

Price formation in a sequential selling mechanism*

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Abstract

This paper studies a dynamic trade institution, where an auction is combined with a “Buy-It-Now” option. This option presents a take-it-or-leave-it price offered by the seller to a potential bidder before the auction. If the buyer rejects this buyout price, the object is auctioned off. In equilibrium, sales should only take place in the auction. An experimental test reveals that average buyout prices and profits are well captured by the theoretical prediction. However, a substantial amount of sales takes place before the auction. This is caused by offering (too) low or accepting (too) high buyout prices. We discuss alternative explanations, as risk preferences and (wrong) formation of beliefs that might account for agents’ behavior.

Keywords: Auction, bargaining, sequential mechanism, risk preferences, experiment.

JEL: C72, C91, D44, D82.

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1 Introduction

Traditionally, bargaining and fixed price trading have been analyzed separately from auctions. More recently, attention has been directed to the analysis of strategic interaction in hybrid environments combining auctions and negotiations. One example of such a hybrid environment is a seller who negotiates the sale of a good with a small number of buyers, before, in case of disagreement, auctioning off the good to a broader set of agents. Such a sequential mechanism is the focus of the current paper.

One of the reasons for the growing interest in combined mechanisms is their increasing use by successful internet auction sites like eBay, Yahoo, and Amazon.¹ Those internet platforms employ a selling mechanism where a call for bids in an auction is combined with a take-it-or-leave-it price offer.² For example, at Yahoo and Amazon, sellers have the possibility to offer their products throughout the auction at a permanent buyout price. At eBay, a seller may announce a temporary buyout price, the so called Buy-It-Now price, additionally to the call for bids. Once a buyer accepts the Buy-It-Now offer, the sale is concluded at this price. Otherwise, a buyer can start the auction by submitting a bid, in which case the buyout price disappears and the final price is determined by the auction. Shortly after the introduction of the Buy-It-Now option in November 2000, eBay reported that 30%, 35% and even 45% (eBay Q1, Q2 and Q4 2001) of all listings in eBay auctions included a Buy-It-Now option. Similar figures have been reported by Reynolds and Wooders (2006) who observe 40% of auctions with a Buy-It-Now offer. The economic relevance of such hybrid mechanisms is reflected in the volume of transactions. eBay, for example, reported that fixed price trades on their sites comprised 4.4 billion USD in the first half of 2004 translating to 28% of the total Gross Merchandize Volume.³

Early theoretical analysis fails to explain these observations. For example, Bulow and Klemperer (1996) hypothesize that "... if a seller could negotiate with N bidders while maintaining the right to subsequently hold an English auction without a reserve price and with an additional bidder, the seller would always do better to proceed directly to the auction." (page 182), a conjecture in clear contrast to the behavior observed in reality.⁴

More recently, Kirkegaard (2004) reconsiders the results by Bulow and Klemperer and shows that the English auction can be improved by negotiations prior to the auction if buyers are asymmetric or the marginal revenue is non-monotonic. Mathews (2004) shows that

¹<http://www.ebay.com>; <http://www.yahoo.com>; <http://www.amazon.com>

²A take-it-or-leave-it price offer, also known as ultimatum bargaining, constitutes one of the simplest of all bargaining procedures (Binmore, 1992, p.197). In the literature on combined mechanisms such a price offer is often referred to as "Buy-It-Now price" (as on eBay), "buyout price" or "buy price." We will use these terms interchangeably.

³Two selling formats on eBay lead to a fixed price trade – an auction with a Buy-It-Now price or a pure fixed price (the item is listed at a set price and bidding is not possible). According to eBay, acceptance of the Buy-It-Now price before an auction is the primary contributor to the fixed price trades.

⁴See Kirkegaard (2006) for a general proof.

the probability of successful settlements using the buyout option increases with the impatience of either sellers or buyers. eBay, for example, indicates that the average auction duration decreased by almost 10% which, according to eBay, is due to an increased use of the Buy-It-Now option (eBay, Q4 2002). This provides some evidence, although not conclusive, supporting the impatience hypothesis.

Risk preferences can also account for the success of the buyout option. For example, Reynolds and Wooders (2006) compare eBay and Yahoo auctions where a buyout price is offered to all buyers, simultaneously. They show that the riskiness of the auction as an outside option can contrive risk averse buyers to accept buyout prices that are higher than the expected price from the auction. Alternatively, Mathews and Katzman (2006) demonstrate that risk averse sellers prefer an agreement at the buy price by asking for lower prices than those expected from the auction. Budish and Takeyama (2001) look at Yahoo and Amazon auctions and show that risk neutral sellers can increase their profits by offering a permanent buy price during the auction to risk averse buyers. Likewise, Hidvégi, Wang and Whinston (2006) consider permanent buy prices allowing for risk aversion of both, sellers and buyers. They show that properly set buy prices increase social welfare and expected utility of all agents.

In this study, we focus on auctions with a temporary buyout price such as, for example, used on eBay. In those auctions, buyers arrive at different points in time and there is always a “decisive buyer” who will either accept the buyout price or start the auction by submitting a bid. In the latter case, the buyout price disappears, hence buyers arriving later are not informed about the rejected price offer. They can only participate in the auction.⁵ Therefore, in contrast to the literature mentioned above, we propose to treat buyers asymmetrically. More precisely, we consider a two-stage mechanism, where the seller offers a buyout price to only one of the buyers. If this buyer rejects, a second-price sealed-bid auction with additional buyers takes place. We test experimentally whether actual behavior in a controlled environment exhibits similar qualitative properties as the theoretical prediction: All sales will take place in the auction, since sellers will post buyout prices that are too high to be accepted.

There are some empirical and experimental papers studying the Buy-It-Now option on eBay. However, these papers are examining this issue in contexts quite different than we are concerned with here. For example, Anderson, Friedman, Milam and Singh (2004) collect transactions data from auctions conducted on eBay and study the impact of the characteristics of the seller, the good, and the transaction on seller’s choice of selling format. Using a field experiment, Durham, Roelofs and Standifird (2004) look at the impact of buyer reputation, seller reputation, and the magnitude of the Buy-It-Now price on buyer behavior.

⁵Note that this combined procedure resembles the situation considered by Bulow and Klemperer (1996): A seller can make a take-it-or-leave-it offer to a buyer who might either accept or reject the offer. In the latter case, a second buyer joins and a second-price auction takes place. (Section II.C “Negotiations followed by an auction,” page 189.)

Our point of concern is to understand why such dynamic trade forms exist at the first place. Therefore, we test the theoretical prediction in an environment controlling for valuations of buyers and sellers as well as for the private value character of the good for sale.

Our experimental results show that average prices and profits are well described by the theoretical prediction. However, we observe a substantial amount of sales at the buyout price and a substantial portion of buyout prices well below the theoretical prediction. Our experimental design excludes time preferences as an explanation for the observed behavior. Therefore, we investigate whether and to which extent risk preferences can help to resolve the puzzle. The literature on buyout options so far has investigated the role of risk aversion either for permanent buyout prices (Hidvégi, Wang and Whinston, 2006) or in the case of temporary buyout prices only for one market side (Mathews and Katzman, 2006, and Reynolds and Wooders, 2006). We study outcomes of auctions with temporary buyout prices allowing for risk aversion on both market sides.

We show that by relaxing the assumption of risk neutrality for both, sellers and buyers, successful sales at the buyout price can occur in equilibrium. Using existing population estimates of risk preferences we provide quantitative predictions for the distribution of sellers' buyout prices. We find that including risk preferences can only partly account for agents' behavior: It improves the fit for buyers, but is not sufficient to explain sellers' deviations from equilibrium buyout prices. More than one third of all observed buyout prices lie outside the predicted price range indicating systematically under- and overpricing. Therefore, we discuss the role of belief formation and learning in order to understand and to explain agents' decisions.

The remainder of the paper is organized as follows. Section 2 introduces the model and benchmark predictions. The experimental design and procedure are presented in section 3. Section 4 contains the analysis of the experimental results. In section 5 we investigate whether and to what extent incorporating risk attitudes into the model can explain our experimental data. In section 6 we discuss alternative behavioral concepts. Section 7 concludes.

2 Theoretical Background: Model and Predictions

We consider a situation where a seller offers a single indivisible object for sale to n potential buyers.⁶ The seller's valuation is common knowledge and, for simplicity, normalized to zero. Buyers' valuations for the good, v_i with $i = 1, \dots, n$, are independent random variables and private information. The seller announces a take-it-or-leave-it offer, i.e., a buyout price p , to one randomly selected buyer, whom we will refer to as "buyer 1." If the offer is accepted, the sale takes place at this price. If it is rejected, a second-price sealed-bid auction without a reserve price and with all n buyers is conducted. In this case, buyers place their

⁶We thank René Kirkegaard and an anonymous referee for suggestions in this section.

bids simultaneously. The bidder who submits the highest bid is awarded the object and pays a price equal to the second highest bid. The other bidders have zero payoffs.

The question arises whether the seller might benefit from the buyout option in the combined mechanism. In case of symmetric bidders and continuous valuations, a pure second-price auction without reserve price is optimal, i.e., maximizes the seller's revenue, subject to the constraint that the good is sold with probability one. In a second-price auction, every bidder truthfully reveals his private valuation. Hence, the object will always be allocated to the buyer with the highest value. If the combined mechanism leads to the same allocation of the good and agents are risk neutral, it will yield the same expected revenue to the seller (Myerson, 1981). In the combined mechanism, however, there is a positive probability that buyer 1 receives the object regardless whether he has the highest value or not. This implies that the second-price auction without reserve price and the combined mechanism are not revenue equivalent. Since the second-price auction is optimal, the seller prefers in any case to sell in the auction.

More precisely, the interaction between seller and buyer 1 before the auction is limited to offering a take-it-or-leave-it price and the reaction to it. Buyer 1 will accept the buyout price if his payoff is at least as good as the expected payoff from participating in the auction. That is

$$v_1 - p \geq \left(v_1 - \mathbf{E}[V^{(2)} | \max_{j \neq 1} V_j < v_1] \right) \Pr(\max_{j \neq 1} V_j < v_1) \quad (1)$$

where j denotes one of the $\{2, \dots, n\}$ bidders, v_1 buyer 1's valuation, $V^{(2)}$ the second highest valuation of all bidders, $\Pr(v_1 > \max_{j \neq 1} V_j)$ the probability that buyer 1 has the highest valuation of all bidders and $\mathbf{E}[\cdot]$ is the expectation operator. This means that buyer 1 will only accept prices p which are smaller or equal to a threshold price $\tilde{p}(v_1)$ satisfying:

$$p \leq \tilde{p}(v_1) = \mathbf{E}[V^{(2)} | \max_{j \neq 1} V_j < v_1] \Pr(\max_{j \neq 1} V_j < v_1) + v_1 \cdot (1 - \Pr(\max_{j \neq 1} V_j < v_1)). \quad (2)$$

Accordingly, a threshold value, $\tilde{v}(p)$, can be derived for each price offer p . If the value of buyer 1 lays above $\tilde{v}(p)$, he would accept the buyout price and reject otherwise.

Let us first consider the special case of symmetric information between seller and buyer 1 when analyzing the seller's decision problem. Given that the seller knows the valuation of buyer 1, he could improve his expected profit by asking for a buyout price p fulfilling the following inequality:

$$\tilde{p}(v_1) \geq p > \mathbf{E}[V^{(2)} | \max_{j \neq 1} V_j < v_1] \Pr(\max_{j \neq 1} V_j < v_1) + \mathbf{E}[V^{(2)} | \max_{j \neq 1} V_j < v_1] (1 - \Pr(\max_{j \neq 1} V_j < v_1)), \quad (3)$$

Since $\mathbf{E}[V^{(2)} | \max_{j \neq 1} V_j < v_1] \geq v_1$, inequalities (2) and (3) cannot be satisfied simultaneously. Consequently, there exists no buyout price at which seller and buyer 1 could reach an agreement.

This will also be true under asymmetric information, i.e., when the valuation is private information of buyer 1. Since the seller never wants to reach an agreement before the auction, he should ask for a buyout price above the threshold price of the bidder with the highest valuation.

In the following, we derive the closed form solution for the parameters used in the experiment, which will be used as benchmark prediction. In the experiment, valuations of $n = 2$ buyers were drawn from the uniform distribution with support $[0, 1]$, where we denote by $F(x) = x$ and by $f(x) = 1$, the cumulative distribution function of each buyers' values and its probability distribution function, respectively. Buyer 1 will accept a buyout price if

$$v_1 \geq \tilde{v}(p) = \begin{cases} 1 - \sqrt{1 - 2p} & \text{if } 0 \leq p < 1/2 \\ 1 & \text{if } 1/2 \leq p \leq 1 \end{cases} . \quad (4)$$

The optimal buyout prices are given by $p^* = \arg_p(\tilde{v}(p) = 1)$, which yields $1/2 \leq p^* \leq 1$, that will never be accepted. If the seller asked for a buyout price below $1/2$ this would lead to an adverse selection effect lowering the expected outcome of the combined mechanism. High value buyers accept buyout prices whereas low value buyers go to the auction. Therefore, the fact that a buyout price below $1/2$ has been rejected or accepted, reveals information about buyer 1's valuation, allowing the seller to update his information about the support of the valuation of buyer 1 and therefore his expected profit from the auction.

More precisely, the seller's maximization problem is

$$p^* = \arg \max_{p \in [0,1]} \Pi^S(p) = p \int_{\tilde{v}(p)}^1 f(x)dx + \int_0^{\tilde{v}(p)} y g^{(1)}(y, \tilde{v}(p)) dy \int_0^{\tilde{v}(p)} f(x)dx, \quad (5)$$

where the seller updates his information about the expected value from the auction by taking into account that either one or both bidders' valuations lay in the interval $[0, \tilde{v}(p)]$, whereby $g^{(1)}(y, \tilde{v}(p))$ denotes the density function of the first order statistic with one or two random variables in this interval.⁷

Since sales will always take place in the auction, ex ante expected earnings are $1/3$ for the seller and $1/6$ for each buyer.

3 Experiment

In the experiment, each participant was either a buyer or a seller. One seller and two buyers constituted a trading group. The composition of the trading groups was changed between periods: Each period sellers and buyers were rematched randomly. An experimental session consisted of 32 periods, which can be divided into four cycles of eight trading periods. Each buyer was in the role of buyer 1 either in the odd or the even cycles, i.e., in 16 out of the 32 periods. In all other periods a buyer joined the auction only if the price offer had been

⁷See Rohatgi (1987) for distributions of order statistics with random sample size. For the problem here, $g^{(1)}(y, \tilde{v}(p)) = (1 + \tilde{v}(p) - 2y)/\tilde{v}(p)$.

rejected. Buyers' private reselling values for the product were randomly and independently drawn from the set $V = \{0, 1, 2, \dots, 99, 100\}$ with all $v_i \in V$ being equally likely. Participants could choose integer buyout prices and bids between 0 and 100. All values were denoted in a fictitious currency termed ECU for Experimental Currency Unit.⁸

In the beginning of a single period the trading groups were formed and sellers were asked to submit their buyout price offer. The buyer who was in the role of buyer 1 was informed about his private value and the buyout price. After buyer 1 had accepted or rejected the buyout price, each group member was told whether or not a sale had taken place. If the price offer was accepted, the sale occurred and there was no auction. If the buyout price was rejected, the other buyer was informed about his private value and a second-price sealed-bid auction with both buyers took place. All group members were informed about the outcome of the auction: who won the auction, the price paid by the winner, and their own payoff in the current period. Buyers who attended only the auction were not informed about the buyout price. At the end of a period, each participant received an account of the own total profit up to this period. In a post-experimental questionnaire participants answered standard demographic questions and were asked to comment briefly on their reasoning during the experiment.

The experiment comprised 10 sessions with a total of 90 participants. We conducted 10 sessions, half of them with 6 and the other half with 12 participants each. We pooled the data from the sessions of different sizes since we did not find significant differences between them.⁹ All experimental sessions were computerized and the software system was created with z-Tree (Fischbacher, forthcoming). The experiment was conducted at Humboldt-University Berlin, Germany, and most participants were students of economics, business administration, law, and physics. One session lasted on average 90 min. The conversion rate of ECU earned by each participant into cash was: 1 ECU = 0.0125 EUR. Participants' total earnings ranged between 8.05 EUR to 16.86 EUR with a mean of 11.82 EUR (as a seller: 13.14 EUR, as a buyer: 11.15 EUR).¹⁰

4 Results

Table 1 reports descriptive statistics of the experimental outcomes for all periods and, in order to illustrate the changes over time, for all cycles. For ease of comparison to the theoretical benchmark, we report our results for normalized valuations, i.e., all experimental outcomes are transformed from the $[0, 100]$ to the $[0, 1]$ -range. In total we observe 960 trades. Average buyout prices (column 1) with $p = 0.51$ as well as average earnings for sellers and buyers

⁸See appendix A for a shortened and translated version of the instructions. Complete sets of the original instructions (in German) are available upon request.

⁹The p-value of Mann-Whitney U Tests (henceforth MWU) on session averages concerning price offers, acceptance rates, final sale prices and efficiencies ranges between 0.22 and 1.

¹⁰These numbers include a starting capital for buyers of 5 EUR.

with 0.33 and 0.15 (columns 3) are rather stable over time and in line with the theoretical prediction.¹¹ The object was allocated to the buyer with the highest valuation in 85% of all sales (column 4). Since in the combined mechanism buyer 1 receives the object with positive probability, regardless whether he has the highest value or not, one might expect efficiency to be lower than in a pure second-price auction. However, the observed share of efficient allocations is quite comparable to those reported in other second-price sealed-bid auction experiments with two bidders (e.g., 88% (Güth, Ivanova-Stenzel and Wolfstetter, 2005), 91% (Pezanis-Christou, 2002)).

These results show that experimental outcomes are on average well captured by the benchmark prediction. However, contrary to the theoretical prediction, we observe one third of all sales taking place at the buyout price, i.e., before the auction (see column 2 of Table 1).¹² In order to better understand these findings, we continue with a more detailed analysis of the data. More precisely, we will first investigate buyers' bidding behavior in the auction and continue with their acceptance behavior of the buyout price before we turn our attention to sellers' price setting behavior.

Bidding should (theoretically) not be influenced by the buyout option since bidding the own value is a weakly dominant strategy. Experiencing the buyout option before the auction seems indeed not to change bidding behavior in the auction. Despite some slight over- and underbidding, we do not find significant differences between bids and the predicted equilibrium bidding strategy. In fact, half of all observed bids are equal to subjects' valuations. When comparing the session average relative bid deviations to a zero vector, we cannot reject the hypothesis that the relative bid deviation is equal to zero.¹³ Moreover, bid deviations do not change over time significantly.¹⁴ Given these observations, truthful bidding turns out to be a reasonably good prediction.

Buyer 1 has to choose between accepting the buyout price or going to the auction. In the experiment, each buyer was confronted half of the time with buyout prices, which leaves us with information about the acceptance behavior of each buyer for 16 periods. We find that only five out of 60 buyers (8%) behave according to the theoretical benchmark, i.e., accept buyout prices when their valuation exceeds the corresponding threshold value of equation (4) and reject otherwise. The majority of buyers either accept buyout prices even when their valuation is below the threshold value (57%) or reject buyout prices even when their valuation is above the threshold value (18%), which obviously violates the theoretical

¹¹A comparison between session averages of those variables reveals no significant difference neither to the benchmark prediction (MWU test: $p = 0.45$ for seller as well as buyer earnings; Sign-test: $p = 0.62$ for price offers) nor between the first half and the second half of the experiment (Wilcoxon signed rank test: $p > 0.28$ for all variables).

¹²Comparing the acceptance rates on session level between first and second half of the experiment reveals that there are no significant changes over time (MWU test: $p = 0.729$). Considering only buyout prices which were below the valuation of buyers, 63% of all sales occur before the auction.

¹³MWU test: $p = 0.114$ for both, the first and second part of the experiment.

¹⁴Wilcoxon signed rank test: $p = 0.625$ comparing session averages of first and second part of the experiment.

prediction.¹⁵

Sellers have to make only one decision: to choose the buyout price. Figure 1 presents the density estimate of buyout prices ranging from 0.05 to 1. The vertical lines present visual aids to compare our data to different theoretical benchmarks. The interval of buyout prices included by the two solid lines present the (risk neutral) benchmark. The two dashed lines describe the interval of buyout prices based on a model relaxing risk neutrality which we will present below. Half of the buyout prices (48.4%) are conform with the risk neutral theoretical prediction, i.e., are greater or equal to 0.50. However, the other half (51.6%) of observed buyout prices is below 0.50, which is clearly not in line with the theoretical benchmark.

All these observations indicate that the game theoretic model assuming homogeneous and risk-neutral agents seems to be a good predictor for average buyout prices and profits. Nevertheless, it cannot very well rationalize observed individual decisions that appear to drive the finding of successful sales at the buyout price.

This leaves us with the possibility that behavior might be based upon unobserved heterogeneity in subjects' preferences. One possible explanation for the observed deviations might be heterogeneity in risk preferences of both, sellers and buyers. Risk aversion might explain, for instance, why the majority of buyers accept buyout prices, which yield a lower profit than the expected profit from the auction and which a risk neutral buyer would have rejected. On the other hand, buyout prices below the theoretical prediction might be driven by risk aversion of sellers.

5 Risk Preferences

In this section we investigate whether and to what extent incorporating risk preferences into the model can explain our experimental data. Therefore, all agents are assumed to be expected utility maximizers and have preferences that can be represented by a utility function $u(\cdot)$ which is twice differentiable, strictly increasing and satisfies $u''(\cdot) \leq 0$ everywhere on its support. More precisely, for our analysis we restrict risk preferences to belong to the class of constant relative risk aversion (hereafter CRRA), $u(x) = x^{(1-\alpha)}/(1-\alpha)$, where α is the Arrow-Pratt measure of relative risk preferences.^{16,17}

¹⁵The remaining 10 buyers (17%) could not be classified as the deviation of their behavior was not consistent, i.e., the same person accepted buyout prices a risk neutral person would have rejected and would reject other buyout prices a risk neutral person would have accepted.

¹⁶This specification implies risk loving behavior for $\alpha < 0$, risk neutrality for $\alpha = 0$ and risk aversion for $\alpha > 0$. When $\alpha = 1$, the natural logarithm, $u(x) = \ln(x)$, is used.

¹⁷We experimented also with an exponential utility function, $u(x) = 1 - \exp^{-\alpha x}$, a specification which exhibits constant absolute risk aversion (hereafter CARA). We found that the CRRA form of the utility function fits our data better than the CARA form (see footnote 22).

Buyer

Allowing buyers to be risk averse might explain acceptance of buyout prices which lay above expected price of the auction. In the following, we are going to investigate whether the level of risk aversion needed to account for the observed acceptance behavior is reasonable.

Given our distributional assumptions and functional form, the threshold price of a buyer with risk preferences of α and valuation v is defined by

$$\tilde{p}(v) = v - \left(\frac{v^{(2-\alpha)}}{2-\alpha} \right)^{\left(\frac{1}{1-\alpha} \right)}.$$

Figure 2 plots the relation between threshold price and valuation for buyers with different levels of risk preferences. A buyer who is risk neutral ($\alpha = 0$) will never accept a buyout price above 0.50, whereas a buyer who has risk preferences of $\alpha = 0.64$ might accept buyout prices up to 0.62. Note that the relation between threshold price and valuation might be non-monotone. For example, a buyer with $\alpha = 0.64$ will not only reject a buyout price of 0.60 if his valuation is lower than 0.73 but also if his valuation is higher than 0.95, implying that a buyer with a very high valuation is more likely to go for the risky outcome from the auction rather than to accept the certain outcome from the buyout option.¹⁸ If a buyer is sufficiently risk averse, i.e. $\alpha \geq 1$, he would be willing to accept a buyout price equal to his valuation.¹⁹ The threshold is shifted upwards with increasing levels of α implying that higher buyout prices are more likely to be accepted the more risk averse a buyer is.

We can estimate the average risk preference of the buyer population directly from the experimental data.²⁰ In the model a buyer accepts a buyout price if

$$u(v - p) + \varepsilon_1 \geq \int_0^v u(v - x)f(x)dx + \varepsilon_2 \quad (6)$$

where we assume the unobservable error terms, ε_i with $i \in \{1, 2\}$, to follow a normal distribution $\varepsilon_i \sim N(0, \sigma^2)$. Assuming that risk preferences can be represented by $u(x) = x^{1-\alpha}/(1-\alpha)$, given the distributional assumptions and the decision rule in equation (6), we estimate the risk preference parameter in the buyers' population by maximum likelihood.²¹

¹⁸This non-monotonicity is driven by the choice of the utility function. With exponential utility, for example, monotonicity of the threshold value - price relation is maintained.

¹⁹This is somewhat counterintuitive since in this case such a buyer would get zero payoff whereas by rejecting he would have a chance of a positive net payoff. On the other hand, given the assumption of CRRA and the specification of the utility function, a buyer with $\alpha > 1$ and a valuation between 0 and 1 will always have negative net utility from entering the auction.

²⁰Since we do not have enough data points to estimate the risk preference parameter of each individual buyer, the analysis is based on pooled data and reflects behavior of the entire population assuming homogeneity and stable preferences among buyers.

²¹For $v \geq p$ ($N = 482$) the choice probabilities are given by

$$Pr \left(\varepsilon > -\frac{1}{1-\alpha} \left((v-p)^{(1-\alpha)} - \frac{v^{(2-\alpha)}}{2-\alpha} \right) \right)$$

The parameter estimate for buyers' risk preferences is $\hat{\alpha} = 0.64$ with a loglikelihood function value of -288.61 . The model assuming risk neutral buyers (fixing $\alpha = 0$), results in a likelihood function value of -319.56 . A likelihood ratio-test with a test value of 61.89 (5% χ^2 critical value of 3.84) corroborates that allowing for risk preferences improves the fit of the data significantly.²² Overall, buyers seem to react in a risk averse manner, which could explain acceptance of high buyout prices.

The estimated level of buyers' risk attitudes is in line with estimates reported in the literature. Numerous studies also based on responses of student subjects estimate average levels of risk preferences to be around $0.3 - 0.7$ and to be quite robust to different decision environments, e.g., gambles, other individual decision tasks, games, and auctions. For example, Cox and Oaxaca (1996), Goeree, Holt and Palfrey (2002), Chen and Plott (1998), and Ivanova-Stenzel and Salmon (2004) estimate relative risk preferences from bids observed in private value auction experiments to be $\alpha = 0.67, 0.52, 0.48,$ and 0.34 , respectively. Goeree, Holt and Palfrey (2003) and Holt and Laury (2002) use experimental data from individual decision tasks to estimate risk parameters for each person. They find the average risk attitudes to be around 0.28 and 0.32 , respectively.²³

Seller

Contrary to the risk neutral case, we could not derive an explicit solution for the case of general risk preferences for sellers. Nevertheless, we can solve numerically for optimal buyout prices and derive the distribution of buyout prices for any given distribution of agents' risk attitudes. This also implies that we can only indirectly investigate whether risk preferences improve the fit of the model for sellers. We will do this by comparing predicted buyout price distributions to the buyout prices observed in the experiment.

To derive quantitative buyout price predictions using "reasonable" levels of risk preferences, we rely on estimated risk preference distributions in the literature. In order to check for the robustness of the predictions, we will use four different frequency distributions of estimated individual risk preferences provided by the studies mentioned above (Cox and Oaxaca (henceforth C&O) and Ivanova-Stenzel and Salmon (henceforth I&S) for auctions as well as Goeree, Holt and Palfrey (2003, henceforth G,H&P) and Holt and Laury (henceforth H&L) for individual decision tasks. Estimated individual risk attitudes of those four studies lay in the interval $-1.48 \leq \alpha \leq 1.37$ and characteristics of the distributions (10%, 50% and 90% quantiles) are reported in column 3 of Table 2.²⁴ Based on these distributions we

with $\varepsilon = \varepsilon_1 - \varepsilon_2$ and $\varepsilon \sim N(0, 1)$.

²² Modeling the decision using the exponential utility function results in a loglikelihood function value of -300.58 . A comparison with the model applying the power utility function results in a likelihood ratio test value of 23.94 , indicating a significant better fit for the power function model.

²³Holt and Laury compare different treatments with normal and extremely high payments. We concentrate on their treatment with comparable real monetary incentives.

²⁴H&L classify their participants in 9 categories. We assign all subjects within a category the mean of this

simulate outcomes allowing for varying risk preferences of both, buyers and sellers.²⁵ We investigate the quantitative change in the decision variables and the expected amount of accepted buyout prices.

Buyers will accept buyout prices up to 1 when they are extremely risk averse, i.e., $\alpha \geq 1$, and only up to 0.45 when they are risk loving, i.e., $\alpha = -1.48$, which is the lowest level of the preference parameter estimates reported by the four studies. This translates into an increase (decrease) of the maximum buyout price a risk neutral agent would accept by 100% (−10%). In order to determine the impact of risk on sellers' price setting behavior, we simulate buyout prices offered by sellers with different risk attitudes. Sellers calculate their optimal buyout price given their own risk attitude and the distribution of risk preferences within the buyer population. Figure 3 presents predicted buyout price frequencies for each of the estimated population distributions of risk preferences. The range predicted by all simulations is $p \in [0.43, 0.69]$. Compared to the benchmark case with risk neutral sellers and risk neutral buyers, this range is smaller in size and is shifted downwards. However, the lowest buyout price is 0.43 and thus still close to the prediction for risk neutral agents of 0.5. The stronger decrease of the upper bound from 1.0 to 0.69 can be explained by the fact that when buyers are risk averse even high buyout prices have a chance of still being accepted. The seller can therefore increase his profit by keeping buyout prices high yet affordable for risk averse buyers.

Medians and quantiles of simulated buyout prices are reported in Table 2. Medians of simulated buyout prices are similar between studies (0.55 (G,H,&P), 0.53 (H&L), 0.54 (C&O) and 0.51 (I&S)), however, simulated buy prices based on parameter estimates elicited via lottery choices (G,H&P and H&L) are spread more widely than those based on auction data (C&O and I&S). Column 4b of Table 2 reports acceptance rates given the simulated price distributions and the distribution of risk preferences among buyers. Predicted acceptance rates of buyout prices vary between 17.6% and 36.9%.

Thus, allowing for general risk preferences opens a price floor within which agreements are possible at the buyout price. The exact magnitude depends, however, on the particular preference distribution.

The acceptance rate of 33% observed in our experiment lies within the range of predicted acceptance rates with heterogeneous agents. The median buyout price observed in the experiment is 0.49 and thus close to the predicted median buyout prices (0.51 – 0.55). However, allowing for heterogeneous risk preferences seems only slightly to improve the explanatory power of the model for sellers. The interval of buyout prices $p \in [0.43, 0.69]$ including all predictions covers more than half of observed buyout prices (56%) (see Figure

category as individual risk parameter. Subjects in the outer categories $\alpha < -0.95$ and $\alpha > 1.37$ were assigned $\alpha = -0.95$ and $\alpha = 1.37$. We do the same for G,H&P who distinguish between 7 risk categories, with $\alpha < -0.56$ and $\alpha > 0.93$ as lower and upper bound.

²⁵We assume common knowledge about the population distribution of risk attitudes, which is assumed to be the same for both, buyers and sellers.

1), which is an improvement by 8% with regard to the (risk neutral) benchmark prediction. Still, almost half of the buyout prices remain unexplained. Buyout prices in lower and higher ranges are much more dispersed than predicted. A Pearson Goodness of fit test strongly rejects the prediction of the model for each of the estimated distributions.²⁶

Furthermore, whereas buyout prices above 0.69 could still be explained by the risk neutral benchmark, buyout prices below 0.43 are not captured by any of the two models. What is puzzling is that those low offers comprise 29% of all buyout prices. This fraction is not only stable over time but is generally caused by the same sellers:²⁷ One third of all sellers offer buyout prices below 0.43 more than half of the time.

6 Discussion

In the previous section we have shown that allowing for risk preferences can theoretically explain the existence of successful sales at the buyout price, i.e., before the auction. Participants' comments in the post-experimental questionnaire confirm that risk attitudes might indeed drive the offer of low or the acceptance of high buyout prices. For example, some participants in the seller's role were concerned about the auction because it generated "too volatile prices" and mentioned that they favored an agreement at the buyout price. Participants in the role of buyers emphasized that they preferred to exercise the buyout option as "the chance of buying the item seemed to be higher." The analysis of the experimental data shows, however, that behavior can only partly be explained by agents' risk attitudes. Even though, relaxing the assumption of risk neutrality improves significantly the fit for buyers' behavior, it is not sufficient to explain sellers' behavior. Observed buyout prices vary much more than predicted with a substantial amount of buyout prices outside the predicted interval.

One might be tempted to explain the excess variance in buyout prices with noise in behavior. There are two problems with this argument. First, the observed distribution of buyout prices is far from uniform, as would be required by a model where sellers randomly choose across all possible price offers. Second, noise would presumably decline over time as participants have the opportunity to learn and adjust their buyout prices during the 32 periods of the experiment. Nevertheless, the distribution of observed buyout prices remains stable over time, with systematically under- and overpricing compared to the theoretical predictions.

Another possible way to look at our results is in light of the bargaining literature investigating environments with asymmetric information. For example, Samuelson and Bazerman

²⁶The Pearson Goodness of Fit test, also known as χ^2 -Test, requires independent observations. As different price offers of an individual seller might not fulfil this requirement, we use mean price offers of individual sellers for the test.

²⁷A comparison of the fraction of low offers between the first and second part of the experiment reveals no significant changes (Wilcoxon signed rank test: $p = 0.977$).

(1985) show that subjects systematically deviate from the predicted behavior and fall prey to the “winner’s curse,” in the sense that they either enter into loss-making purchases or forgo profit-making opportunities. The latter might apply also to our experimental situation where the seller (the uninformed party) has to condition his behavior on the strategic reaction of buyer 1 (his informed opponent).

In our experiment a seller faces a cognitively very demanding decision task. First, he has to consider buyers’ acceptance threshold values. Second, conditional on these threshold values, he has to calculate his own expected utility for different buyout prices choosing the price offer that maximizes this utility. Such reasoning requires that sellers not only optimize but also correctly condition their buyout price on the buyer’s reaction.

Let us consider, for example, a risk neutral seller who does not condition on the buyer’s reaction. From the point of view of such a (boundedly rational) seller any accepted buyout price, p , which is above the expected profit from the auction will be preferable. Such seller has to ensure that his price offer is above the expected auction profit and will be accepted with positive probability such that $E(\pi_A) \leq p \leq E(v)$. For example, with $E(\pi_A) = 1/3$ and $E(v) = 1/2$, a non-conditioning seller might offer prices between $1/3 \leq p \leq 1/2$.

Following this argument we can not only explain the existence of low buyout prices but also the fact that the observed under pricing remains stable over time. Suppose a seller neglects the strategic reaction of a buyer towards his own buyout price and uses solely his experience to build his expectations. A seller who offers low buyout prices in order to avoid low (expected) outcomes in the auction is more likely to experience low profits in the auction. Buyers with relatively high values will accept low buyout prices, but buyers who cannot even afford those low price offers, reject and go to the auction. This leads to the selection of low value buyers into the auction and consequently to low auction prices, reinforcing the seller’s expectation about low prospects of the auction. In order to form correct experience-based beliefs about auction profits, sellers would need to experiment with different buyout prices. Experimentation might be costly in the short run (because of foregone profit opportunities) and might therefore deliberately not be chosen by decision makers (Einhorn and Hoghart, 1981). However, if a seller is not willing to “invest” in learning, he might form wrong expectations about the relation between demanded buyout price and final profits.

In the answers to the post-experimental questionnaire we found some evidence supporting the possibility that subjects in our experiment fall prey to such “seller’s curse.” Some sellers indeed argued that the “auction generated too low prices” and that this was the reason why they preferred to reach an agreement before the auction. However, our data does not allow to test this conjecture directly. Experimental investigations of this issue and other behavioral explanations might yield promising answers and further insights in behavior in such hybrid mechanisms.²⁸

²⁸We plan to pursue such investigations in our future research.

7 Summary

In this paper, we study a dynamic trade institution that combines an auction with a take-it-or-leave-it price offer, the so called buyout option. Under standard assumptions, sales should always take place in the auction rendering the existence of the buyout option obsolete. An experimental test of the theory suggested that the theoretical benchmark can very well predict average buyout prices and profits in such combined mechanism. However, persistent departure from the theoretical prediction at the individual level, i.e., offering too low or accepting too high buyout prices, resulted in a substantial volume of transactions before the auction. This finding led us to explore other behavioral explanations in order to account for the observed deviations.

First, we showed that allowing for individual heterogeneity in risk preferences for both market sides might lead to sales before the auction. This result seems to be driven rather by risk aversion of buyers than of sellers as risk averse buyers accept higher buyout prices more frequently. Sellers, on the other side, lower their buyout price only marginally below the lowest price set by risk neutral sellers. By using existing population estimates of risk preference parameters we were able to make quantitative predictions about the distribution of sellers' price offers and acceptance behavior of buyers. When we compared these predictions to the experimental data, however, we found that behavior can only partly be explained by agents' risk preferences. Relaxing the assumption of risk neutrality improves the fit of the model for buyers, but cannot account for a substantial part of individual sellers' decisions. This is especially striking for low price offers. Even though participants gained experience during the experiment, they did not increase their buyout prices, thus their profit opportunities.

We therefore discussed an alternative explanation of individual seller behavior. An important issue seems to be whether sellers are aware of the information asymmetry: If sellers fail to anticipate buyers' strategic reaction to their buyout price they might choose buyout prices which are too low and forgo profit-making opportunities, a fallacy which resembles the winner's curse in negotiations.

8 Appendix

A Instructions

The original instructions are in German and available upon request. What follows is the translated main part of the instructions explaining the decision task. In the beginning of the instructions, participants were informed that instructions were the same for everybody and that any decision made would be anonymous. At the end of the instructions, participants were also informed that gains and losses from all periods would be added, that the exchange rate from ECU (Experimental Currency Units) to EURO was: 40 ECU = 1 EURO, and that buyers would receive an initial endowment of 5 EURO. The main part of the instructions read as follows:

In every period one person (a seller) offers two other persons (buyers) a fictitious commodity for sale. At the beginning of the experiment each participant is randomly assigned to a role (seller or buyer) and keeps this role throughout the entire experiment.

All valuations are denoted in a fictitious Experimental Currency Unit (ECU). In each period the private value for the product of each buyer, v , is independently drawn from the interval $0 \leq v \leq 100$, with every integer number between 0 and 100 being equally likely. Each buyer is informed only about his own private value and will not get to know the private value of the other buyer. The seller is not informed about the private values of the buyers.

Each period consists of either one or two stages and proceeds as follows:
In the first stage, the seller bargains with one of the two buyers. He makes a price offer (in the range from 0 to 100) to this buyer. The buyer can either accept or reject this price offer.

- 1.) If he accepts, then he pays the price and receives the product. The period is terminated. The buyer's profit is the difference between his private value for the product and the price. The seller receives the price. The other buyer (who has not participated in the bargaining) does not receive anything and does not pay anything, i.e., he makes a zero profit.
- 2.) If he rejects then the period proceeds to the second stage. In the second stage, an auction takes place with the seller and the two buyers. Both buyers submit simultaneously their bids. The bidder with the highest bid buys the commodity. The price he has to pay is equal to the second highest bid. His profit is the difference between his private value for the product and the price. The seller receives the price. The bidder who submits the second highest bid does not receive anything and does not pay anything, i.e., he makes a zero profit. If both bids are equal, the buyer is chosen by the flip of a fair coin. In this case the second highest bid is equal to the highest bid.

Each participant receives the following information: After the first (bargaining) stage the seller and both buyers are informed whether the sale takes place.

- 1.) In case of a sale, the parties involved in the negotiation (the seller and one of the buyers) are informed about the price and own profits in this period. In addition all participants are informed about their own total profit up to this period.
- 2.) In case of a second (auction) stage the seller and both buyers are informed about the winner of the auction, the price which has to be paid by the buyer, the own profit in this period, and the own total profit up to this period.

In each period, trading groups (one seller and two buyers) are formed randomly. Altogether, there will be 32 periods, which consist of 4 cycles of 8 trading periods. After each cycle buyers who participated in the first (bargaining) stage will change and participate only in the auction and vice versa.

B Figures and Tables

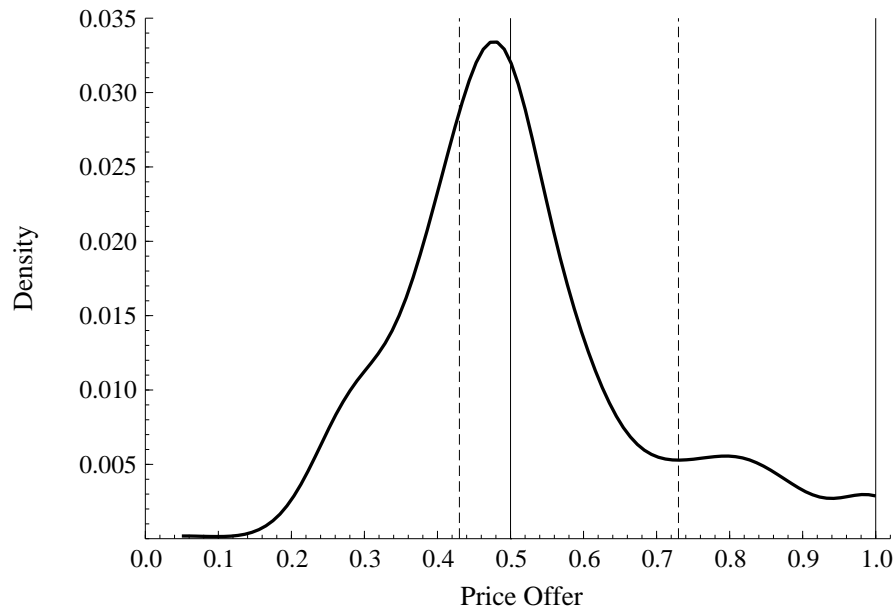


Figure 1: Buyout price density estimation, gaussian kernel

Solid lines represent the interval of optimal buyout prices assuming risk neutral agents. Dashed lines represent the interval of buyout prices predicted by the simulation for agents with heterogeneous risk preferences

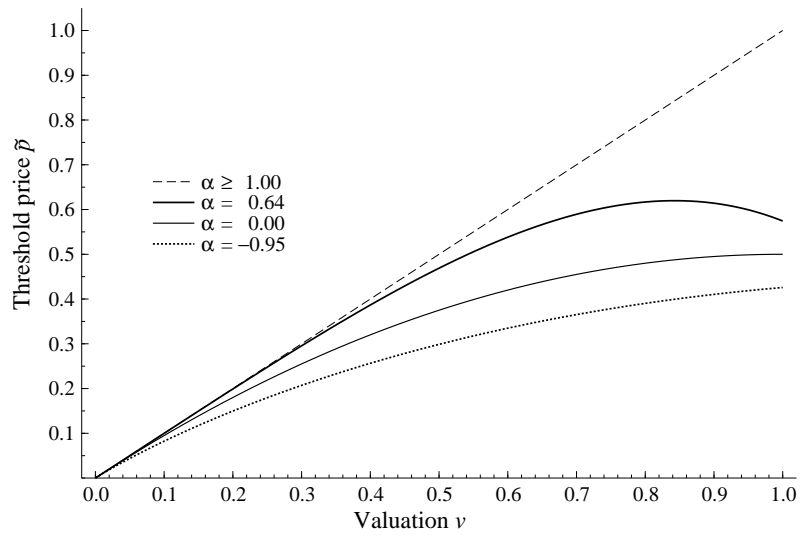


Figure 2: Relation between threshold price and valuation for different levels of risk aversion

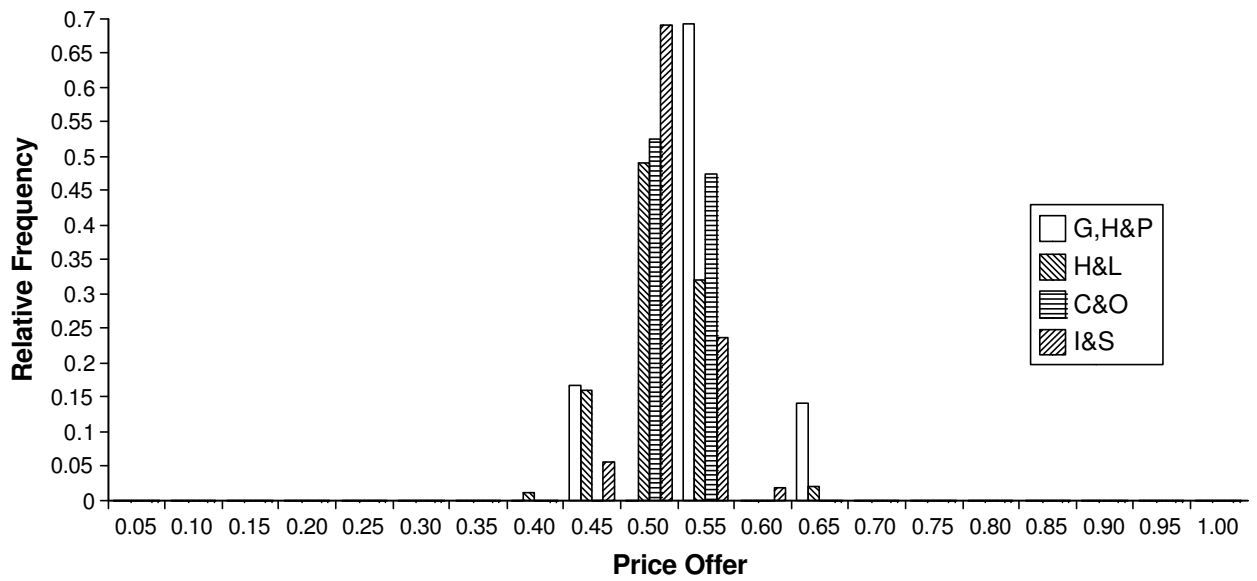


Figure 3: Predicted buyout prices based on risk preference distribution estimates of four studies

“G, H & P”-Goeree, Holt and Palfrey (2003), “H & L”-Holt and Laury (2002),
 “C & O”-Cox and Oaxaca (1996), “I & S”-Ivanova-Stenzel and Salmon (2004)

cycle	Number of observations	(1)		(2)	(3)				(4)
		Buyout price		Acceptance rate	Seller		Buyer [‡]		Efficiency
		Mean	(StD.)	(in %)	Mean	(StD.)	Mean	(StD.)	(in %)
1	240	0.53	(0.17)	35	0.34	(0.19)	0.14	(0.21)	80.4
2	240	0.51	(0.18)	35	0.32	(0.20)	0.16	(0.23)	85.0
3	240	0.52	(0.18)	28	0.33	(0.19)	0.16	(0.23)	87.9
4	240	0.50	(0.16)	36	0.32	(0.18)	0.16	(0.23)	86.7
all	960	0.51	(0.17)	33	0.33	(0.19)	0.15	(0.22)	85.0
Theory:		$0.5 \leq p \leq 1$		0	0.33		0.17		100

Table 1: Descriptive statistics for all periods and per cycle (1 cycle = 8 periods) and theoretical predictions

(‡ Number of observations=480 per cycle, since there were two buyers per trading round)

(1)	(2)	(3)			(4a)			(4b)
Study	Sample Size	Distribution of α -Estimates			Prediction of Buyout prices (p)			Acceptance rate
		Quantiles			Quantiles			(in %)
		10%	50%	90%	10%	50%	90%	
G, H & P	42	-0.38	0.14	0.89	0.48	0.55	0.68	17.6
H & L	175	0	0.28	0.83	0.48	0.53	0.56	21.2
C & O	40	0.37	0.72	0.92	0.53	0.54	0.56	36.9
I & S	55	-0.17	0.46	0.72	0.51	0.51	0.56	25.8

Table 2: Summary of different studies

(Col. 1): "G,H&P"-Goeree, Holt and Palfrey (2003), "H&L"-Holt and Laury (2002), "C&O"-Cox and Oaxaca (1996), "I&S"-Ivanova-Stenzel and Salmon (2004); (Col. 3): reported distribution of individual risk preference estimates; (Col. 4a and 4b): predicted buyout price distributions and acceptance rates based on those estimates

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