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Byungjoon Yoo

*Korea University, byoo@korea.ac.kr*

Seungwoo Kwon

*Korea University, winwin@korea.ac.kr*

Jinbae Kim

*Korea University, jinbae@korea.ac.kr*

Wei Shang

*Harbin Inst. of Tech, shangwei@hit.edu.cn*

Gunwoong Lee

*Korea University, mixyou@korea.ac.kr*

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## 22. Reserve Price Reporting Mechanisms for Negotiation Support Systems

Byungjoon Yoo  
Korea University  
byoo@korea.ac.kr

Seungwoo Kwon  
Korea University  
winwin@korea.ac.kr

Jinbae Kim  
Korea University  
jinbae@korea.ac.kr

Wei Shang  
Harbin Inst. of Tech  
shangwei@hit.edu.cn

Gunwoong Lee  
Korea University  
mixyou@korea.ac.kr

### Abstract

*Information and Communication Technologies (ICT) changed our everyday business drastically. Business routines have been transformed to online activities. New theories and models were developed for the brand new online environment. For online negotiations, however, the research on new mechanisms is not enough, especially for bilateral distributive negotiations. A reserve price reporting mechanism (RPR) together with its extended version (ERPR) is proposed in this paper. The key improvement of reserve price reporting mechanisms is to let the negotiators report their reserve price to a third-party system before they actually start the negotiation. Analytical models of these mechanisms are built to prove truth revelation condition and the reduction of total social welfare comparing with traditional direct bargaining (TDB). A prototype of this RPR system is developed and a lab experiment is conducted to test the performance of the three mechanisms. The results of the experiment support that the reserve price report mechanisms proposed are more efficient than the traditional one in several dimensions.*

**Keywords:** Negotiation support systems, reserve price, experiment, mechanism

### Introduction

Negotiation, as a means to resolve conflict, has been examined and used for years in business transactions, political affairs, etc. With the development of information and communication technology, Internet-based applications thrive. Internet based negotiations, which is also referred to as online negotiations became popular in both academic and practice domains.

The idea of conducting negotiation with the support of information technology was first implemented in decision support system (DSS) [Bui, 1992]. Evolved from Group Decision Support System (DSS), Negotiation Support System (NSS) is a man-machine interaction system, in which operation theory, game theory, decision theory, behavior science, computer technology, information technology and man-machine engineering are applied to help negotiators to analyze and solve negotiation problems. [Wei, 2001] Early studies on NSS are mainly from DSS perspectives. Well-known NSS, such as Negotiator [Bui, 1999], and Negoisst [Schoop, et al., 2003], focus on how to help the users making better decisions and maximize their profits. One measure is to offer the feature of decision process support, with which users who are called as agents in negotiaion may structure their preferences and view the necessary decision related data etc. Another measure is to provide optimized solutions to both sides, which is usually implemented as a post-settlement.

Although IT facilitates 1) convenient information exchange with less temporal and geographical restrictions and 2) decision support functions with higher expected profits, there is still a long way to go for pure Internet-based negotiations to be effectively implemented in real business practices. Practitioners perceive online negotiation as a useful option, but they usually have no confidence to do pure online negotiation especially when big risks related to their businesses are involved [Dai and Kauffman, 2001]. However, it is believed that greater efficiency can be achieved when more information to participants is provided in online transaction by information systems even if information provided is somewhat noisy [Barua et al., 1989]. If online negotiation facilitates a better information exchange mechanism, following which the participants may enjoy greater payoffs by sharing more information without damaging their own profits, pitfalls of online communication can be mitigated. Mechanism design in online auctions and e-marketplaces has been studied extensively. However, most previous studies on online negotiations focus on how to help negotiators to structure their decision procedures rather than how to design distinct mechanisms for online negotiations to encourage better information exchange.

This paper focuses on mechanism design for third-party NSS to support bilateral business negotiations among agents. In the next section, a literature review on economics models and mechanism design for negotiation is presented. Based on the existing studies, two new mechanisms, reserve price reporting mechanism (RPR) and extended reserve price reporting mechanism (ERPR), are proposed in the third section, following which the analytical models under the proposed mechanism are discussed in the fourth section. The fifth section discusses about an experiment designed to assess the proposed mechanisms. The results and discussions of the experiments are presented in the sixth section. And conclusions are finally drawn at the last section together with future work.

## **Literature Review**

There are three domains involved in studies on negotiations: psychology, economics and decision sciences. From psychological perspectives, agents' behaviors in negotiations are described in theoretical models which are usually tested with empirical evidence. From economics perspectives, negotiation and agents are represented by normalized analytical models, the results of which are trying to predict the agents' behavior as well as the negotiation's final solution. From decision science perspectives, negotiation and agents are examined in a pre-descriptive way. Proper decision processes and criteria are believed to help the agents get better off in negotiations. We will review the basic concepts of negotiations research before we focus mainly on the economic perspectives.

## ***Research Fundamentals***

Negotiation occurs when two or more parties encounter conflicts of interests, and try to influence others to reach a mutual agreement. [Lewicki et al. 1997] Since negotiators engage in the negotiation for their own interest, how much they can get from the negotiation is the most important factor influences their behaviors. A negotiator's gaining is usually referred to as his/her payoff. For the simplest case of price bargaining from economics perspectives, seller's payoff is the final price of dealing minus his/her cost and that of the buyer's will be his/her budget price minus the final dealing price.

To ensure minimum payoffs, negotiator always has a baseline, which means s/he can not bear any deal under this baseline. For example, negotiator as a seller will have a minimum price in mind, which is his lowest willingness to sell. This minimum price is the seller's baseline. And for the buyer the highest price s/he is willing to pay is his baseline. This baseline is referred to as reserve price (or reservation price) of buyer's (or seller's). When the buyer's reserve price is lower than the seller's reserve price, there is almost no chance of deal.

This kind of situation is referred to as negative bargaining zone. There are always bidding costs in each round of negotiation, which consist the spending of time, money and manpower. If a negotiator rejects an offering and drag the partner(s) as well as himself into another round, besides bidding cost, there will be also opportunity loss suffered by each party. Bidding cost and opportunity loss are referred to as back-dragging cost.

### ***Economical models for bilateral negotiation***

Economical models on negotiation are originated to explain people's behavior and predict the outcome by game theory [Neumann and Morgenstern, 1953]. People's behaviors in negotiations are usually modeled as players' strategies, which are indicated by sequences of bidding prices. Negotiators' payoffs are usually calculated by the differences of the dealing prices and their costs or reserve prices. Expected outcome of a negotiation is predicted by the equilibrium of a particular game. Sophisticated economical models of bilateral negotiations have been developed. For the circumstance that two parties bid in turn and both of them suffer a certain amount each round, both party's bidding strategy and final solution can be predicted by Rubinstein's model [Rubinstein, 1982]. Based on this model, there are further studies on one-sided incomplete information settings [Grossman and Perry, 1986] and two-sided information settings [Cramton, 1992].

Most economical negotiation models only consider one issue of price, since the price can always be generalized as a utility function in multi-issue negotiation problem according to utility theory. This simplification is necessary when we focus mainly on the bidding strategy and final outcomes. Contextual factors which influence the process of negotiation are usually studied in behavioral negotiation studies [Neale and Northcraft, 1991] and are beyond our economical approach. Therefore, without losing any generality, the price bargaining between a buyer and a seller is taken as the context of bilateral negotiation model in this study.

### ***Research on mechanism design for online negotiations***

Online negotiations can be conducted directly between participants by means of information technology such as emails, virtual meetings etc. However, third-party mediated online negotiations are considered as the most promising one. A third party may neutrally serve as a mediator or a host of e-marketplace. Buyers and sellers get together at this third-party website to negotiate with each other. This research focuses mainly on mechanism design for third-party negotiations.

Online negotiation can be classified according to the number of involved parties [Raiffa, 1982]. Two extreme cases are bilateral negotiations and auctions. Mechanisms for e-auctions are widely discussed. Most e-auction mechanisms are designed on the basis of existing auction mechanisms, such as English Auction or Vickery Auction. Trust and shill-bidding are among main issues to solve in terms of mechanism design [Wang et al, 2002]. However, there is little research on mechanism design focus on bilateral electronic negotiations. Existing NSS systems mostly try to imitate the traditional face-to-face (F2F) negotiations. The suggested benefits of using NSS mainly include helping negotiators to construct their interests and offering them some kind of post-transaction settlement [Bui and Shakun, 1996]. Although issues such as preference elicitation and conflict resolution have been studied extensively, very few studies employ mechanisms beyond the frame of traditional F2F negotiation. Specially designed negotiation mechanisms are indispensable for more effective online negotiations.

## **Mechanism Design for Online Negotiations**

### ***Reserve Price Reporting mechanism***

In F2F negotiations, revelation of reserve prices could be risky, since the other party will attain more negotiation power by capturing your baseline. However, without declaration of the reserve prices, a party might possibly waste the time and energy only to find out that it had been devoting itself in a negotiation actually with negative bargaining zone. Electronic third-parties have the advantages of neutrality and reliability compared to physical third-parties. And reporting reserve price to the electronic third-party could be less risky and avoid useless negotiation in negative bargaining zone.

We therefore proposed a Reserve Price Reporting mechanism (RPR mechanism) for bilateral business negotiation to increase efficiency in online negotiations. One thing to clarify here is that 'reserve price' here is not the same meaning as 'reserve price' in auction where usually reserve price is known to bidders. In reality, it is very exceptional in negotiation to announce reserve price of sellers or buyers because, if this is known to the opposite party, the party who release the information will be very disadvantageous in negotiation. Three steps are involved in RPR mechanism. 1) Potential sellers and buyers report their reserve offers to the mediation system. 2) the system checks whether there is positive bargaining zone between the pairs of buyers and sellers. If there is, then a negotiation session will be initialized. Otherwise the process terminates. 3) If a negotiation session begins, the buyer and the seller will bid in turn, until a proposal is accepted by both sides or at least one side quits. In our study, we focus on the negotiation on price, which may be generalized to multi-criteria cases when the utility of different issues can be calculated in one dimension.

### ***An example of negotiation under RPR***

We present an example of trading laptop computers to illustrate how the RPR mechanism works. Generally, either a seller or a buyer can be the initiator of a transaction. No matter which side starts, it is a symmetric situation concerning a starter and a follower. Without losing generality, we suppose some laptop computer providers first publish their product on the website, and a buyer comes and decide whether to start a negotiation with one of the sellers.

According to RPR mechanism, the providers should submit their reserve prices to the system together with other information related to their products. The reserve price is submitted but not presented to visitors other than the owner of this product. After viewing the product information, if the buyer is interested in the product of Company A, then he is required to give out his highest willingness to pay, which is not revealed to Company A. Let's say his highest willingness to pay is \$1000. The system, as a mediator, will then decide whether there is any chance of a final deal according to the reserve prices reported by both sides. If Company A's reserve price is higher than the buyer's, the system will notify them and the negotiation will not start since it is just only a waste of time for them to bargain with each other. Suppose Company A's reserve price is \$900. The buyer's willingness to pay is higher than Company A's reserve price, i.e. there is some positive bargaining zone between the two reported reserve prices, the system will consider there is chance of a final deal and let the two parties start to negotiate. Then there comes the third step. Company A give out its first bid \$1150. The buyer cannot accept this price, but he is aware that the lowest possible selling price is lower than his reserve price, \$1150. So he is still confident that he can make a deal with Company A and refuse the proposal and give out a counter bid of \$900. It is acceptable price for Company A, but the company wants to make more profit and also thinks the customer may accept a price higher than this. Accordingly, the company proposes \$970. The buyer likes this price and he does not want to take the trouble of continue bargaining. So he

accepts this price. If Company A does not make concession for several rounds, he may think of it not cooperative and quit the negotiation.

### ***Extended RPR Mechanism***

It is believed that Information Systems may facilitate efficiency by offering more information. Priceline.com offers some extra information when users bid. According to some pre-designed criteria, a message, “Your bid is too far from acceptable” will be presented. The bidder may increase the price if it is still affordable to him. This is a way to make the whole process quicker without revealing too much private information, such as reservation price etc.

Although there is trade-off in whether bid near or far from your baseline, people always tend to bid far from the baseline, especially at the early stage of negotiation, to ensure larger room to negotiate. This strategy, however, is not efficient in that the more room to negotiation the more time it will take and both sides may suffer more cost in terms of bidding and time. Therefore, we design a guiding mechanism during negotiations, which is similar to the message in Priceline.com. Before a bid is submitted, the user will have a chance to alter it with the system’s advice. For example, when the bidder decides to bid at \$800, he will firstly get the system’s advice. Since \$800 is lower than Company A’s reserve price and even lower than the middle point of their reserve prices. So the system will inform the bidder that this price is too low and a higher price may have more chance to be accepted. Given this information, the bidder may increase his bidding to get a quicker deal or he may not change the bid if he is not so eager to make a deal at the moment.

The guiding mechanism should be carefully designed, otherwise the bidder may find out the other’s reserve price by analyzing the system’s advices. Firstly, the advice must be given only once each time. And secondly, the criteria can be designed based on some random coefficients. More details will be presented in the fifth section.

## **Analytical Models**

### ***Basic Model***

In order to assess the proposed RPR mechanism, we study a simplified economics model in this section. Some basic assumptions on the negotiation process under RPR Mechanism are as follow:

#### *Assumptions*

In order to assess the proposed RPR mechanism, we study a simplified basic model in this section. Some basic assumptions on the negotiation process under RPR Mechanism are as following:

- A1. Two agents, a buyer and a seller, involve in a price bargaining. There is **positive bargaining zone**. A dealing price must be decided within the bargaining zone.
- A2. Each agent tries to maximize his/her own utility. Their payoffs can be calculated by the difference between dealing price and reserve prices.
- A3. Each agent’s preferences are private information but the probability distributions are uniform distributions, which is common knowledge.
- A4. Agents bid in turn. Without losing generality, suppose the seller is the first to bid. Each agent’s bidding price sequence is monotonic.
- A5. Time is precious. Failed to make a deal at a certain round will cost both agent a fixed amount of cost.
- A6. Each agent is risk averse. They would rather make an early deal than seek a later deal, even it is possibly a more profitable one.

### Payoff structure

Without losing generality, we study the seller's payoff structure. Suppose  $P_S(t)$  is the price proposed by the seller at time  $t$ . Seller's utility of  $P_S(t)$  is calculated by function  $U_S(P_S(t), t)$ , if buyer accepts  $P_S(t)$ . However, the buyer has two more options, one of which is to quit. If the buyer quit the negotiation, then the seller can only get  $U_S^0(t)$ , for his leaving the negotiation at time  $t$ . The third option of the buyer is to bargain. Suppose the buyer is not satisfied with the seller's proposed price, yet he/she is confident of making a better deal at a later time, he/she will choose to bargain which means  $P_S(t)$  is rejected and a new price  $P_B(t+1)$  is proposed by the buyer. The process will accordingly continue to a next round and it the seller's turn to make the decision of whether accept, quit or bargain. Seller's utility in the next round can be denoted by  $EU_S(t+1)$ .

Since the seller is not sure of whether the other party will accept or reject or bargain in response to its proposed price  $P_S(t)$ , we may adopt subjective probability to model the seller's belief on the buyer's reaction. Herewith, the seller's expected utility of price  $P_S(t)$  at time  $t$  is:

$$\begin{aligned} EU_S(P_S(t), t) &= U_S(P_S(t), t) \cdot \Pr(\text{buyer accepts}) + EU_S(t+1) \cdot \Pr(\text{buyer bargains}) \\ &\quad + U_S^0(t) \cdot \Pr(\text{buyer quits}) \\ \Pr(\text{buyer accepts}) + \Pr(\text{buyer bargains}) + \Pr(\text{buyer quits}) &= 1 \end{aligned} \quad (1)$$

According to A2 and A5, agent's utility of price  $P$  at time  $t$  can be calculated by the difference between dealing price and the reserve price minus the back dragging cost at time  $t$ . Thus the seller's utility function is  $U_S(P_S(t), t) = P_S(t) - R_S - (t-1) \cdot C_S$ . Since to quit the negotiation does not bring either parties anything good but the loss of all the cost already happened, the payoff of 'quit' option can be denoted as:  $U_S^0(t) = -(t-1) \cdot C_S$  and  $U_B^0(t) = -(t-1) \cdot C_B$ .

For the expected utility of next round, the best thing is a deal made at  $P_S(t)$  and the worst thing is the seller have to quit the negotiation. Therefore, we have  $-t \cdot C_S \leq EU_S(t+1) \leq P_S(t) - R_S - t \cdot C_S$ . Let  $\alpha$  be the coefficient of risk preferences, we have

$$EU_S(t+1) = (-t \cdot C_S) \cdot (1 - \alpha) + (P_S(t) - R_S - t \cdot C_S) \cdot \alpha = -t \cdot C_S + (P_S(t) - R_S) \cdot \alpha, (0 \leq \alpha \leq 1).$$

. As totally risk averse agents in A6,  $\alpha$  here is supposed to be 0. Therefore, the utility function is

$$\begin{aligned} EU_S(P_S(t), t) &= U_S(P_S(t), t) \cdot \Pr(\text{buyer accepts}) + EU_S(t+1) \cdot \Pr(\text{buyer bargains}) \\ &\quad + U_S^0(t) \cdot \Pr(\text{buyer quits}) \\ &= (P_S(t) - R_S - (t-1) \cdot C_S) \cdot \Pr(\text{buyer accepts}) - t \cdot C_S \cdot \Pr(\text{buyer bargains}) \\ &\quad - (t-1) \cdot C_S \cdot \Pr(\text{buyer quits}) \\ &= -(t-1)C_S + (P_S(t) - R_S) \cdot \Pr(\text{buyer accepts}) - C_S \cdot \Pr(\text{buyer bargains}) \end{aligned} \quad (2)$$

### Bidding strategy

In economics models, subjects are supposed to maximize their utility. That is:

$$\begin{aligned} \text{Max}_{P_S(t)} EU_S(P_S(t), t) &= -(t-1)C_S + \text{Max}_{P_S(t)} [(P_S(t) - R_S) \cdot \Pr(\text{buyer accepts}) \\ &\quad - C_S \cdot \Pr(\text{buyer bargains})] \end{aligned} \quad (3)$$

The fundamental trade-off of our model is accord with that in general bargaining situation. If a higher  $P_S(t)$  is proposed, the seller may possibly get higher profit, however, the possibility of buyer's acceptance could be lower.

Given the seller's proposed price  $P_S(t)$ , the buyer will choose an action which makes him better off according to his payoff structure:

$$\begin{cases} U_B(P_S(t), t) & , \text{accept} \\ EU_B(P_B(t+1), t+1) & , \text{bargain} \\ U_B^0(t) & , \text{quit} \end{cases} \quad (4)$$

Based on the model proposed above, we will study truth revelation and efficiency of the RPR mechanism in the following part of this section.

### ***Truth revelation***

Whether the reported reserve prices are the same with the actual ones is crucial to the performance of RPR mechanism. We therefore study the agents' strategies and possible equilibriums and then prove truth revelation under the risk-averse situation.

### ***One-round bidding***

In the context of one-round bidding, only one round is made. Each side bids only once. If the bidding price of one side is acceptable to the other side, deal is made at this bidding price. Otherwise, the negotiation breaks down. Suppose all the bidding prices are in the range  $[P_{\min}, P_{\max}]$ . Seller knows  $P_{\max}$  and buyer knows  $P_{\min}$ . Since RPR guarantee positive bargaining zone and both sides are rational, we may suppose probability of quit the negotiation is almost zero. And condition of acceptance is seller's bid is no less than buyer's reserve price. According to (3), in order to maximize his expected utility, the seller's bidding price  $P_S$  should satisfy:

$$\begin{aligned} \max_{P_S} EU_S(P_S) &= (P_S - R_S) \cdot \Pr(R_B \geq P_S) - C_S \cdot \Pr(R_B < P_S) \\ &= (P_S - R_S) \cdot \int_{P_S}^{P_{\max}} f_B(R_B) dR_B - C_S \cdot \int_{R_S}^{P_S} f_B(R_B) dR_B \\ &= (P_S - R_S) \cdot \frac{P_{\max} - P_S}{P_{\max} - R_S} - C_S \cdot \frac{P_S - R_S}{P_{\max} - R_S} \end{aligned} \quad (5)$$

$$P_S = \frac{P_{\max} + R_S - C_S}{2} \quad (6)$$

Chance of dealing is the value of the probability that seller's bidding price is greater than or equal to the buyer's reservation price, i.e.

$$\begin{aligned} \Pr(\text{dealing at first round}) &= \Pr(R_B \geq P_S) = \frac{P_{\max} - P_S}{P_{\max} - R_S} \\ &= \frac{P_{\max} - \frac{P_{\max} + R_S - C_S}{2}}{P_{\max} - R_S} \\ &= \frac{P_{\max} - R_S + C_S}{2(P_{\max} - R_S)} \end{aligned} \quad (7)$$

Similarly we may have the buyer's bidding price and chance of dealing if the buyer has the chance to make a counter offer.

$$P_B = \frac{P_{\min} + R_B + C_B}{2} \quad (8)$$

$$\begin{aligned}
 \Pr(\text{dealing at second round}) &= (1 - \Pr(R_B \geq P_S)) \cdot \Pr(R_S \leq P_B) \\
 &= \frac{P_B - P_{\min}}{R_B - P_{\min}} \cdot \frac{\frac{P_{\min} + R_B + C_B}{2} - P_{\min}}{R_B - P_{\min}} \\
 &= \frac{R_B - P_{\min} + C_B}{2(R_B - P_{\min})}
 \end{aligned} \tag{9}$$

### *Equilibrium for risk-averse agents*

Risk-averse agents perceive minimized expected utility on future rounds on condition that no deal is made in the current round. Therefore, if the proposed price of the seller is considered as maximum possible dealing price  $P_{\max}$ , and that of the buyer is considered as minimum possible dealing price  $P_{\min}$ , then the situation is no difference with one-shot bidding within one round. Pricing strategy of the seller and the buyer at time  $t$ , ( $t \geq 1$ ) can be induced from the previous section:

$$P_S(t) = \frac{R_S + P_S(t-1) - C_S}{2} \tag{10}$$

$$P_B(t) = \frac{R_B + P_B(t-1) + C_B}{2} \tag{11}$$

If the first bidding prices are known, the recursive expression of bidding strategy can be solved as dependent variable of first bidding prices and time  $t$ :

$$P_S^*(t) = \frac{1}{2^t} P_{\max} + (R_S - C_S) \left(1 - \frac{1}{2^t}\right) \tag{12}$$

$$P_B^*(t) = \frac{1}{2^t} P_{\min} + (R_B + C_B) \left(1 - \frac{1}{2^t}\right) \tag{13}$$

With reserve-price-dealing rule, seller will accept any offer which is higher or equal to its reserve price and buyer will accept offer which is lower or equal to its reserve price. According to the proposed mechanism, the final dealing price can be proposed by either the seller or the buyer. Suppose there are equal chances for these two cases:

$$\begin{aligned}
 EP^*(t) &= P_S^*(t) \cdot \Pr(\text{Buyer proposes the final dealing price}) \\
 &\quad + P_B^*(t) \cdot \Pr(\text{Buyer proposes the final dealing price}) \\
 &= \frac{R_S + P_S^*(t-1) - C_S}{2} \cdot \frac{1}{2} + \frac{R_B + P_B^*(t-1) + C_B}{2} \cdot \frac{1}{2}
 \end{aligned} \tag{14}$$

Suppose the extreme case when the bargaining zone is so small that maximum turns are needed before a price in the range of reserve prices is proposed by one side. In this case, deal is made when  $t \rightarrow \infty$ , and we can assume  $P^*(t) \approx P^*(t-1)$ . If substitute this into (14), we may get:

$$EP^*(t) = \frac{R_S + R_B - C_S + C_B}{2} \tag{15}$$

If the chance of seller proposing the final dealing price is  $\alpha$ , and buyer proposing is  $1 - \alpha$ , then the expected dealing price can be:  $EP^*(t) = (R_S - C_S) \cdot \alpha + (R_B + C_B) \cdot (1 - \alpha)$

If the back-dragging costs are the same with the two sides, the expected dealing price under the given mechanism is accord with the ‘‘fair’’ allocation rule in common system-mediated mechanisms. i.e. Divide the cake half and half.

*Proof of truth revelation*

According to (15), if truthfully reporting the reserve prices, the seller's expected utility is:

$$\begin{aligned} EU_S^T &= (EP^* - R_S) \cdot \Pr(\text{positive bargaining zone}) - C_S \cdot \Pr(\text{negative bargaining zone}) \\ &= \left( \frac{R_S + R_B - C_S + C_B}{2} - R_S \right) \cdot \frac{P_{\max} - R_S}{P_{\max} - P_{\min}} - C_S \cdot \frac{R_S - P_{\min}}{P_{\max} - P_{\min}} \end{aligned} \quad (16)$$

If falsely reporting the reserve prices by increase the reserve price  $\Delta R_S > 0$ , the seller's expected utility is:

$$EU_S^F = \left( \frac{(R_S + \Delta R_S) + R_B - C_S + C_B}{2} - R_S \right) \cdot \frac{P_{\max} - (R_S + \Delta R_S)}{P_{\max} - P_{\min}} - C_S \cdot \frac{(R_S + \Delta R_S) - P_{\min}}{P_{\max} - P_{\min}} \quad (17)$$

Comparing the expected utility:

$$EU_S^T - EU_S^F = \frac{\Delta R_S^2 + (R_B + C_B + C_S - P_{\max}) \cdot \Delta R_S}{2(P_{\max} - P_{\min})} \quad (18)$$

Therefore, if buyer's back-dragging cost is large enough to satisfy  $C_B + C_S \geq P_{\max} - R_B$  (i.e.  $R_B + C_B + C_S - P_{\max} \geq 0$ ), then there is no need for seller to fake reporting his reserve price (as shown in figure 1), since (18) will always greater than zero, which means truth-telling may bring more expected utility to the seller.

If  $C_B + C_S < P_{\max} - R_B$  (as the dashed curve in Figure 1.), when seller increases his reserve price by  $\Delta R_S = \frac{P_{\max} - R_B - C_B - C_S}{2}$ , he will get maximum expected utility. When the seller make the decision of whether to tell the truth, he/she does not know the buyer's exact reserve price, which is needed in evaluating whether truth telling is more profitable. The expected value of the buyer's reserve price, however, can be estimated by  $ER_B = \frac{P_{\max} + P_{\min}}{2}$  according to A3. And the truth telling decision condition will be  $C_B + C_S \geq \frac{P_{\max} - P_{\min}}{2}$ . If this condition is not held, then the seller will fake report their reservation price by  $\Delta R_S = \frac{P_{\max} - P_{\min} - C_B - C_S}{2}$ . The higher the sum of back-dragging cost, the less will be the faked report amount.

Similarly, we may infer that the buyer will also have incentive to tell the truth on this condition and the fake report amount will be  $\Delta R_B = \frac{P_{\max} - P_{\min} - C_B - C_S}{2}$ , if this condition is not hold. Therefore, we have our first proposition:

**Proposition 1:** *If the sum of the buyer's and the seller's back-dragging cost is no less than half of the difference between the maximum price and minimum price, then both sides will report their true reserve prices. And both sides will be more honest if the sum of back-dragging cost is relatively higher.*

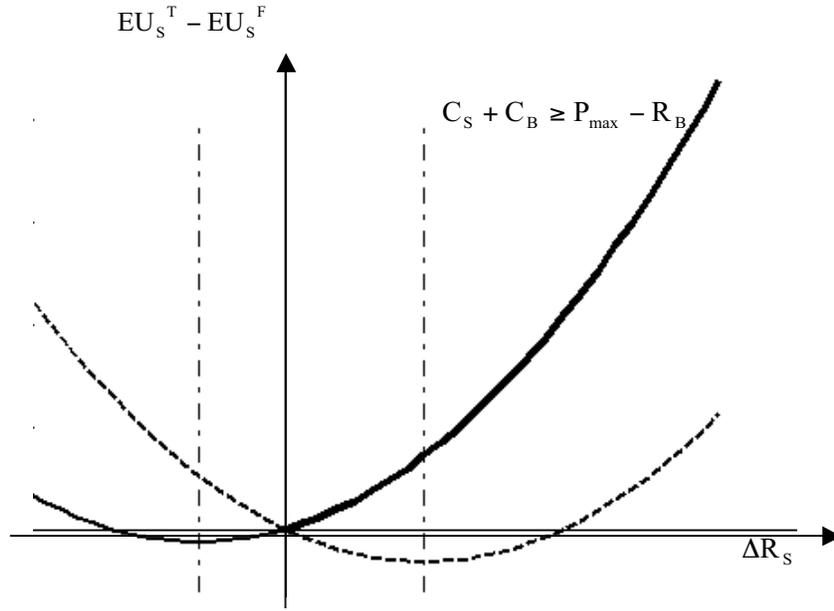


Figure 1. Difference on expected utility

### *Increasing social welfare*

RPR mechanism is superior to traditional bargaining mechanism, in that it may increase the chance of dealing by ensuring positive bargaining zone before the negotiation starts. And total social welfare is also expected to increase, by decreasing total back-dragging cost.

### *Reduce the expected number of rounds*

RPR mechanism may increase the chance of dealing, because 1) Terminate the negotiation process before the very first round, if there is negative bargaining zone; 2) Facilitate trust among agents by insure them that there is positive bargaining zone and the other side has truth-telling incentives. We will then discuss the case of free bargaining and compare it with the situation under RPR mechanism.

Without the dealing guarantee in RPR, besides acceptance and rejection, even for rational agents, there is a third possibility of quit (i.e. negotiation terminates without further communications) in free bargaining. Expected utility function in the context of free bargaining is as shown in the following function. In the case of one-round bidding, we have

$$\begin{aligned}
 \max_{P_S} EU_S(P_S) &= (P_S - R_S) \cdot \Pr(R_B \geq P_S) - C_S \cdot \Pr(R_S \leq R_B < P_S) + U_S^0 \cdot \Pr(R_B < R_S) \\
 &= (P_S - R_S) \cdot \int_{P_S}^{P_{\max}} f_B(R_B) dR_B - C_S \cdot \int_{R_S}^{P_S} f_B(R_B) dR_B + U_S^0 \cdot \int_{P_{\min}}^{R_S} f_B(R_B) dR_B \\
 &= (P_S - R_S) \cdot \frac{P_{\max} - P_S}{P_{\max} - P_{\min}} - C_S \cdot \frac{P_S - R_S}{P_{\max} - P_{\min}} + U_S^0 \cdot \frac{R_S - P_{\min}}{P_{\max} - P_{\min}} \\
 P_S &= \frac{P_{\max} + R_S - C_S}{2}
 \end{aligned} \tag{19}$$

$$\tag{20}$$

We can see the pricing strategy is no difference with the under RPR mechanism. However, chance of dealing is different from that under the RPR mechanism:

$$\begin{aligned} \Pr_{\text{FREE}}(\text{dealing at first round}) &= \Pr(R_B \geq P_S) = \frac{P_{\max} - P_S}{P_{\max} - P_{\min}} \\ &= \frac{P_{\max} - R_S + C_S}{2(P_{\max} - P_{\min})} \end{aligned} \quad (21)$$

Suppose the possible range of dealing prices  $[P_{\min}, P_{\max}]$  and the back-dragging costs are same in free bargain and RPR, we may compare this with (7):

$$\begin{cases} \Pr_{\text{FREE}}(\text{dealing at first round}) \leq \Pr_{\text{RPR}}(\text{dealing at first round}) & , P_{\min} \leq R_S \\ \Pr_{\text{FREE}}(\text{dealing at first round}) > \Pr_{\text{RPR}}(\text{dealing at first round}) & , P_{\min} > R_S \end{cases} \quad (22)$$

This shows that when conflict is low (i.e.  $P_{\min} > R_S$ ), free bargains have higher probability of dealing at first round; when conflict is high (i.e.  $P_{\min} \leq R_S$ ), bargains under RPR have higher probability of dealing at first round. Similarly, probability of dealing at later rounds is higher under RPR mechanism than free bargain respectively on condition that conflict is relatively high.

Therefore, comparing with free bargaining, RPR mechanism facilitates higher chance of dealing. And at the same time expected payoff of the agent under RPR mechanism are no lower than that under free bargaining, since the pricing strategy is almost the same in the two cases. Therefore, to some extent we may conclude that the RPR mechanism has incentive capability for rational agents.

Expected number of rounds before dealing  $Et^*$  can be calculated by the sum of probability of dealing at each round manipulated the number of round:

$$Et^* = \sum_{t=1}^{\infty} t \cdot \Pr(\text{dealing at } t) \quad (23)$$

As we have already proved previously, chance of dealing in each round is increased under the RPR mechanism. Therefore, total expected rounds will decrease accordingly.

**Proposition 2:** *When buyer and seller's reserve prices are within the range of the minimum price and the maximum price, negotiations under RPR mechanism will have fewer rounds than those under TDB mechanism.*

#### Overall increase in return

According to our assumptions, in a certain round the situation of bargaining under RPR mechanism can be considered as a zero-sum game, in which one side's gaining is the other side's lost. However, from the view of the whole negotiation process, if a deal is not made in a certain round, both sides will suffer some amount of back-dragging cost.

$$\begin{aligned} U_{\text{social}} &= U_S + U_B = (P^* - R_S - C_S \cdot Et^*) + (R_S - P^* - C_B \cdot Et^*) \\ &= -(C_S + C_B) \cdot Et^* \end{aligned} \quad (24)$$

It has been proved that  $Et^*$  is decreased under RPR mechanism. Therefore, we expect an average increase in terms of social welfare.

RPR mechanism facilitates an overall increase in return, because: 1) Eliminate occasions of negative bargaining zone which will definitely lead to no deal; 2) Reserve-price dealing rule help agents save time, since any quote between reserve prices will end the negotiation and further rounds are eliminated.

#### The ERPR mechanism

Given the guidance such as 'your bid is good' or 'your bid is not reasonable', the agents may alter their bids before submission. According to A4 and A5, after viewing the system's guidance, the seller will lower his price or not change the bid and the buyer will higher his

price or not change it. Suppose the seller will alter his bid by  $\Delta P_s$  ( $\Delta P_s \leq 0$ ), the bidding price of the seller's will be  $P_s + \Delta P_s$ . If substitute the new bidding price into (7),

$$\Pr_{\text{ERPR}}(\text{dealing at first round}) = \frac{P_{\max} - R_s + C_s - 2\Delta P_s}{2(P_{\max} - R_s)}. \text{ Since } \Delta P_s \text{ is no greater than zero. We}$$

have  $\Pr_{\text{ERPR}}(\text{dealing at first round}) \geq \Pr_{\text{RPR}}(\text{dealing at first round})$ . Similar to previous discussion, we may conclude that negotiations under ERPR mechanisms have fewer expected rounds than those under RPR mechanisms since the chance of acceptance is greater in each round under ERPR mechanisms.

**Proposition 3:** *With extended information on their bids, buyer and seller tend to make greater concession and the rounds will be fewer under ERPR mechanism than under the RPR mechanism*

### Experimental Design

We conduct an experiment to test the effectiveness of TDB, RPR, and ERPR mechanisms in a controlled negotiation context. Combinations of buyer/seller's reserve prices and back-dragging costs are designed to prove the three propositions in our analytical model.

#### *A prototype NSS*

We develop a prototype NSS for the experiments. This system should 1) generate experimental negotiation sessions; 2) support TDB (traditional bargaining), RPR and ERPR mechanism; 3) randomly assign buyers and sellers to one negotiation session. Subjects who participate in the experiment are asked to login the NSS. Then the system matches negotiation pairs and report their reserve prices to the subjects. The system is designed as a three layered B/S based architecture. Persistent data entities, process handlers, and interface presentations are dependent, so that further modification of the system would be relatively easy. We implemented the system using a java framework, which has been used in several other applications and is proved to be reliable.

#### *Methodology*

We adopt the scenario of trading laptop computers as presented in the third section. Subjects are randomly assigned to the roles of buyer and seller using the prototype NSS. There are 3 types of NSS mechanism. First, TDB (Traditional Direct Bargaining) mechanism leads negotiators to take turns to bid through the website. Second, RPR mechanism informs subjects of their reserve prices. Then, subjects are asked to report their true reserve price to the system. We warn the subjects that reporting false reserve price may cause a failure to start a negotiation session. Third, ERPR mechanism extends RPR mechanism in that it provides negotiators with advice on their biddings besides reporting their reserve price to the system. That is, negotiators get advices from the system regarding their biddings before the biddings are actually delivered to the negotiation partner. Therefore, negotiators have one chance to alter their biddings before it is delivered to the negotiation partner.

We generate four negotiation sessions for each subject. The first two sessions are practice sessions for subjects to get familiar with the operation of the website. The other two sessions are real experiments and the final reward is calculated based on the results of these two sessions. The first session of the real experiment is a high back dragging cost condition (4% of the size of bargaining zone for seller and buyer each) and the other is low back-dragging cost condition (1% of the size of bargaining zone). A negotiator does not know who his or her negotiation partner is. Only a three digit user ID is revealed to the negotiation partner.

Experimenters explain the process to subjects. Then we let the subjects bid with their partner using website. Based on their profits from their regular sessions, participants were rewarded with cash after the experiment.

## Results and Discussions

Table 1 summarizes the bidding records as well as the final results of each negotiation session. Since the payoff structures are not the same, we normalize all records to make them comparable. Table 1 reports success rate, average rounds, and average profit in three mechanisms. Negotiators had positive bargaining zone, therefore they had possibility of reaching an agreement. In all three mechanisms, however, there are some negotiators who could not reach an agreement. We discuss our results in terms of total rounds, truth revelation, and fairness in this section.

**Table 1. Summary of the results**

	TDB	RPR	ERPR
<b>Total number of Sessions</b>	<b>38</b>	<b>53</b>	<b>32</b>
<b>Success rate</b>	<b>0.97</b>	<b>0.91</b>	<b>0.88</b>
<b>Successful sessions</b>			
<b>Number</b>	<b>37</b>	<b>48</b>	<b>28</b>
<b>Average rounds</b>	<b>4.0</b>	<b>3.1</b>	<b>2.4</b>
<b>Average total profit</b>	<b>92.32</b>	<b>92.91</b>	<b>96.04</b>
<b>Failed sessions</b>			
<b>Number</b>	<b>1</b>	<b>5</b>	<b>4</b>
<b>Average rounds</b>	<b>5.0</b>	<b>3.4</b>	<b>1.3</b>
<b>Average total profit</b>	<b>-18.00</b>	<b>-5.00</b>	<b>-2.00</b>

### *Total rounds and social welfare*

Generally speaking, less number of rounds and more total profits represent efficient negotiation sessions. Since there is only one distributive issue of price in our experiment, total profits can be calculated by zero minus total back-dragging cost. In addition, we compare three mechanisms (TDB, RPR and ERPR) by total rounds in successful sessions, since fewer rounds bring more social welfare.

Planned contrasts can be used to determine whether RPR and ERPR mechanisms shorten the number of rounds compared with TDB mechanism (proposition 2) (Keppel, 1982). Planned contrast test indicates that RPR and ERPR mechanisms lead negotiators to reach an agreement faster than did TDB mechanism ( $t=2.488$ ,  $p < .01$ ). This is consistent with the proposition 2 of our analytical model. Compared with TDB, that is, RPR and ERPR are effective to reduce the number of total rounds.

To test proposition 3 (RPR vs. ERPR), t- test is used. ERPR engender less number of negotiation rounds than does RPR (ERPR 2.4 vs. RPR 3.1,  $t=1.44$ ,  $p<.10$ ). Therefore, proposition 3 is marginally supported.

### *Truth revelation*

The truth revelation condition in proposition 1 is empirically supported by our experiment. In our experiment, the extent of truth revelation is calculated by the average deviation ratio as in table 2. The average deviation ratio of seller is positive when the reporting price is higher than their actual cost of item while that of buyer is positive when the reporting price is lower than their true willingness to pay. We find that the average deviation ratio of reporting price with high back-dragging cost (24.5%) is higher than that with low back dragging cost (18.5%) ( $t=2.10$ ,  $p < .05$ ). Therefore, proposition 1 is supported. This result suggests that mechanism designers should increase back-dragging costs with careful estimation to induce truth revelation of true value of negotiation items of sellers and buyers.

Table 2. Truth revelation

Data	High back-dragging cost	Low back-dragging cost
Success Sessions	82	88
AverageRatio	0.245	0.185
SD	0.24	0.14
t	2.10 (p < .05)	

### ***Fairness***

In our experiment, sellers are asked to bid first and buyers are asked to bid following the sellers' initial offers. For TDB and RPR groups, there are no differences of payoffs between initiators (sellers) and followers (buyers). In an ERPR mechanism, however, the buyers' payoffs are much higher than sellers' (average payoff of buyer: seller=61.9: 34.2) ( $t=5.081$ ,  $p < .001$ ). This is an interesting result we have not expected in our analytical model. With the examination of subjects' bidding behaviors, we find that the information given in ERPR sessions affect the sellers' starting bids much less aggressive and this makes the starting point and final point of negotiation much higher. For this part, further study should investigate the way to reduce the unfairness resulted from more information given in ERPR mechanism.

### **Conclusions**

Two mechanisms are proposed to support online negotiations. Both mechanisms are designed based on the reserve price reporting mechanism. In RPR mechanism, negotiators should report their reserve price to the NSS system at the start of a negotiation and they can start a negotiation only when there is a positive bargaining zone detected by the NSS system. ERPR mechanism provides negotiators with the information on how far a bid is from acceptable range before a negotiator's bid is delivered to the negotiation partner. An analytical model is developed to find the equilibrium points and access the performance of the mechanisms. Under the assumption of uniformly distributed reserve prices and risk aversion, the agents are proved to have incentives to reveal their actual reserve price to the system. If the agents do not reveal the truth, more back-dragging costs rather than less back-dragging costs will reduce the ratio of dishonesty. In terms of increase in social welfare, it is expected that RPR mechanism is more efficient than traditional free bargaining and ERPR mechanism is more efficient than RPR mechanism.

In our lab experiment, the efficiency of three mechanisms is found to be ordered as we expected in our analytical study. Also, the higher back-dragging costs make both sides be honest as expected. In fairness test which is not considered in our analytical model, an interesting phenomenon is found that ERPR mechanism is more favorable to followers rather than initiators. This result, however, does not hold in RPR mechanism. This may be interpreted as a problem of providing more information in ERPR than in RPR.

Generally speaking, we conclude that reserve price reporting mechanism will help the negotiators to achieve better performance than traditional ones. The design of the online negotiation mechanism as well as the online negotiation website is valid for distributive negotiation situations. However, the assumptions of the analytical model need to be relaxed to represent more general cases, such as arbitrary reserve price distribution cases and risk neutral or risk seeking cases. Also, further experiments on fairness and truth revelation with different conditions are expected to reveal more detailed suggestions on the design of negotiation supporting systems.

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