevalence of multilateral negotiations as a means of exchange, it is important to understand them for the same reasons that it is important to understand other common price formation processes, such as auctions and bilateral bargaining. We are interested in such issues as the institution's efficiency, 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.

We also are interested in the relationship between the outcomes of multilateral negotiations and of various auction formats for two reasons. First, this relationship has important implications for institutional design. For example, a buyer attempting to procure services from potential sellers has incentives to use the most profitable means of exchange. 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 more favorable than the other. Identifying these factors should lead to a more informed selection of an exchange process. Concerns about institutional design are particularly important in the emerging e-commerce field, where buyers and sellers are in the process of developing software agents to handle the procurement process online.[5] For example, Su, Huang, and Hammer [2000] have implemented a prototype server for automated, Web-based negotiations between buyers and sellers in e-commerce exchange. More generally, a bevy of researchers and practitioners in computer science and management information systems are creating artificially intelligent mechanisms for negotiations and auctions. Regrettably, there is no empirical and little theoretical economic research comparing these institutions that could guide them in their work. This paper 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, auction models have been employed by U.S. competition authorities and private parties to evaluate the impact of proposed mergers.[6] Even if transactions resemble multilateral negotiations more closely than auctions, an analyst

[5] According to an article in *Business Week*, 1/17/2000, "By the end of next year, 91% of U.S. firms will use the Internet for procurement, compared with today's 31 percent."

[6] For example, auction results were used to evaluate the recent merger between Rite-Aid and Revco. See Baker [1997]. Section 2.2.1 of the 1992 Merger Guidelines highlights the possible effect of mergers in auction markets.

might elect to study behavior by using an auction model because such models have been extensively studied, while at present there do not exist any formal multilateral negotiation models. If we find that the outcomes of auctions and multilateral negotiations are similar,[7] then there should be less concern about using a modeling approach that does not precisely fit the market's characteristics. Otherwise, caution should be used in applying auction models in settings in which 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. When multilateral negotiations are employed, the buyer can communicate electronically in real-time with the sellers, but the sellers cannot communicate with each other. When auctions are employed, 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. Finally, we exploit within-group differences in the outcomes of the different institutions to test whether sellers' behavior later in the session depends upon their prior institutional experience.

With two sellers who have no prior experience with either institution, we find that the transaction prices in multilateral negotiations are statistically higher than the transaction prices in first-price auctions. However, with four sellers, we cannot statistically distinguish between the transaction prices in the two institutions. We also find an experience effect in the two-seller treatment, in that sellers first exposed to multilateral negotiations set higher prices in first-price auctions than do sellers first exposed to first-price auctions. Moreover, examination of the within-group behavior with two sellers suggests there is virtually no difference between the two institutions. From these results we conclude that the number of sellers and their prior experience have an economically significant effect on the relationship between first-price auctions and multilateral negotiations. Specifically, with no prior experience with multilateral negotiations or first-price auctions, the transaction prices of first-price auctions and multilateral negotiations are statistically indistinguishable if there are sufficiently many sellers. Efficiency of multilateral negotiations is slightly higher. With a small number of sellers, multilateral negotiation prices are

[7] This similarity could involve either equivalence in price levels or equivalence in percentage price changes as the number of sellers changes.

higher and efficiency is the same. In contrast, our within-group results suggest that a buyer who traditionally has used multilateral negotiations may not receive lower price offers by switching to an auction process. However, given that multilateral negotiations are costly in terms of the time spent determining the transaction price, our results suggest that buyers in this setting should prefer to employ first-price auctions rather than multilateral negotiations.

The paper is structured as follows. Section 2 describes the existing theory most closely relevant to multilateral negotiations, and explains the reasoning underlying our hypothesis that the outcomes of first-price auctions and multilateral negotiations will be similar. Section 3 describes the experimental design and the procedures we use to examine the relationship between the two institutions. Section 4 presents our results, while Section 5 briefly concludes and provides directions for future research.

2. Related Theoretical Background

The exact exchange mechanism we wish to study has not been formally modeled in the bargaining literature, presumably due to the difficulty in finding a tractable solution to a complex problem. Hence, the basis of our study is driven by our intuition about how first-price auctions and multilateral negotiations should be related. To begin, we first describe first-price auction theory and the theoretical setting we envision as being an appropriate starting point for formalizing multilateral negotiations. Next we describe existing work that relates to multilateral negotiations, and finally we explain our intuition about the relationship between auctions and multilateral negotiations.

Consider a setting in which S risk-neutral sellers compete to fulfill a contract for a single risk-neutral buyer. V_B is the commonly known value that the buyer places on having the contract fulfilled. Each seller's cost c is a privately known independent draw from the continuous distribution function

7.92 Tf -0.005 Tc 5.28 -1.44 Td (w -0.0858 Tc 0./TTs378 Tc 0.822 Tw 5.04 1.44 Td (is

seller must be concerned that the buyer is not being truthful about the terms or the existence of the rival's offer. Consequently, the seller must be aware of the danger that he could end up bidding against himself by offering price reductions that are undercut by fictitious discounts from a rival.

To explain our intuition more carefully, note that in many auction settings a seller must be concerned about bidding against itself, just as in multilateral negotiations. For example, in the "button auction" described by Milgrom and Weber [1982], 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 the button once the button has been released, so a firm cannot exit and then re-enter the bidding. The winning firm is the last firm 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 have no knowledge of whether any other firms are participating at any point in time. Thus, a seller must be concerned that it is continuing to depress its button after all other sellers have dropped out. The outcome of this game seemingly 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 we hypothesize that there should exist a relationship between first-price auctions and multilateral negotiations without credible revelation of offers.

For several reasons, the preceding relationship may not be exact, either empirically or theoretically. 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 non-isomorphism results from bidders mistakenly adjusting their beliefs that their rivals' values are lower than what they initially anticipate, when no one takes the item as the clock ticks down. They argue that the real-time nature of the Dutch clock auction leads to a failure in the isomorphism. Therefore, in a procurement auction, if multilateral negotiations are isomorphic to Dutch auctions, then we would expect multilateral negotiation prices to exceed first-price auction prices.

Second, in practice the outcomes of multilateral negotiations likely depend critically on the players' ability to haggle. For example, suppose that one seller has a low cost draw relative to his rivals, and that all of 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. Thus, the transaction price may be higher with multilateral negotiations than with a one-shot first-price auction. However, a skilled buyer may be able to keep a seller offering discounts below his equilibrium first-price auction offers, because losing sellers in first-price auctions would be willing to lower their initial price offers in order to win the contract. Hence, the buyer might have the power to extract more favorable price offers in a multilateral negotiation than in a one-shot first-price auction.

Another reason that the relationship between multilateral negotiations and first-price auctions may differ behaviorally is that in the multilateral negotiations one must provide incentives for the sellers 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 are concerned that serious initial offers will be used against them later in the negotiation.[12] In our experimental framework there exists a time limit on each negotiation period, and there clearly exist frictions that prevent the buyer from receiving infinitely many offers. Consequently, a seller might be concerned that it will be left out of the communication process if it 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.

Reputation effects may also prevent a buyer from pushing sellers too hard to obtain offers better than he could receive in first-price auction. For example, if the buyer purchases from a seller who refused to lower its price in the face of an alleged offer made by another seller, then the seller will know that the buyer has lied in the past about competing offers. Presumably, this will make the seller more wary about the veracity of future competitive offers alleged by the buyer. Also, relationships may develop between the buyer and the sellers, if the transactions are more appropriately considered to be the stage games of a repeated game.

3. Experimental Design and Procedures

Because of the difficulty in finding a tractable solution for what appears to be a complex theory of multilateral negotiations, we conducted a heuristic experiment (see Smith [1982], pp. 941-942) to compare and contrast market performance and behavior in first-price auctions and multilateral negotiations. In the absence of a formal theoretical analysis, we determined it is better to design our multilateral negotiation process to look more like real-world multilateral negotiations than the structure we outlined in Section 2. We focus on the case without credible revelation of rivals' offers because it seems to be the more empirically relevant case. Moreover, the conclusions regarding the relationship between auctions and multilateral negotiations seem less likely to hold in this setting than in the setting with credible revelation of offers, so the case we examine seems likely to be the more interesting one.

Our experimental design permits us to compare the outcomes of first-price auctions and multilateral negotiations, both across and within subject groups. Moreover, our design also permits us to compare the efficiency of the two institutions, and to compare the first-price auction outcomes with their theoretical predictions.

Using "*F*" to denote a sequence of first-price auctions and "*N*" to denote a sequence of multilateral negotiations, our initial intent was to use both *FNF* and *NFN* sequences of treatments, to permit across- and within-group comparisons of the institutions, and to test for experience effects. However, time constraints prevented this due to the time necessary to conduct the multilateral negotiations. Specifically, we wanted the *N* and *F* sequences that were paired across treatments to have the same number of transactions, but our pilot session indicated that the treatment with two sets of negotiations would have taken too much time for the number of paired auctions we wanted to conduct.[13]

To compensate, we derived an alternative design that gives us a sufficiently large number of observations to make the desired statistical comparisons of the institutions. Specifically, we pair two treatments, one with the sequence *NFFN*, and one with the sequence *FFNF*. The first and third sequences consist of 12 transactions; the second consists of 16, while the fourth

[12] Multilateral negotiation will be equivalent to a first-price auction if the buyer's per-period delay cost exceeds the maximum possible gain from obtaining additional offers, or if the discount factor is zero. In both cases the buyer will accept an offer in the first period.

[13] We wanted a large enough number of first-price auction observations so that we could estimate each seller's price-setting function with a minimal 20 degrees of freedom.

consists of 6.[14] 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 sellers, 4 sellers} × {*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 draws from the Uniform distribution on [0, 6.00]. 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. We maintained a constant support for the cost draws across the two- and four-seller treatments because we did not want the distance between the order statistics to affect the real-time negotiations. A larger dispersion in cost draws may make it easier or harder for sellers to extract more surplus from the buyer, and because we did not know if or how the variance of the cost draws mattered, we held it constant.

Our experiment consisted of a total of 736 first-price auctions or rounds of multilateral negotiation using sixty-four undergraduate student volunteers. Some students had participated previously in market experiments, but with significantly different trading institutions. No subject participated in more than one of the sessions reported in this experiment.

The instructions for the first-price auction sequences are based upon those used by Cox, Roberson, and Smith [1982] and Cox, Smith, and Walker [1983, 1988]. The instructions for the multilateral negotiation sequences are newly developed, as our experiment is the first to study this institution.

In addition to reading the self-paced instructions displayed by the software, the subjects followed along as the experiment monitor read out loud from a handout with both additional and review information. 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. While revealing the buyer's value may create incentives that are affected by the perceived financial benefit of being a buyer rather than a seller in the experiment,[15] it is consistent with prior auction experiments. Most auction experiments use buying auctions rather than selling auctions, and bids are

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

[15] For example, sellers may not compete as vigorously, if doing so can be supported, because they realize the large profits being enjoyed by the buyer. In most auction experiments, there is no subject playing the auctioneer and obtaining monetary prizes. This hypothesis is certainly testable; however, we do not pursue it in this paper.

constrained to be nonnegative. This implicitly informs the subjects that bids in excess of zero have a chance of being accepted. Revealing the buyer's value also helps to avoid the possibility of no trade in the first-price auctions, which would occur if the lowest offer exceeded the buyer's value.

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.[16] The computer automatically awarded the item to the seller that submitted the lowest offer once all of the offers had been submitted, provided that the lowest offer was less than 6.00. At the end of the auction, 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.

buyer revealed it to them 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 in advance the rules of any future trading institution, as the instructions for any particular institution were displayed only prior to commencing trade in that institution. It was public information that the same set of sellers was matched with the same buyer for the duration of the experiment.[20]

Participants received $5 for showing up on time, plus their salient earnings. In the IPV first-price auctions reported in Cox, Roberson, and Smith [1982], the subjects earned considerably less than the risk-neutral predictions. Hence, calibrating US$ payoffs on the risk-neutral predictions is not helpful per se in targeting a salient earnings amount for a two-hour experiment. For this reason and because we were holding the support of the cost draws constant for all sessions, the subjects in the two-seller and four-seller treatments were given different exchange rates imputed from the US$ payoffs of subjects in the aforementioned IPV first-price auction experiments.[21] 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 0.25 experimental dollars. In the two-Tw (ddi of)Tsionslimeus tr safee)he experTj -0.0655 Tc 3.3415 Tw 36 -2utral 1.718ll sessions, the In 2

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, as well as each seller's initial and subsequent offers in the multilateral negotiations.

***Finding 1*:**

Reference to Figure 1, but now comparing the graphs from left to right, illustrates the across-institution differences per period. The price patterns in the four-seller treatments are strikingly similar, while the price patterns in the two-seller treatments are noticeably higher. However, as we discussed in Section 2, ex ante we had no hypothesis whether the multilateral negotiation would grant either the buyers or the sellers more power than they have in a first-price auction. Because the baseline treatment in the linear mixed-effects model is four sellers in first-price auctions, the estimate of the *Negotiation* coefficient ($\hat{b}_2$) represents the amount by which the *Negotiation* treatment affects transaction prices vis-à-vis first-price auctions, holding the number of sellers constant at four. Table 3 reports that the point estimate for *Negotiation* is nearly zero and is highly insignificant (*p*-value = 0.9856). This is not too surprising, given our visual examination of the four-seller transaction prices in Table 2 and Figure 1. However, for two sellers the negotiation treatment significantly raises transaction prices by $\hat{b}_2 + \hat{b}_3 =$ -0.004 + 0.884 = 0.880 experimental dollars above the level for two sellers in first-price auctions (*p*-value = 0.0038). With two sellers in first-price auctions, the estimated transaction price is 2.98 = $\hat{m} + \hat{b}_1 =$ 1.878 + 1.105, and so the

-seller transaction pricauctwionoultsiledgotiationtionisslhdyorisefcanienfilnst-0.ice

sellers the *Negotiation* primary effect of increasing efficiency is more than offset by the *Two Sellers* × *Negotiation* interaction effect ($\hat{g}_2 + \hat{g}_3 = 2.98 - 3.36 = -0.39$). Non-parametric tests do not reject the null hypothesis of equal efficiency levels between the first-price and multilateral negotiation institutions with four sellers or with two sellers. Given that both institutions are highly efficient and that there are several instances in which both institutions are 100% efficient, it is not surprising that a (low power) nonparametric test would fail to detect a mere 3-percentage point difference in the *Negotiation* treatment with four sellers. ■

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. From these

transcripts from each of the four two-seller *NFFN* discussions indicate that the sellers are attentive to how competitive their offers are.

Our third finding illustrates how the history of trading with different institutions affects market performance. As procurement moves onto the Internet, agents that adopt new institutions will have had experience with other institutions. Firms that employ negotiations in traditional procurement settings may move towards auctions on the Internet, and vice versa. Hence, the impact of historical experience with a particular institution is an interesting question to investigate. 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. The quantitative support is drawn from Table 3.

Finding 3a: *With two sellers, sellers in first-price auctions who only have prior experience with multilateral negotiations transact at significantly higher prices than sellers who only have prior experience with first-price auctions. With four sellers, there is no difference in transaction prices.*

Evidence: The average prices for periods 13 through 28 that are reported in Table 2 support this finding. With two sellers, the average price is 3.01 for those sellers only with prior auction experience and is 4.01 for those sellers only with prior negotiation experience, which is a 33% increase. With four sellers, the average price is 2.01 for those sellers only with prior auction experience, and it is 2.12 for those sellers only with prior negotiation experience, which is only a 5% increase.

Figure 2 displays by treatment the transaction prices for periods 13 through 28. The sellers in the *FFNF* sessions have had 12 periods of experience with first-price auctions, while the sellers in the *NFFN* sessions have had 12 periods of experience with multilateral negotiations. Recall that the cost draws are common for all bidders of the same seller identification. Visual examination of the average prices illustrates the across-institution differences. The price patterns in the two-seller treatments are quite different, while the price patterns in the four-seller treatments look very similar. The alternative to the null hypothesis that the transaction prices are identical is that a history of negotiation may have a permanent effect such that first-price auction prices are higher in the *NFFN* sessions. We employ a one-sided test for the two-seller treatment because we have already observed that *N* prices are statistically

higher than *F* prices in the initial 12 periods, but we employ a two-sided test for the four-seller treatment. Referring to Table 3, for two sellers the negotiation treatment significantly raises transaction prices by $\hat{b}_2 + \hat{b}_3 = 0.108 + 0.965 = 1.073$ experimental dollars above the level for two sellers in first-price auctions (*p*-value = 0.0002). However, we find no evidence of a difference in the transaction prices in the four-seller treatment ($\hat{b}_2 = 0.108$, *p*-value = 0.6513). A nonparametric test yields the same conclusion for two sellers, but not with four. ■

Finding 3b: *With two sellers, sellers in first-price auctions who have prior experience with multilateral negotiations and first-price auctions transact at higher prices than do sellers in multilateral negotiations who only have prior experience with first-price auctions. With four sellers, there is no difference in transaction prices.*

Evidence: The average prices for periods 29 through 40 that are reported in Table 2 support this finding. With two sellers, the average multilateral negotiation price is 3.22 for those sellers only with prior auction experience, and the average first-price auction price is 4.07 for those sellers with prior negotiation and auction experience. With four sellers, the average price is 1.69 for those sellers only with prior auction experience, and is 1.74 for those sellers with prior negotiation and auction experience.

Figure 3 displays by treatment the transaction prices for periods 29 through 40. The sellers in the *FFNF* sessions have had 28 periods of experience with first-price auctions, while the sellers in the *NFFN* sessions have had 12 periods of experience with multilateral negotiations and 16 periods of experience with first-price auctions. Because of the potentially offsetting effects of the history of the *NFFN* sellers and treatment effect of the multilateral negotiations in the *FFNF* sessions, ex ante we have no clear prediction how prices might differ across the two institutions. Therefore, we employ a two-sided test for equivalence of transaction prices. Referring to Table 3, for two sellers the history of negotiation significantly reduces transaction prices by $-\hat{b}_2 - \hat{b}_3 = 0.068 + 0.733 = 0.801$ experimental dollars below the level for two sellers in first-price auctions (*p*-value = 0.0139). However, we find no evidence of a difference in the transaction prices in the four-seller treatment ($\hat{b}_2 = -0.068$, *p*-value = 0.8205). ■

Finding 3c: *With equal amounts of differently ordered experience in both first-price auctions and multilateral negotiations, there is an across-group "return to baseline effect" of the institution treatment. That is, transaction prices are statistically indistinguishable in the first-price auctions and the multilateral negotiations with four sellers, but multilateral negotiation prices are higher than first-price auction prices with two sellers.*

Evidence: The average prices for the final 6 periods that are reported in Table 2 support this finding. With four sellers, the average price is 1.60 in the first-price auctions and is 1.54 in the multilateral negotiations. With two sellers, the average price is 3.01 in the first-price auctions and is 3.52 in the multilateral negotiations.

Figure 4 displays by treatment the transaction prices in each of the final six periods of the sessions. At the start of period 41, all subjects have the same amount of experience in both institutions, but in a different order. At this point in the session each subject has experience with 12 multilateral negotiations and with 28 first-price auctions. Again, we employ a one-sided test for the two-seller treatment because we have already observed that *N* prices were statistically higher than *F* prices in the initial 12 periods, but we employ a two-sided test for the four-seller treatment. Referring to Table 3, for two sellers the negotiation treatment significantly raises transaction prices by $\hat{b}_2 + \hat{b}_3 = -0.095 + 0.596 = 0.501$ experimental dollars above the level in first-price auctions (*p*-value = 0.0371). However, with a two-tailed test we find no evidence of a difference in the transaction prices in the four-seller treatment ($\hat{b}_2 = -0.095$, *p-value* = 0.7644). ■

The three parts of Finding 3 indicate that the order in which subjects are exposed to the two institutions has a lasting effect on the transaction prices. With two sellers, initial exposure to multilateral negotiations leads to higher prices throughout the session than does initial exposure to first-price auctions. One explanation for these results is that the competition induced by the one binding offer of the first-price auction overwhelms the opportunity for the sellers later to keep prices higher with multilateral negotiations. Another explanation is that the nature of the competition induced by the initial institution may permanently affect how sellers formulate their bidding/negotiating strategies conditional on their cost draws. Regardless of the reason, the experience effect in the two-seller treatment has a nontrivial effect on the subjects' earnings. The data reported in Table 1 indicate that a Seller 1 first exposed to the two-seller multilateral negotiations earns on average US$8.49 more (or 76%) than its counterpart first exposed to first-

price auctions, and a Seller 2 earns *twice* as much as its counterpart (US$14.29 versus US$7.14). All of this comes at a cost to the buyers, who earn US$6 less when first exposed to multilateral negotiations.

Finally we turn our attention to assessing the

From Finding 2 we conclude for the two-seller treatment that transaction prices for the two institutions across subjects are initially different (*N* prices exceed *F* prices in the first 12 periods). However, as the examination of the individual behavior in Finding 4 indicates, the within-subject behavior is largely unaffected by the change in the institution. The *NFFN* and *FFNF* sequences take separate paths based upon the initial prices, such that *N* and *F* prices *at the subject level* are statistically the same for the remaining 34 periods. Hence, we find that both initial institutions have a permanent effect on the individual's offering and negotiation behavior. Finding 5 further examines this effect on the offer functions.

Finding 5: *With two sellers, the first-price offer function at low cost draws is closer to the risk-neutral prediction for sellers with a history of multilateral negotiations than for sellers without a history of multilateral negotiations.*

Evidence: Inspection of Figures 5 and 6 provides clear support for this finding. For 7 of the 8 subjects in the *NFFN* treatment, the confidence intervals for the mean response include or exceed the risk-neutral prediction for low cost draws. Except for the obvious and highly variable seller 1 in *FFNF* session 2, the *FFNF* confidence intervals for the offer functions noticeably lie in the risk-averse area. Table 6 reports the predicted offers from the subject-specific first-price offer functions for two low cost draws, 1.00 and 2.00 (2.00 is the expected value of the minimum order statistic of two *U*[0yf two

5. Conclusion

experience. Hence, if a buyer and his suppliers traditionally have engaged in multilateral negotiations off the Internet, then switching to an online auction may not result in lower prices.

Second, we find that negotiated prices are never less than first-price auction prices, both across and within subject groups. This result suggests that buyers in our setting should prefer to employ first-price auctions rather than multilateral negotiations, given that multilateral negotiations are costly in terms of the time spent determining the transaction price. Of course, this conclusion raises the question of why first-price auctions are not observed more frequently in common transactions. One explanation is that reputation effects create a barrier for buyers trying to implement first-price auctions. For example, a car buyer is a short-run player in the

first-price auctions become indistinguishable, or whether the price-concentration relationship is actually linear. In the latter case, multilateral negotiation prices would be less than first-

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Table 1. Average and Predicted Session Payoffs (US$) by Sequence and Player Type*

	Average Payoff		Nash Prediction
	FFNF	*NFFN*	
Four Sellers			

Two Sell[.184 W n BT /T/TT ( )Tj /T-Sellers

Table 3. Estimates of the Linear Mixed-Effects Model

$$Price_{ij} = m + e_i + b_1 TwoSellers_i + b_2 Negotiation_i + b_3 TwoSellers_i \times Negotiation_i + e_{ij},$$

$$\text{where } e_i \sim N(0, s_1^2),\ e_{ij} \sim N(0, s_{2,i}^2).$$

	Estimate	Std. Error	Degrees of Freedom*	*t*-statistic	*p*-value
Regime 1: Periods 1 – 12					
m	1.878	0.166	174	11.302	0.0000
Two Sellers	1.105	0.268	12	4.117	0.0014†
Negotiation	-0.004	0.233	12	-0.018	0.9856
Two Sellers × *Negotiation*	0.884	0.339	12	2.612	0.0227
			190 Obs.		
				H_a: $b_2 + b_3 \neq 0$	0.0038
Regime 2: Periods 13 – 28					
m	2.012	0.167	240	12.018	0.0000
Two Sellers	1.009	0.246	12	4.107	0.0008†
Negotiation History	0.108	0.233	12	0.463	0.6513
Two Sellers × *Negotiation History*	0.965	0.313	12	3.079	0.0048†
			256 Obs.		
				H_a: $b_2 + b_3 > 0$	0.0002†
Regime 3: Periods 29 – 40					
m	1.757	0.209	176	8.406	0.0000
Two Sellers	2.464	0.249			

0.209 . 0(†)Tj /TT0 10.08 Tf 0 Tc -0.011 Tw 3.33
[.184 W n BT /T/TT ( )Tj /T-Sellers 1T0 7.04 0 Td2 416.4 0.72 0.723-0.012 re f 470.72 0.72 reET q

11.52 0.209 4 -0.011 Tw 3.36 -4.56Tc 11.28 -1.44 Td (2)Tj /TT0 10.08 Tf 0.1958 Tc -33353.28 416.4 6.28 -1.44 Td (2)Tj TT37370.58 Tc -336 T0

Table 4. Average Efficiency by Regime

Sequence	*Two Sellers*	*Four Sellers*
FFNF		
Periods 1-12: *F*	96.4%	96.8%
Periods 13-28: *F*	99.5%	98.8%
Periods 29-40: *N*	97.1%	97.1%
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%

Table 6. Subject-Specific Offer Predictions for the Two-Seller Treatment

	$c = 1.00$		$c = 2.00$	
Session, Subject	*FFNF*	*NFFN*	*FFNF*	*NFFN*
Session 1, Subject 1	1.67	2.26	2.72	2.68
Session 1, Subject 2	1.59	2.96	2.11	3.43
Session 2, Subject 1	4.61	3.82	4.89	3.97
Session 2, Subject 2	1.60	4.20	2.70	4.27
Session 3, Subject 1	1.48	3.52	2.43	3.83
Session 3, Subject 2	1.69	3.95	2.56	4.09
Session 4, Subject 1	2.37	4.12	3.61	4.51
Session 4, Subject 2	2.69	3.82	3.24	4.22
Average	2.21	3.58	3.03	3.87
Risk Neutral Prediction	3.50		4.00	

Appendix A

This appendix reports nonparametric tests as support for Findings 1, 2, and 3.

Finding 1:

We use the average per-period prices across the sessions shown in Figure 1 in a one-tailed Wilcoxon signed rank test for data paired by period.[31] We reject the null hypothesis of equal transaction prices in favor of the alternatin Figure 1 in a one-

Finding 3a:

We employ a one-sided test for the two-seller treatment because we have already observed that *N* prices are statistically higher than *F* prices in the initial 12 periods, but we employ a two-sided test for the four-seller treatment. The Wilcoxon signed rank tests using the per-period average prices shown in Figure 2 lead us to reject the null hypothesis in favor of the alternative for both the four-seller and two-seller treatments (for the four-seller treatment: $V = 114$, *p-value* = .0155, $n = 16$, and for the two-seller treatment: $V = 130$, *p-value* = .0002, $n = 16$).

Finding 3b:

For the two-seller treatment, we reject the null hypothesis in favor of the alternative of different

Appendix B

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

Session 1, period 11:

(Seller 1's cost is 0.20 with an initial offer of 3.50. Seller 2's cost is 0.41 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 once again....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

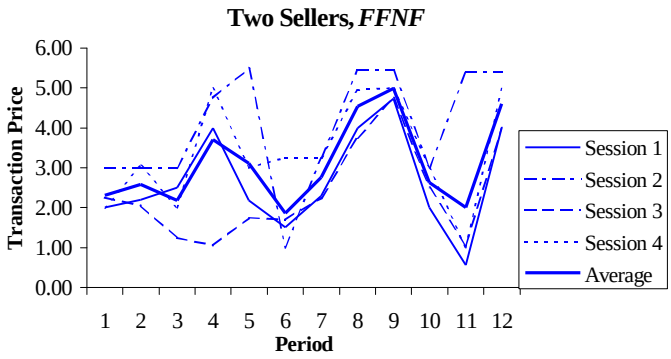
The buyer accepted Seller 1's offer of 3.75.

Session 4, period 11:

(Seller 1's cost is 0.20 with an initial offer of 5.75. Seller 2's cost is 0.41 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 offers were: 3.82, 3.50, 3.25, 3.05, 2.98, 2.85, and 2.65.



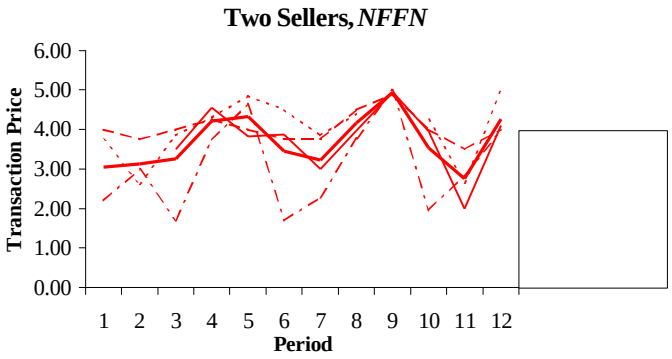


Figure 1. Transaction Prices by Treatment for Periods 1-12

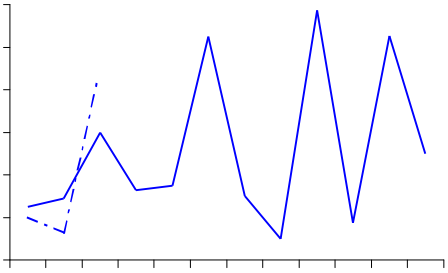


Figure 3. Transaction Prices by Treatment for Periods 29-40

Figure 4. Transaction Prices by Treatment for Periods 40-4(

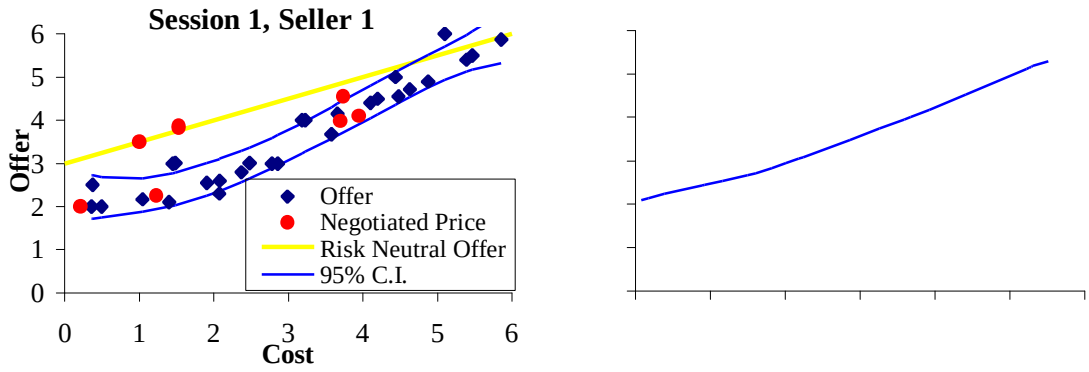


Figure 5. Negotiated Contract Prices and Offer Functions for *NFFN* Two-Seller Treatment

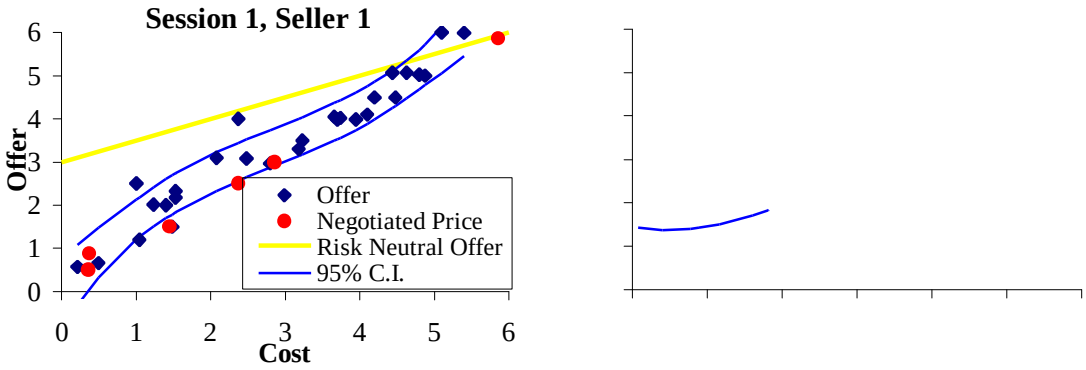


Figure 6. Negotiated Contract Prices and Offer Functions for *FFNF* Two-Seller Treatment