Auctions with Anticipated Regret: Theory and Experiment*

Emel Filiz †
Columbia University

Erkut Y. Ozbay ‡
New York University

June 2006

Abstract

This paper demonstrates theoretically and experimentally that in first price auctions overbidding with respect to the risk neutral Nash equilibrium might be driven from anticipated loser regret (felt when bidders lose at an affordable price). Different information structures are created to elicit regret: bidders know they will learn the winning bid if they lose (loser regret condition); or the second highest bid if they win (winner regret condition); or they will receive no feedback regarding the other bids. Bidders in loser regret condition anticipated regret and significantly overbid, however bidders in the winner regret condition did not anticipate regret and hence did not overbid. (JEL D44, C91)

*We are grateful to Atila Abdulkadiroglu, Kyle Bagwell, Prajit Dutta, Guillaume Frechette, Kyle Hyndman, Yusufcan Masatlioglu, Ariel Rubinstein, Bernard Salanie, Andrew Schotter for fruitful discussions. We would like to thank the participants of Murat Sertel Memorial Conference on Economic Theory 2004, SED 2004, ESA International Meetings 2005, Amsterdam-New York Conference on Experimental Economics2005. Our research has been supported by C.E.S.S. at NYU.

†Department of Economics, Columbia University, 420 West 118th Street, New York, NY 10027. E-mail: ef2011@columbia.edu

‡Department of Economics, New York University, 269 Mercer St. 7th Floor, New York, NY 10003. E-mail:eyo200@nyu.edu

Why do we observe overbidding in first price private value auctions? This paper aims to answer this question, which has been extensively studied in the literature, from a nonstandard point of view.

William Vickrey (1961) derived risk neutral Nash equilibrium (RNNE) bidding behavior in private value first price sealed bid auctions. However, bidding higher than the RNNE (overbidding) in first price private value auctions is one of the consistent findings of the experimental literature (see James C. Cox, Bruce Roberson and Vernon L. Smith, 1982; Cox, Smith and James M. Walker, 1988, as the seminal papers; and John H. Kagel, 1995, for a detailed survey). Cox, Smith and Walker (1988) explained this phenomena by risk aversion. The intuition is simple: risk averse bidders bid higher to increase the chance of winning even if this decreases their payoff. Glenn W. Harrison (1989) argued that bidders deviate from the RNNE because of the low monetary cost of deviation, i.e., in the experiment, by bidding more, bidders increased their probability of winning substantially but the amount they gave up was very small in monetary terms. So, he concluded that overbidding was observed because of lack of incentives not to deviate. However, Cox, Smith and Walker (1992) and Daniel Friedman (1992) highlighted the theoretical problems in Harrison's critique, and concluded that Harrison's reasoning was not sufficient to explain overbidding (for additional shortcomings of Harrison's critique see also Kagel and Alvin E. Roth, 1992; and Antonio Merlo and Andrew Schotter, 1992). Nevertheless, there is no consensus on the risk aversion explanation of the overbidding puzzle (see e.g., Kagel and Dan Levin, 1993, for overbidding in third-price auction with respect to the RNNE which goes against the implications of risk aversion in such a setting). The reason for the wide acceptance of risk aversion despite of its problems seems to be that other proposed explanations, such as joy of winning, are not powerful enough to explain the experimental findings in comparison to the risk aversion explanation (see e.g., Jacob K. Goeree, Charles A. Holt and Thomas R. Palfrey, 2002). Recently, Vincent P. Crawford and Nagore Iriberri (2005) provided a theoretical analysis on overbidding in general first price auctions by using level-k thinking model but the implication of this theory coincides with the equilibrium behavior for independent-private-value first price auctions with the uniform value distributions.

Our paper tries to shift the focus of discussion from risk aversion. We offer a different explanation of overbidding, namely anticipated regret.

The underlying motive of this paper is that in a game with incomplete information what seems as the best action ex-ante may not turn out to be the best one ex-post (after the information is revealed). Auctions are typical examples to observe such a discrepancy. For example, consider a first price private value auction in which a bidder values an object at \$1,000 and bids \$900. At the end of the auction, she learns not only that she is the highest bidder, but also that the second highest bid is \$50. Although bidding \$900 might be the best bid ex-ante, it is definitely not the best bid ex-post, e.g., she would still win with a bid of \$51 but pay less. In this situation, the fact that the ex-ante best bid is no longer the best bid ex-post will make her regret her ex-ante decision. Since this regret may be experienced only by the winner, we will call it "winner regret".

The above scenario is not the only way that regret can be felt in an auction. Consider the above situation again, but this time after she bids \$900, she learns that she lost the object because the highest bid was \$901. Again, bidding \$900 is not the best bid ex-post because she could have won the object in a profitable way by bidding \$902. Since this regret may be felt by the losing bidders only, we will call it "loser regret".

Intuitively, if the bidders anticipate that they are going to feel winner regret, they will shade their bids. In contrast, if their anticipation is loser regret, then they will overbid. In this paper, first we theoretically show that these intuitions are indeed equilibrium behaviors of risk neutral bidders with regret concerns. However, this theory is built on the assumption that bidders do anticipate regret. In this direction, we conduct experiments to answer whether they anticipate regret and if so, whether they reflect it into their bids.

The relevance of feedback regarding the bids of the others was initially studied by R. Mark Isaac and Walker (1985). They provided two types of feedback to different groups: one group is informed about the winning bid, the other is informed about all the submitted bids. In our terminology, the bidders in the first group may have loser regret, while the bidders in the second group may have both winner and loser regret. They observed higher bids in the first group. Axel Ockenfels and Reinhard Selten (2005) investigated effect of feedback on bidding behavior in repeated first price auctions same as in Isaac and Walker (1985). They also found that the bids in the second group (feedback treatment) are lower than that in the first group (no-feedback treatment) in every period except the first one. They argued that the concept of weighted impulse balance equilibrium is capable of explaining the results except the behavior in the first period. In the concluding section of our paper, we will argue that our model is capable of explaining their first period result as well.

Additionally, in the experiment of Cox, Smith and Walker (1988) where overbidding was observed, participants learnt only the bid of the winner; so the bidders in their experiment may feel loser regret. Although their study did not give a regret based explanation either, our regret intuition is capable of explaining their findings.

In this paper we argue that if the bidders know that they are going to receive some feedback, then they reflect it into their bids. The repeated nature of the above mentioned experiments does not allow us to study our argument clearly because in the repeated setup, feedback may create experience dependent regret. In other words, regret felt in the previous round or simple learning, rather than anticipated regret, might be the determinant of the bids in the next rounds.

Regret is not a novel concept in the economics literature (see Graham Loomes and Robert Sugden, 1982; and David E. Bell, 1982).[1] Regret theory generalizes expected utility theory by making the Bernoulli utilities depend on not only the payoff of the chosen outcome but also the payoff of the forgone alternative. Bell (1982) argued that when the uncertainty is resolved, the comparison between the current state of the chosen alternative and the forgone alternative may lead to regret. In order to feel regret, the decision maker should learn the resolution of the uncertainty of the unchosen alternative. Additionally, in order to anticipate regret, the decision maker should know that she is going to learn this complete resolution before the decision. To sum up, decisions may be affected by anticipated regret if the relevant feedback about the resolution of the uncertainty regarding other alternatives is expected to be received by the decision maker. A series of lab experiments has shown that indeed anticipated regret can affect the behavior of decision makers (see e.g. Ilana Ritov, 1996; and, for a detailed review, see Marcel Zeelenberg, 1999).

Both theoretically and experimentally, anticipated emotions have been examined extensively, but mostly in single decision making problems. The regret in auction setting is introduced by Richard Engelbrecht-Wiggans (1989). Here, we will first redefine anticipated regret more clearly by distinguishing two types of regret. Additionally, we will consider a more general functional form of regret, and we will characterize the symmetric equilibrium bidding strategy. These are studied in Section I.

In Section II, we will develop a set of first price sealed bid auction experiments by changing the information structure of the auctions. More precisely, we conduct experiments to check if bidders change their bidding strategies in a first price auction depending on the information that can potentially make the bidders anticipate regret. Unlike the standard lab auction experiments, our design will be one-shot because we want to avoid any learning or experience-dependent regret explanations. In this way, we will also check if overbidding is observed in a one-shot first price auction experiment. In Section III, we will argue that our model is capable of explaining the findings of our experimental results. In Section IV, in order to check how introducing regret perturbs the revenue equivalence theorem, we will consider other well-known auctions, namely second price, English and Dutch auctions. Section V concludes.

I. Model

There is a single object for sale, and there are N potential bidders, indexed by $i = 1, ..., N$. Bidder i assigns a private value of v_i to the object. Each v_i is independently and identically drawn from $[\underline{v}, \overline{v}]$ according to an increasing distribution function F, and f is the density function corresponding to F. Let v_o be the reservation price of the seller. Without loss of generality, assume $v_o = 0$.

Suppose the seller sells the object by first price sealed bid auction (FP), i.e. until a prespecified deadline, the participants submit their bids in sealed envelopes and the highest bidder gets the object at the price she offered by her bid. Assume that any tie is broken by assigning the object to one of the highest bidders, randomly.

The traditional auction theory specifies the utility of a risk neutral bidder in an FP as the difference between her valuation of the object and the amount she pays if she wins and zero otherwise. We generalize the traditional theory such that the information bidders receive at the end of the auction about the bids submitted in the auction may affect their utilities. In other words, at the end of the auction, the bidder may reevaluate her bid and her position in the auction when she receives the feedback. We modify the utility function used in the traditional theory such that this reevaluation may cause regret about the decision of the bidder and the regret term may appear in the utility. This modification in utility makes the rational bidders anticipate regret and determine their bidding strategies accordingly.

The subsections below analyzes two possible forms of regret, winner and loser regret, in first price sealed bid auctions.

A. Winner Regret in First Price Sealed Bid Auction

Suppose at the end of the auction, bidders know not only their winning/losing position but also, if they win, they learn the submitted second highest bid. The utility of a winner depends on her valuation of the object, the price she pays and the regret she feels. The winner regret is a function of the difference between actual payment (her bid) and the minimum amount that would preserve her winning position after she learned the other bids. Notice that in an FP, the lower bound of the bids a winner can make while keeping her winning position after she learns the other bids is the second highest one. Any bid above this lower bound guarantees her winning ex-post. Additionally, the closer the bids to this lower bound as long as it is higher than the bound, the smaller the payment the winner makes. So the source of winner regret is going to be the difference between her winning bid and the second highest bid. Since the bidders who did not get the object do not have access to any information, the utility form for losers is as in the traditional theory. More formally, the utility function of bidder i, with valuation v_i and bid b_i, in first-price sealed bid auction takes the following form:

$$u_i\left(v_i, b_i | b^2\right) = \begin{cases} v_i - b_i - h(b_i - b^2) & \text{if} \quad i \text{ wins} \\ 0 & \text{if} \quad i \text{ loses} \end{cases}$$

where b^2 is the second highest bid and $h(\cdot) : \mathbb{R}_+ \to \mathbb{R}_+$ is the winner regret function. Since regret is a negative emotion that may decrease the utility, assume that h is nonnegative valued. Additionally, if a bidder wins the object with a tie then ex-post she may not feel any regret because by bidding any smaller amount she would lose or any bigger amount she would pay more, so assume $h(0) = 0$. The bigger the discrepancy between the actual bid and the ex-post best bid is, the more regret may be felt, therefore assume h is a nondecreasing function. Finally, for technical reasons, assume h is differentiable.

Observe that in the above formulation setting $h(\cdot) = 0$, i.e., assuming that bidders do not have winner regret concerns, our model is equivalent to the traditional risk neutral bidder setting.

Intuitively, in our model since the winner's monetary payoff is shaded by regret, we should expect, in equilibrium, lower bids than those in the traditional risk neutral case. Knowing that some ex-post regret may be experienced, the individuals may be afraid of bidding too aggressively.

THEOREM 1: *In a first price sealed bid auction with winner regret, the symmetric equilibrium bidding strategy ($b^{FP_{wr}}(\cdot) : [\underline{v}, \overline{v}] \to [0, \infty)$) must satisfy the following condition:*

$$E_X[X | X < v] = b^{FP_{wr}}(v) + E_X[h(b^{FP_{wr}}(v) - b^{FP_{wr}}(X)) | X < v] \tag{1}$$

where X is the highest of $N-1$ values.

PROOF:

See Appendix A.

REMARK 1: *The left hand side of Equation (1) is the symmetric equilibrium strategy (RNNE) in a first price auction in the traditional theory. Hence, in a first price sealed bid auction with winner regret, the symmetric equilibrium strategy is less than that of without winner regret, i.e.* $b^{FP_{wr}}(v) \leq b^{FP}(v)$ *for all* $v \in [\underline{v}, \overline{v}]$ *since* $h(.)$ *is assumed to be nonnegative. In other words, if the bidders anticipate winner regret then they will underbid.*

REMARK 2: *Winner regret concerns of the bidders decrease the seller's expected revenue in FP since the bidding strategy will be lower as explained in Remark 1, i.e.* $ER^{FP_{wr}} \leq ER^{FP}$. *Hence, the seller prefers bidders not to anticipate winner regret.*

B. Loser Regret in First Price Sealed Bid Auction

Suppose at the end of FP, the bidders not only learn their winning/losing position but also if they lose, they learn the winning bid. The utility of a losing bidder depends on the regret she feels. The loser regret is a function of the difference between her valuation and the winning bid if the winning bid is affordable, i.e., the winning bid is less than her valuation.

More formally, consider FP with the following change in the form of utility:

$$u_i\left(v_i, b_i | b^w\right) = \begin{cases} v_i - b_i & \text{if} \quad i \text{ wins} \\ -g(v_i - b^w) & \text{if} \quad i \text{ loses} \end{cases}$$

where b^w is the highest bid (the bid of the winner), and $g(\cdot) : \mathbb{R} \to \mathbb{R}_+$ is the loser regret function which is assumed to be nonnegative, nondecreasing, differentiable, analogous to the properties of winner regret function, $h(\cdot)$. The bigger the difference between her value and the winning bid is, the more loser regret may be felt by a bidder. Moreover assume $g(x) = 0$ for all $x \leq 0$ because if a bidder loses and learns that winning bid is not affordable to her, i.e., $v_i \leq b^w$, then there is no reason for loser regret. In other words, even if she has bid more than the winning bid, she would not have made positive profit because that bid would have been more than her valuation. So, when she learns that the winning bid was greater than or equal to her valuation, she would not feel loser regret. More precisely, the utility is constructed by modifying the utility in the traditional theory via introducing loser regret function.

Similar to winner regret, observe that in the above formulation setting $g(\cdot) = 0$, i.e., assuming that bidders do not have loser regret concerns, our model reduces to the traditional risk neutral bidder setting.

Intuitively, since in our model the bidders who did not get the object may reevaluate their bids by considering the winning bid and some of them may regret about their too little bids, by anticipating the regret possibility, they may end-up bidding more than the traditional case, i.e., overbidding may be observed if the bidders are motivated by loser regret.

THEOREM 2: *In a first price sealed bid auction with loser regret the symmetric equilib-*

rium bidding strategy ($b^{FP_{lr}}(\cdot) : [\underline{v}, \overline{v}] \rightarrow [0, \infty)$) *must satisfy the following condition:*

$$E_X[X|X < v] = b^{FP_{lr}}(v) - E_X[g(X - b^{FP_{lr}}(X))|X < v] \tag{2}$$

where X is the highest of $N - 1$ values.

PROOF:

See Appendix A.

REMARK 3: *The left hand side of Equation (2) is the symmetric equilibrium strategy in a first price auction in the standard theory. Hence, in FP with loser regret, the symmetric equilibrium strategy is higher than that standard theory suggests, i.e., $b^{FP_{lr}}(v) \geq b^{FP}(v)$ for all $v \in [\underline{v}, \overline{v}]$ since $g(\cdot)$ is assumed to be nonnegative. In other words, if bidders anticipate loser regret then they will overbid.*

REMARK 4: *Loser regret concerns of the bidders increase the seller's expected revenue in FP since the bidding strategy will be higher as explained in Remark 3, i.e., $ER^{FP_{lr}} \geq ER^{FP}$. Hence, the seller prefers bidders to anticipate loser regret.*

II. A First Price Auction Experiment

In Section I, we have shown that winner regret and loser regret have different implications on the equilibrium bidding strategies. In FP, winner regret concern leads to underbidding, whereas loser regret concern leads to overbidding compared to the RNNE. Now, the natural question is whether the bidders anticipate any form of regret and reflect this concern into their bids. In order to answer this question, we conduct an FP experiment under different information structures so that either form of regret might be anticipated. More precisely, we will create three conditions which differ only in terms of information structures. In the no-feedback condition, the bidders will not learn anything about others' bids; in the winner regret condition the winner will learn the second highest bid but the losers will not learn anything; and in the loser regret condition, the losers will learn the winning bid, but the winner will not learn anything. It is important to note that we want to conduct an experiment to see whether individuals reflect their concern of regret in their bidding strategies, not to see what they feel after the auction. It is hypothesized that the bids in the loser regret condition will be higher than that in the no feedback condition, and the bids in the winner regret condition will be lower than that in the no feedback condition.

Regret is a feeling one might experience after the action is taken and the uncertainty of the forgone actions is also resolved. Therefore, someone facing the same decision problem in a repeated fashion might reflect the regret of the previous round on the decision of the next round. However, our theory relies on the fact that bidders anticipate the future regret and they take this into account in their current decisions. To avoid this history-dependent regret explanation, unlike the standard lab auction experiments, we conduct a one-shot auction experiment. The problem with running a one-shot auction experiment is that each subject gives a single data point from which it is not possible to estimate the bidding strategy as a function of all possible valuations. In order to solve this problem, we propose a variation of the strategy method which we call the "bid on list method", in which each subject reports bids for several different valuations. The details of this method will be explained later.

A. Method

The experiments have been run at New York University, the Center for Experimental Social Science (CESS). All the participants were undergraduate students at New York University. The experiment involved 6 sessions. In each session one of the three conditions was administered. The numbers of participants in condition 1, 2, and 3 were 28, 32, and 36, respectively. No subject participated in more than one session. Participants were seated in isolated booths.[2]

In our auction experiment, we created groups of 4 bidders and gave each of them a list of ten possible valuations (see Appendix B for a sample of bidding list). The different lists were given to each of the 4 bidders but the same lists were used for each group. Each number on each list was drawn uniformly and independently between 0 and 100, rounded to the nearest cent, and this was common knowledge for the participants.[3] Additionally, the participants were informed that only one of those ten numbers in their lists was their correct value but they did not know which one. They needed to bid for every value they saw in the list as if it was the correct valuation of the object for them. The participants were told that after everyone submitted their bids, one valuation would be randomly selected[4] and this would determine the relevant value and bid for each of them. The bidder who had submitted the highest bid for the selected row of the list won the fictitious good at the price of her bid and she was paid in experimental dollars the difference between her valuation and her bid.[5]

Each group of 4 bidders were assigned to one of the three different conditions. Their condition was told in a separate page in the instructions in order to make sure that they read this part of the instructions. The conditions were as follows:

Condition 1 (No feedback): It was told to the participants before they bid that at the end of the auction, they were going to learn if they won or not, and no additional information would be given.

Condition 2 (Winner regret): It was told to the participants before they bid that at the end of the auction, they were going to learn if they won or not and if they won, they would also learn the second highest bid that had been submitted.

Condition 3 (Loser regret): It was told to the participants before they bid that at the end of the auction, they were going to learn if they won or not and if they did not win, they would also learn the highest bid that had been submitted.

After each participant had submitted their lists of bids, and before determining their true valuations, a survey adopted from Zeelenberg and Rik Pieters (2004) was administered (see the Appendix B for the survey). In this survey, we listed a set of emotions and asked the subjects to rate the intensity of emotions that they may feel after they get the relevant information. The ratings were between 1 and 9, where 1 stands for "not at all" and 9 for "very much". The survey did not include any other questions.

B. Results

For each condition the averages of the bids corresponding to the same valuations were calculated. The average bids for the corresponding valuations are plotted for no feedback, winner regret and loser regret conditions in Figure 1. The linear estimation of plotted points of each condition is drawn in the same figure. The slope of the linear estimation (passing through zero) of the average bids under loser regret is .87 which is significantly higher than that under winner regret which is .77 (see Table 1, first two columns), since the 95 percent confidence intervals of each estimate do not overlap. Similarly, the slope of the linear estimation (passing through zero) of the average bids under no feedback is significantly lower than that under loser regret (see Table 1, columns two and three), since the 95 percent confidence intervals of each estimate do not overlap. However, there is no significant difference between the no feedback and winner regret conditions since the 95 percent confidence intervals of each estimate overlap (see Table 1, columns one and three).[6]

Additionally, the averages of the emotions under each condition is summarized in Table 2. A t-test on the survey data suggests that the average intensity of regret under loser regret is significantly higher than that under winner regret ($t = 6.2548$, $p < 0.01$).

In order to tell more about individual bidding behavior, we may define a typical variable for each individual to measure how she shades her value while bidding. To generate this variable for a given subject, we calculated first the bid/value ratios for the subject's each bid-value pair and then took the average of these ratios. We call this variable the individual bid/value coefficient. Figure 2 demonstrates the cdfs of individual bid/value coefficients under winner and loser regret conditions. First observe that there is a first order stochastic domination between the cdfs. This domination indicates that the individual level data still has the property that under loser regret treatment the bid/value coefficients are higher than the winner regret one. Observe from Figure 2 that in the winner regret condition 31% of the subjects have bid/value coefficient below .7. However, this percentage is 5 in the loser regret condition. This means that loser regret condition made most of the subjects bid aggressively. Additionally, these coefficients are dense around the estimated slope of the bidding function (.87) for the loser regret condition (80% have coefficients between .75 and .95). On the other hand the winner regret condition did not affect the bids of the subjects in a clear way. The bid/value coefficients in this group varies a lot.

III. Combining Experimental Results with Theory

In this section, we will try to explain these experimental results with our theory. For this attempt, we need to determine the RNNE for FP in the traditional theory and take it as a benchmark. This benchmark is going to be used to detect overbidding/underbidding behavior if there is any. First of all, the RNNE of a bidder with valuation v is the expected second highest valuation given that v is the highest, i.e., $b^*(v) = E[X \mid X < v]$. In our setting with 4 bidders whose valuations are drawn from $[0, 100]$ uniformly, this equilibrium bidding strategy corresponds to the following:

$$b^*(v) = .75v$$

In the loser regret condition, the estimated bidding strategy is $\widehat{b}^{FP_{lr}} = .87v$ which is significantly above the RNNE bidding strategy. In other words, overbidding with respect to the RNNE is observed if the bidders are informed that at the end of the auction they are going to learn the winning bid if they do not get the object. This is in line with our theoretical predictions (see Remark 3). However, in the winner regret condition, the estimated bidding strategy is $\widehat{b}^{FP_{wr}} = .77v$ which is not significantly different from what the RNNE suggests. Our theory predicts that underbidding needs to be observed in this condition.

The experimental results suggest that bidders anticipate loser regret. Moreover, they reflect this anticipated loser regret into their bids and hence overbidding in first price auction can be explained by loser regret concern of bidders. However, bidders do not anticipate winner regret, and they do not reflect this concern into their bids. In other words, underbidding suggested by winner regret motivation has not been observed in the experiment.

At this point it is important to look at the survey findings because Bell (1982) argues that regret has to be anticipated by the decision maker in order to be reflected in her decision. Table 2 indicates that the average intensity of anticipated regret under winner regret condition is 2.69 while it is 6.19 under the loser regret condition. Therefore, the bidders anticipated winner regret significantly less than loser regret. By taking Bell's argument into account, bidders who did not anticipate regret may be expected not to reflect it into their bidding decision. Hence, the absence of anticipation of winner regret may be the reason for not observing underbidding.

In our theory, not anticipating winner regret formally imposes $h(\cdot) = 0$; hence, our theory for winner regret coincides with the traditional theory. Then, both the traditional theory and our theory are capable of explaining bidding behavior under winner regret condition because they are the same.

On the other hand, under the loser regret condition bidding behavior of subjects significantly increases. Since the information structure has no role in traditional theory, in the loser regret condition the prediction of the RNNE will still be the same and therefore unable to explain this overbidding phenomena. Nevertheless, by Remark 3, experimental findings can be explained by our loser regret motivation.

In the theoretical analysis, we found the equilibrium bidding strategy for a general loser regret function, g. Now, assume a linear form to estimate the slope by using the experimental data:

$$g(x) = \begin{cases} \alpha x & \text{if } x \geq 0 \\ 0 & \text{o/w} \end{cases} \tag{3}$$

where $\alpha \geq 0$.

Applying Theorem 2 for $N = 4$ with valuations distributed uniformly on $[0, 100]$, the first order condition (in the proof of the Theorem) becomes

$$(4-1)v^{4-2}[v-b(v)] - v^{4-1}b'(v) + \alpha(v-b(v))(4-1)v^{4-2} = 0$$

By solving this, we get the symmetric equilibrium strategy

$$b^{FP_{lr}} = \frac{3+3\alpha}{4+3\alpha}v \tag{4}$$

We can estimate α from the data on bids and values. α can be thought as a measure of loser regret. When $\alpha = 0$ this bidding function is equal to the RNNE bidding function. Moreover, as α increases this bidding function becomes steeper. In other words, the more loser regret concerned the bidder is, the higher she bids. As α approaches to ∞, i.e. the bidder is super concerned about loser regret, the optimal bidding strategy is to bid one's value.

Our experimental results suggest that in the loser regret condition, the estimated bidding strategy is $\widehat{b}^{FP_{lr}} = .87v$. By solving $\frac{3+3\widehat{\alpha}}{4+3\widehat{\alpha}}v = .87v$, the corresponding $\widehat{\alpha} = 1.23 > 0$. The sign of $\widehat{\alpha}$ matches with our intuition that decision makers act as if they have loser regret concerns, i.e. $g(\cdot)$ in the model is a non negative function.

If the winner's bid is interpreted as a reference point for a loser, then our estimate of loser regret coefficient is in line with other studies on reference dependent utility models (see Amos Tversky and Daniel Kahneman 1991; Kahneman, Jack L. Knetsch, and Richard

H. Thaler, 1990; and Shlomo Benartzi and Thaler, 1995). Similar to those models, we also estimated that the marginal effect of a negative emotion is bigger than that of monetary gain.

Some further analysis can be carried out in order to relate the survey data with the individual bidding behavior. For the subjects in loser regret treatment, the correlation between the intensity of regret they marked in the survey and their average individual bid/value coefficients is .26 (with $t = 1.559$, $p < .1$). Since one may think that the measure of intensity of an emotion can be a subjective issue, we created a new dummy variable which is 1 for individuals who marked their regret level above the group average and zero otherwise. This new variable is also found to be positively correlated with the individual bid/value coefficients. We found the correlation between these two .33 (with $t = 2.061$, $p < .05$). Finally, we looked at the correlation between subjects who marked their regret level above average and the subjects whose bidding coefficient is higher than the estimated loser regret bidding coefficient of the pooled data and we found that the correlation is .43 (with $t = 9.084$, $p < .01$). This analysis shows that the subjects who stated that in case they lost the object at an affordable price they would feel regret, bid significantly higher when it is actually time to bid. Alternatively, for each individual under the loser regret condition the bids are regressed onto the underlying valuations. Based on individual bid coefficients, the loser regret coefficients (α) for each subject are calculated according to the formula in Equation (4). We found that the correlation between individual loser regret coefficients and their reported regret is .33 (with $t = 2.058$, $p < .05$). All these positive correlations may suggest that as the regret anticipation increases, the regret function becomes steeper and hence bids become more aggressive.

The no feedback condition is designed as a control group. In this condition we found that the estimated slope of bidding function is .79 which is significantly higher than what the RNNE suggests (.75). Perhaps a bidder in the no feedback condition may feel loser regret *in expectation* because they may expect the winning bid given that they lost at their bids. However, since the subjects do not anticipate winner regret, it may not be plausible to assume that they will anticipate it *in expectation* when they are not informed about the second highest bid. Since we found that the subjects are capable of anticipating loser regret, similarly they may be capable of anticipating loser regret *in expectation* as well and therefore still bid higher under the no feedback condition. It is worthwhile to note that the subjects in the no feedback condition reported that they would feel more regret when they lose (3.89) than when they win (1.39) in the survey.

IV. Further Discussion

Vickrey (1961) showed the revenue equivalence among four well-known auctions: first price, second price sealed bid, English and Dutch auctions. Now, we will analyze if the anticipation of regret affects the bidding strategies in other types of auctions and how regret alters the revenue equivalence result.

A. Winner Regret in Other Auctions

Suppose the seller sells the object by a second price sealed bid auction (SP), i.e., until a prespecified deadline, the participants submit their bids in sealed envelopes and the highest bidder gets the object at the price of the second highest bid. Theoretically, unlike the first price, in the second price sealed bid auction, the winner will not regret her bid. In this type of auction, by changing their bids, the bidders can only affect their winning/losing positions; in other words there is no bid level that the winner would ex-post prefer to the original one while maintaining her winning/losing position. Therefore, the difference between the payment under the actual bid and that under the ex-post best bid is zero, and since $h(0) = 0$, the utility function will not have any regret component in it:

$$u_i\left(v_i, b_i|b^2\right) = \begin{cases} v_i - b^2 - h(b^2 - b^2) & \text{if } i \text{ wins} \\ 0 & \text{if } i \text{ loses} \end{cases} = \begin{cases} v_i - b^2 & \text{if } i \text{ wins} \\ 0 & \text{if } i \text{ loses} \end{cases}$$

where v_i is the value of bidder i, b_i is bidder i's bid and b^2 is the second highest bid.

REMARK 5: *Since the utility form remains the same as in the traditional case, the optimal bidding strategy will not change in the second price auction. So, it is still optimal to bid one's own valuation as in the traditional theory. Hence, the expected revenue will be unaltered under winner regret, i.e.* $ER^{SP} = ER^{SP_{wr}}$.

The English auction is an ascending price auction in which bidders increase the current price, and the last remaining bidder receives the object at the amount that no one increases the price anymore. Similar to SP, in the English auction, introducing winner regret into the model does not affect the form of utility. Obviously, in the ascending auction the winner already pays the smallest possible amount which makes her the winner. Therefore, she does not regret at the end.

The Dutch auction is a descending price auction in which a public price clock starts out at a high level and falls down until the first participant accepts to pay it. In a Dutch auction, it is not possible to define the effect of regret because in the descending auction the winner never learns whether she would have won if she waited a bit more. In our model, the source of regret is the information that bidders receive about the other bids at the end of the auction. In mechanisms, like the Dutch auction, which do not provide this extra information, it is not possible to talk about regret. Here, we do not want to diverge from the regret theory in which information regarding the forgone alternative has to be realized in order to consider regret (see Bell, 1982). However, it is possible to consider regret *in expectation* which would lead to similar analysis in the FP (recall the discussion at the end of Section III).

REMARK 6: *Since winner regret does not enter the utility in second price, English or Dutch auctions, the optimal bidding strategy will be the same as in the traditional case. Hence, the expected revenue of the seller will be the same whether the bidders have winner regret or not. However, due to Remark 2 the expected revenue decreases in FP if the bidders have winner regret concerns. By combining with Vickrey (1961), the expected revenue in FP is the lowest among these four auctions, and it is same among second-price, English and*

Dutch auctions.

B. Loser Regret in Other Auctions

Unlike the winner regret, the bidders may feel loser regret in SP because for example, a bidder might bid less than her valuation and might learn that the winning bid is less than her value. However, this does not happen in the equilibrium because truth-telling is the dominant strategy for the SP with loser regret as in the traditional theory.

THEOREM 3: *In a second price sealed bid auction with loser regret the symmetric equilibrium bidding strategy is* $b^{SP_{lr}}(v) = v$ *for all* $v \in [\underline{v}, \overline{v}]$.

PROOF:

See Appendix A.

REMARK 7: *Since the equilibrium bidding strategy remains the same as in the traditional case as stated in Theorem 3, the expected revenue will be unaltered under loser regret, i.e.,* $ER^{SP} = ER^{SP_{lr}}$.

Unlike the analysis under winner regret, this time loser regret may be felt in a Dutch auction because the information of winning bid is known. More precisely, the ones who lost the object observe the winning bid in a Dutch auction and may reevaluate their original bids. The way bidders anticipate loser regret is exactly the same as that in FP. Therefore, the same analysis done for FP applies here, and implies the same equilibrium strategy.

Similar to SP, in the English auction, loser regret is not felt in equilibrium, since bidders will increase the bids until their true values so the winning bid will not be affordable by the ones who lost the auction in the equilibrium.

REMARK 8: *The loser regret is not felt in the second price and English auctions in equilibrium, and hence the expected revenue remains the same as in the traditional case. However, the loser regret can be felt and increases the optimal bid in comparison to the RNNE in first price and Dutch auctions, and hence it increases the expected revenue of the seller. To sum up, if the bidders have loser regret concerns, the expected revenue of the seller is higher in first price and Dutch than in second-price and English.*

C. Combining Theory with Experiments on Other Auctions

The experimental literature suggests that the bids in English auction are not different from the RNNE (see e.g. Kagel, Ronald M. Harstad, and Levin (1987); and Vicki M. Coppinger, Smith and Jon A. Titus (1980)). This is in line with what regret would imply theoretically.

However, in the second price sealed bid auction, Kagel et al. (1987) findings differ from Coppinger et al. (1980). The former did not force the subjects not to bid above their valuations and overbidding is observed in the second price auction. This is not observed in Coppinger et al. since they had a price ceiling. Regret does not imply overbidding in the second price auctions, since overbidding is a dominated strategy. Therefore regret is capable of explaining the Coppinger et al., but not Kagel et al.

In early Dutch auction studies, it has been found that bids in a Dutch auction are less than those in first price. However, recently Anthony M. Kwasnica and Elena Katok (2005) observed that waiting time in a Dutch auction matters. More precisely, as waiting time increases, the bids in Dutch auction became as high as those in first price. Our theoretical discussion in the Dutch auction suggests that since the bidders are going to learn the winning bid, they may feel the loser regret and if they can anticipate it, they will bid as high as in the first price auction. Perhaps, the waiting time has an effect on the anticipation of the loser regret in Katok and Kwasnika's experiment. In other words, as the bidders wait longer for the clock, they will have more time to anticipate loser regret, especially when the clock is around affordable prices. However, if there is not enough time, they may not anticipate the loser regret and bid less in comparison to the first price auction.

V. Conclusion

In this paper, we argue that overbidding in the first price auction is driven by the anticipation of regret. The bidders who did not get the object may regret their bids after they learn the winner's bid and anticipation of this situation may make them bid more aggressively. We provide a theoretical basis by introducing regretful bidders who bid more than the RNNE in the equilibrium. Experimental results suggest that bidders can indeed anticipate loser regret.

On the other hand, the bidders do not anticipate winner regret and hence do not reflect these feelings into their bids, i.e. the bids are not significantly different from the RNNE.

These results are indeed capable of explaining some other feedback experiments in the literature. For example, Ockenfels and Selten (2005), mentioned in our introduction, found that giving feedback on the losing bid lead to lower bids comparing to no feedback on the losing bid in every period of their repeated first price auction experiment. However, in the first period, the bids under different treatments did not differ but were above the RNNE. They showed that the impulse balance equilibrium theory can explain the later periods results but the first period result was remained unexplained. If we interpret their treatments in terms of regret, the loser regret is always in play since in their different treatments they always tell the winning bid. Their treatments differ in activation of winner regret. Hence, (1) since loser regret is active in both treatments, our theory will predict overbidding under both treatments; (2) since treatments differ only in stimulating winner regret and our experiment suggests that winner regret is not anticipated, we would predict not to see differences in bids under two treatments in the first period data of their experiment. Indeed, this is what they observe in the first period of their experiment, so our theory is capable of explaining the unexplained part of their data. Due to the one shot nature of our experiment, we attempt to explain their first period data. For the later periods they found that the bids in the feedback group (winner+loser regret) became lower than no feedback group (loser regret). This suggests that perhaps in repeated setups, the bidders may learn winner regret, although they cannot anticipate it before experiencing it.

Furthermore, Timothy N. Cason and Friedman (1997, 1999) were interested in the bids/asks in the call market. They defined two types of ex-post errors: (i) from missing out on a profitable transaction opportunity (error type m), and (ii) from adversely affecting the price of a realized transaction (error type p). They found that the error type m is more strongly reacted than error type p and reaction to error type p is almost negligible. They posit their finding as a puzzle. The Cason and Friedman analysis did not involve regret at all, but error type m and p can be interpreted, in our terminology, as loser and winner regret, respectively. Under this interpretation, their findings are in line with our results.

From a different point of view, regret might be related to the externalities where the utility of the bidders affected by some factors other than their own valuations and bids. Auctions with externalities is not a new concept, and it has been discussed extensively in the literature. For example, John Morgan, Ken Steigletz and George Reis (2003) considered the externality in the form of a spiteful motive. The utility of the winner affects the utility of the losing bidders as a negative externality. Alternatively, identity of the bidders may create an externality, in other words who won the object may affect the utility of the other bidders (see e.g. Philippe Jehiel, Benny Moldovanu and Ennio Stachetti, 1996, 1999; and Jehiel and Moldovanu, 2000).

The major distinction between the regret and externality literatures is that regret is an externality created by the bidder herself, rather than a spiteful motive. In our setting, the bidder is not dissatisfied by the identity of winner or the winner's payoff, but rather she is dissatisfied by losing the object at an affordable price. Nonetheless, our survey results suggest that envy is also significantly anticipated when the bidders thought that they were going to lose.

In conclusion, we considered an anticipated emotion, regret, in a game theoretical setup: first price auction. More generally, regret might be felt in any Bayesian game due to differences between ex-ante and ex-post optimal decisions. It might be a fruitful exercise to apply the regret idea to general Bayesian games.

Appendix A

LEMMA 1: *Incentive compatible equilibrium bidding strategy in a first price sealed bid auction with winner regret is a strictly increasing function.*

PROOF:

Let $b(.) : [\underline{v}, \overline{v}] \to \mathbb{R}$ be the equilibrium bidding function for a first price auction with winner regret. Let two valuations v_1, and v_2 be such that $v_2 > v_1$, b_1 and b_2 be the corresponding bids, and b^2 be the second highest bid.. Then since we are interested in incentive compatible bids, we have

$P(win\ with\ b_1)(v_1 - b_1 - h(b_1 - b^2)) \geq P(win\ with\ b_2)(v_1 - b_2 - h(b_2 - b^2))$

and

$P(win\ with\ b_2)(v_2 - b_2 - h(b_2 - b^2)) \geq P(win\ with\ b_1)(v_2 - b_1 - h(b_1 - b^2))$.

By adding up these two inequalities and rearranging the terms, we have

$[P(win\ with\ b_1) - P(win\ with\ b_2)]\,(v_1 - v_2) \geq 0$

Since $v_1 - v_2 < 0$, then $P(win\ with\ b_1) - P(win\ with\ b_2) \leq 0$. This gives $b_1 \leq b_2$. Moreover, $b_1 < b_2$ since otherwise if there exists an interval $[v_1, v_2]$ such that $b_1 = b_2 = b(v)$ for any $v \in [v_1, v_2]$ then $\widetilde{b}(v) = b(v) + \varepsilon$ for $v \in (v_1, v_2)$ is a profitable deviation given that all the opponents are bidding $b(v)$.

LEMMA 2: *In a first price sealed bid auction with winner regret, local and global incentive constraints (IC) are equivalent.*

PROOF:

It is trivially the case that global IC implies local IC.

The expected utility of a bidder who has valuation v_1 and bids as if her valuation is z is

$$EU(v_1, z) = P(win\ with\ b(z))\,[v_1 - b(z) - E[h(b(z) - b(X))|X < z]]$$
$$= F^{N-1}(z)[v_1 - b(z)] - \int_0^z h(b(z) - b(X))(N-1)F^{N-2}(X)f(X)dX.$$

Observe that the cross derivative of this EU is

$$EU_{zv} = \tfrac{\partial}{\partial z}F^{N-1}(z) = (N-1)F^{N-2}(z)f(z) > 0$$

To prove the converse of the statement, let the local IC constraint hold, then $\frac{\partial EU(v_1,z)}{\partial z}|_{z=v_1} = 0$.

Then for $y < v_1$

$$EU(v_1, v_1) - EU(v_1, y) = \int_y^{v_1} \tfrac{\partial EU}{\partial z}(v_1, z)dz$$
$$= \int_y^{v_1} \left(EU_z(v_1, z) - EU_z(z, z)\right)dz \qquad \text{since } EU_z(z,z) = 0 \text{ by local IC}$$
$$= \int_y^{v_1}\int_z^{v_1} EU_{zv}(k, z)dkdz > 0 \qquad \text{since } EU_{zv} > 0.$$

For $y > v_1$

$$EU(v_1, v_1) - EU(v_1, y) = -\int_{v_1}^{y} \tfrac{\partial EU}{\partial z}(v_1, z)dz$$
$$= -\int_{v_1}^{y} \left(EU_z(v_1, z) - EU_z(z, z)\right)dz \qquad \text{since } EU_z(z,z) = 0 \text{ by local IC}$$
$$= \int_{v_1}^{y}\int_{v_1}^{z} EU_{zv}(k, z)dkdz > 0 \qquad \text{since } EU_{zv} > 0.$$

Therefore, for every y $EU(v_1, v_1) > EU(v_1, y)$, i.e. global IC holds.

PROOF OF THEOREM 1:

Consider any representative bidder motivated by winner regret and participating in a first price auction. Let $b(\cdot)$ be her optimum incentive compatible bidding strategy. If we consider the symmetric equilibrium (hence the identity index of bidder can be dropped) and solve the problem in an incentive compatible way then the solution to the following problem gives the optimal bid:

$$\begin{aligned}
\max_w EU(v, b(w)) &= \max_w P(win)[v - b(w) - E[h(b(w) - b(X))|X < w]] \\
&= \max_w G(w)\{v - b(w) - E[h(b(w) - b(X))|X < w]\} \\
&= \max_w G(w) \left\{ v - b(w) - \frac{\int_{\underline{v}}^{w} [h(b(w) - b(X))G'(X)]d(X)}{G(w)} \right\}
\end{aligned}$$

where $G(w) = F^{N-1}(w)$. Above $P(win) = G(w)$ because the equilibrium bid function is increasing by Lemma 1.

Since the local and global IC are equivalent in this setting (by Lemma 2), the corresponding first order condition is: $\left.\frac{\partial EU(v, b(w))}{\partial w}\right|_{w=v} = 0.$

$$G'(v)[v - b(v)] - G(v)b'(v) - \int_{\underline{v}}^{v} [h'(b(v) - b(X))b'(v)G'(X)]d(X) = 0$$

$$G'(v)v = G'(v)b(v) + b'(v)G(v) + b'(v)\int_{\underline{v}}^{v} [h'(b(v) - b(X))G'(X)]d(X)$$

The solution of the above differential equation implicitly solves[7]

$$E[X|X < v] = b^{FP_{wr}}(v) + E_X[h(b^{FP_{wr}}(v) - b^{FP_{wr}}(X))|X < v].$$

LEMMA 3: *Incentive compatible equilibrium bidding strategy in a first price sealed bid auction with loser regret is a strictly increasing function.*

PROOF:

Let $b(.) : [\underline{v}, \overline{v}] \rightarrow \mathbb{R}$ be the equilibrium bidding function for a first price auction with loser regret. Let two valuations v_1, and v_2 be such that $v_2 > v_1$, b_1 and b_2 be the corresponding bids, and b^w be the winning bid. Since we are interested in incentive compatible bids, we have

$$
\begin{aligned}
&P(winwithb_1)(v_1 - b_1) + P(feelingloserregretwithb_1|b^w)(-g(v_1 - b^w)) \\
&\qquad \geq P(winwithb_2)(v_1 - b_2) + P(feelingloserregretwithb_2|b^w)(-g(v_1 - b^w))
\end{aligned}
$$

and

$$
\begin{aligned}
&P(winwithb_2)(v_2 - b_2) + P(feelingloserregretwithb_2|b^w)(-g(v_2 - b^w)) \\
&\qquad \geq P(winwithb_1)(v_2 - b_1) + P(feelingloserregretwithb_1|b^w)(-g(v_2 - b^w)).
\end{aligned}
$$

By adding up these two inequalities and rearranging the terms, we have

$$
\begin{aligned}
&\left[P(win\ with\ b_2) - P(win\ with\ b_1)\right](v_2 - v_1) \\
&\qquad + \left[P(feelingloserregretwithb_2|b^w) - P(feelingloserregretwithb_1|b^w)\right] \\
&\qquad\qquad \cdot (g(v_1 - b^w) - g(v_2 - b^w)) \geq 0
\end{aligned}
$$

then

$$[P(win\ with\ b_2) - P(win\ with\ b_1)]\,(v_2 - v_1)$$
$$+ [(1 - P(win\ with\ b_2) - P(b^w > v)) - (1 - P(win\ with\ b_1) - P(b^w > v))]$$
$$\cdot\,(g(v_1 - b^w) - g(v_2 - b^w)) \geq 0$$

then

$$[P(win\ with\ b_2) - P(win\ with\ b_1)]\,[(v_2 - v_1) + (g(v_2 - b^w) - g(v_1 - b^w))] \geq 0$$

Since $v_2 - v_1 > 0$ and $g(v_2 - b^w) - g(v_1 - b^w) > 0$ then $P(win\ with\ b_2) - P(win\ with\ b_1) \geq 0$. This gives $b_2 \geq b_1$. Moreover, $b_2 > b_1$ since otherwise if there exists an interval $[v_1, v_2]$ such that $b_1 = b_2 = b(v)$ for any $v \in [v_1, v_2]$ then $\widetilde{b}(v) = b(v) + \varepsilon$ for $v \in (v_1, v_2)$ is a profitable deviation given that all the opponents are bidding $b(v)$.

LEMMA 4: *In a first price sealed bid auction with loser regret, local and global incentive constraints (IC) are equivalent.*

PROOF:

The proof of this statement is exactly the same as the proof of Lemma 2 once we show that under loser regret condition the cross derivative of expected utility is still positive, i.e. $EU_{zv}(v_1, z) > 0$. The expected utility of a bidder who has valuation v_1 and bids as if her valuation is z is

$$\begin{aligned}
EU(v_1, z) &= P(win\ with\ b(z))[v_1 - b(z) - E[P(feeling\ loser\ regret\ with\ b(z)|b^w)g(v_1 - b^w)]] \\
&= F^{N-1}(z)(v_1 - b(z)) - \int_z^{b^{-1}(v_1)} g(v_1 - b(s))NF^{N-1}(s)f(s)ds.
\end{aligned}$$

Then

$$EU_{zv} = \frac{\partial}{\partial v}\left((N-1)F^{N-2}(z)f(z)(v_1 - b(z)) - b'(z)F^{N-1}(z) + g(v_1 - b(z))NF^{N-1}(z)f(z)\right)$$

$$= (N-1)F^{N-2}(z)f(z) + g'(v_1 - b(z))NF^{N-1}(z)f(z) > 0.$$

The last inequality holds since g is assumed to be increasing.

Now applying the same argument as in the proof of Lemma 2, one can immediately show that global and local ICs are equivalent in a first price sealed bid auction with loser regret.

PROOF OF THEOREM 2:

Any representative bidder with loser regret in FP solves the following expected utility maximization problem to decide on the optimal incentive compatible bidding strategy:

$$\begin{aligned}
\max_s EU(v, b(s)) &= \max_s \{P(win) \cdot [v - b(s)] \\
&\quad - P(\text{feeling loser regret}) \cdot E[g(v - b^w)|b(s) < b^w < v]\} \\
&= \max_s \{F^{N-1}(s) \cdot [v - b(s)] \\
&\quad - P(b(s) < b^w < v) \cdot E[g(v - b^w))|b(s) < b^w < v]\} \\
&= \max_s \{F^{N-1}(s) \cdot [v - b(s)] \\
&\quad - \int_s^{b^{-1}(v)} [\ g(v - b(y))(N-1)F^{N-2}(y)f(y)]d(y)\}
\end{aligned}$$

where b^w is the winning bid. Here $P(win) = F^{N-1}(s)$ since the equilibrium bid function is increasing by Lemma 3.

Since the local and global IC are equivalent in this setting (by Lemma 4), the corresponding first order condition is: $\left.\frac{\partial EU(v,b(s))}{\partial s}\right|_{s=v} = 0.$

$$(N-1)F^{N-2}(v)f(v)[v-b(v)] - F^{N-1}(v)b'(v) + g(v-b(v))(N-1)F^{N-2}(v)f(v) = 0$$

$$\begin{aligned}(N-1)F^{N-2}(v)f(v)v &= b(v)(N-1)F^{N-2}(v)f(v) + b'(v)F^{N-1}(v) \\ &\quad -g(v-b(v))(N-1)F^{N-2}(v)f(v)\end{aligned}$$

The solution of above differential equation implicitly solves[8]

$E_X[X|X<v] = b^{FP_{lr}}(v) - E_X[g(X - b^{FP_{lr}}(X))|X<v]$

where X is a random variable which is a maximum of N-1 random variables.

PROOF OF THEOREM 3:

For any bidder i the bid $b_i = v_i$ is a dominant strategy. Consider another action of player i and call it x_i. If $\max_{j\neq i} b_j \geq v_i$ then by bidding x_i, bidder i either gets the object and receives a nonpositive payoff or does not get the object and her payoff is $-g(v_i - b^w) = 0$, since $b^w = \max_{j\neq i} b_j \geq v_i$. While by bidding b_i, she guarantees herself a payoff of zero (observe that if she loses by bidding b_i, this will not create loser regret since $v_i > b^w > b_i$ is never a case). If $\max_{j\neq i} b_j < v_i$ then by bidding b_i, player i obtains the good at the price of $\max_{j\neq i} b_j$, while bidding x_i either she wins and gets the same utility or loses and gets non positive utility because of loser regret ($-g(v_i - b^w) \leq 0$ since $v_i > b^w > x_i$).

Appendix B

Instructions for the Experiment:

Introduction

This is an experiment on the economics of market decision making. The following instructions are simple, and if you follow them carefully and make good decisions, you may earn a considerable amount of money.

During the experiment your payoff will be in experimental dollars that will be converted into dollars at the end of the experiment at the following rate:

2 Experimental Dollars = 1 US Dollar

Payments will be made privately at the end of the experiment.

Your Experimental Task

As you arrive in the lab, you will be randomly divided into markets consisting of 4 people each. Your role in this market is as a bidder to bid for a fictitious commodity.

At the beginning of the experiment, you will receive a sheet of paper on which you will see a list of 10 numbers. Each number is between 0 and 100 Experimental Dollars (randomly drawn with equal probability) and has been rounded to the nearest cent. Each number represents a possible valuation that you may have for the fictitious commodity. The process of selecting possible valuations is exactly the same for everyone. So, each member of your market will have a different list of 10 numbers; each is drawn randomly and independent of yours.

For each of your 10 possible valuations, you should write down a bid in the space provided on the sheet of paper. After all of the participants have chosen their bids for each of the 10 possible values, the lists will be collected.

At this point we will determine each player's actual value. The process is as follows. The experimenter has 10 cards numbered from 1 to 10. At the end of the experiment, one of you will randomly select one of these cards, and the number selected will determine each subject's valuation. For example, if the number 4 is selected, it means that your true valuation is given by the fourth number that was on your list, and the bid is the corresponding fourth number that you wrote. Hence, you should enter each bid as if that value is going to be your true value.

We are now ready to determine the winner and the payoffs. The person in each market with the highest bid wins the fictitious good and pays the exact amount of his or her bid. In the case of a tie, the winner will be determined randomly by rolling a dice. If you are the highest bidder, you will earn the difference between your true value and your bid. If you are not the highest bidder, you will not earn any money. Hence, your earnings can be described as follows:

Earnings = your true value - your bid

(if you are the highest bidder or win the draw in case of a tie)

Earnings = 0

(if you are the low bidder or lose the draw in case of a tie)

Are there any questions?

Information Structures:

1. *The following is given only to the participants in the loser regret condition:*

After the lists have been collected and a winner determined, you will learn whether you are the winner or not, and also **YOU WILL LEARN THE HIGHEST BID.** Any other information regarding the bids of the other bidders will not be given.

Now, please write your bids for each possible valuation.

2. *The following is given only to the participants in the winner regret condition:*

After the lists have been collected and a winner determined,

if you are the winner, you will learn that you won**,** and also **you will learn the SECOND HIGHEST BID**;

if you are not the winner, you will only learn that you did not win. You will not learn any additional information.

Now, please write your bids for each possible valuation.

3. *The following is given only to the participants in the no regret condition:*

After the lists have been collected and a winner determined, **you will only learn whether you are the winner or not.** You will not learn any additional information.

Now, please write your bids for each possible valuation.

An Example of Bidding List:

	Possible Valuations	*Your Bids*
1	98.38	
2	48.07	
3	94.37	
4	61.86	
5	61.23	
6	11.55	
7	45.28	
8	77.54	
9	88.43	
10	22.16	

Survey:

1. *Loser regret condition:*

Suppose at the end you are not the winner, and you learn the highest bid. Please rate the intensity of the emotions listed below you anticipate experiencing in that situation:

2. *Winner regret condition:*

Suppose at the end you are the winner, and you learn the second highest bid. Please rate the intensity of the emotions listed below you anticipate experiencing in that situation:

3. *No feedback condition:*

a. Winning:

Suppose at the end you are the winner, and you did not learn any additional information. Please rate the intensity of the emotions listed below you anticipate experiencing in that situation:

b. Losing:

Suppose at the end you are not the winner, and you did not learn any additional information. Please rate the intensity of the emotions listed below you anticipate experiencing in that situation:

Survey Table:

	1 Not at all	2	3	4	5	6	7	8	9 Very much
Anger									
Elation									
Envy									
Happiness									
Irritation									
Regret									
Relief									
Sadness									

REFERENCES

Bell, David E. "Regret in Decision Making under Uncertainty." *Operations Research*, 1982, 30, pp. 961-981.

Benartzi, Shlomo and Thaler, Richard H. "Myopic Loss Aversion and the Equity Premium Puzzle." *Quarterly Journal of Economics*, February 1995, 110(1), pp. 73-92.

Cason, Timothy N. and Friedman, Daniel. "Learning in a Laboratory Market with Random Supply and Demand." *Experimental Econometrics*, 1999, 2, pp. 77-98.

Cason, Timothy N. and Friedman, Daniel. "Price Formation in Single Call Markets." *Econometrica*, 1997, 65, pp. 311-345.

Coppinger, Vicki M.; Smith, Vernon L. and Titus, Jon A.. "Incentives and Behavior in English, Dutch and Sealed-Bid Auctions." *Economic Inquiry*, 1980, 18(1), pp. 1-22.

Cox, James C.; Roberson, Bruce and Smith, Vernon L. "Theory and Behavior of Single Object Auctions," in Vernon L. Smith, ed., *Research in experimental economics*, Vol. 2. Greenwich, Conn: JAI Press, 1982, pp. 1-43.

Cox, James C.; Smith, Vernon L. and Walker, James M. "Theory and Individual Behavior of First-Price Auctions." *Journal of Risk and Uncertainty*, March 1988, 1(1), pp. 61-99.

Cox, James C.; Smith, Vernon L. and Walker, James M. "Theory and Misbehavior of First-Price Auctions: Comment." *American Economic Review*, December 1992, 82(5), pp. 1392-1412.

Crawford, Vincent P. and Iriberri, Nagore. "Level-k Auctions: Can a Non-Equilibrium Model of Strategic Thinking Explain the Winner's Curse and Overbiding in Private-Value Auctions?" Unpublished Manuscript, 2005.

Engelbrecht-Wiggans, Richard. "The Effect of Regret on Optimal Bidding in Auctions." *Management Science*, 1989, 35(6), pp. 685-692.

Friedman, Daniel. "Theory and Misbehavior of First-Price Auctions: Comment." *American Economic Review*, December 1992, 82(5), pp. 1374-1378.

Goeree, Jacob K.; Holt, Charles A. and Palfrey, Thomas R. "Quantal response Equilibrium and Overbidding in Private Value Auctions." *Journal of Economic Theory*, 2002, 104, pp. 247-272.

Harrison, Glenn W. "Theory and Misbehavior of First-Price Auctions." *American Economic Review*, September, 1989, 79(4), pp. 749-762.

Isaac, R. Mark and Walker, James, M. "Information and Conspiracy in Sealed Bid Auctions." *Journal of Economic Behavior and Organization*, June 1985, 6, pp. 139-159.

Jehiel, Philippe and Moldovanu, Benny. "Efficient Design with Interdependent Valuations." *Econometrica*, 2000, 69, pp. 1237–1260.

Jehiel, Philippe; Moldovanu, Benny and Stacchetti, Ennio. "How (Not) to Sell NuclearWeapons." *American Economic Review*, 1996, 86, pp. 814–829.

Jehiel, Philippe; Moldovanu, Benny and Stacchetti, Ennio. "Multidimensional

Mechanism Design for Auctions with Externalities." *Journal of Economic Theory*, 1999, 85, pp. 258–293.

Kagel, John H. "Auctions: A Survey of Experimental Research," in John H. Kagel and Alvin E. Roth, eds., *The Handbook of Experimental Economics.* Princeton: Princeton University Press, 1995, pp. 501-585.

Kagel, John H.; Harstad, Ronald M. and Levin, Dan. "Information Impact and Allocation Rules in Auctions with Affiliated Private Values: A Laboratory Study." *Econometrica*, 1987, 55, pp 1275-1304.

Kagel, John H. and Levin, Dan. "Independent Private Value Auctions: Bidder Behavior in First-, Second- and Third-Price Auctions with Varying Number of Bidders." *Economic Journal*, 1993, 103, pp. 868-879.

Kagel, John H. and Roth Alvin E. "Theory and Misbehavior in First-Price Auctions: Comment." *American Economic Review*, December 1992, 82(5), pp. 1379-1391.

Kahneman, Daniel; Knetsch, Jack L. and Thaler, Richard H.. "Experimental Tests of the Endowment Effect and the Coase Theorem." *Journal of Political Economics*, December 1990, 98(6), pp. 1325-1348.

Kwasnica, Anthony M. and Katok, Elena. "The Effect of Timing on Bid Increments in Ascending Auctions." Unpublished Manuscript, 2005.

Loomes, Graham and Sugden, Robert. "Regret Theory: An Alternative Theory of Rational Choice under Uncertainty." *Economic Journal*, 1982, 92, pp. 805-824.

Merlo, Antonio and Schotter, Andrew. "Theory and Misbehavior of First-Price Auctions: Comment." *American Economic Review*, December 1992, 82(5), pp. 1413-1425.

Morgan, John; Steiglitz, Ken and Reis, George. "The Spite Motive and Equilibrium Behavior in Auctions." *Contributions to Economic Analysis & Policy*, 2003, 2(1), Article 5.

Ockenfels, Axel and Selten, Reinhard. "Impulse Balance Equilibrium and Feedback in First Price Auctions." *Games and Economic Behavior*, April 2005, 51(1), pp. 155-170.

Ritov, Ilana. "Probability of Regret: Anticipation of Uncertainty Resolution in Choice." *Organizational Behavior and Human Decision Processes*, 1996, 66, pp. 228–236.

Tversky, Amos and Kahneman, Daniel. "Loss Aversion in Riskless Choice: A Reference-Dependent Model." *Quarterly Journal of Economics*, November 1991, 106(4), pp. 1039-1061.

Vickrey, William. "Counterspeculation, Auctions, and Competitive Sealed Tenders." *Journal of Finance*, March 1961, 16(1), pp. 8-37.

Zeelenberg, Marcel. "Anticipated Regret, Expected Feedback and Behavioral Decision-Making." *Journal of Behavioral Decision Making*, 1999, 12, pp. 93–106.

Zeelenberg, Marcel and Pieters, Rik. "Consequences of Regret Aversion in Real Life: The Case of the Dutch Postcode Lottery." *Organizational Behavior and Human Decision Processes*, 2004, 93(2), pp. 155–168.

NOTES:

1. In a single person decision making problem, regret is capable of explaining some paradoxes, such as Allais paradox and preference reversal phenomenon (see Bell (1982) for a detailed analysis).

2. See Appendix B for the instructions of the experiment.

3. Drawing values independently and identically from a uniform distribution controls for "level-k" model explanation of any overbidding behavior (Crawford and Iriberri, 2005).

4. A subject in the laboratory was asked to pick a card without looking from a deck of cards numbered 1 to 10. The number on the selected card determined which valuations, and the corresponding bids in the submitted lists were going to be considered as the true valuations and actual bids of the subjects. For example if the randomly selected card said 4 on it, then the 4^{th} line in the lists became the true valuation of each participant.

5. The conversion rate was 1USD = 2 Experimental Dollars.

6.The results are robust when the estimations are done without calculating average bids for each value. When the individual bids are regressed onto the underlying valuations, we estimated the coefficients as .77 (winner's regret), .88 (loser's regret) , .79 (no feedback).

7. To see this, take the derivative of

$$\frac{\int_{\underline{v}}^{v} XG'(X)dX}{G(v)} = b^{FP_{wr}}(v) + E[h(b^{FP_{wr}}(v) - b^{FP_{wr}}(X))|X < v] \text{ with respect to } v.$$

8. To see this take the derivative of $\frac{\int_{\underline{v}}^{v} X(N-1)F^{N-2}(X)f(X)dX}{F^{N-1}(v)} = b^{FP_{lr}}(v) - \frac{\int_{\underline{v}}^{v} g(y-b(y))(N-1)F^{N-2}(y)f(y)dy}{F^{N-1}(v)}$ with respect to v.

List of Figures

Table 1

Linear Estimations of Bidding Strategies under Each Condition

	Winner Regret	Loser Regret	No Regret
Slope	0.77	0.87	0.79
	(0.012)	(0.01)	(0.007)
Lower 95 percent	0.748	0.852	0.775
Upper 95 percent	0.796	0.893	0.805

Table 2
Averages and Standard Deviations of the Intensities of Emotions under Each Condition

		Anger	Elation	Envy	Happiness	Irritation	**Regret**	Relief	Sadness
Loser Regret	Avg	3.42	2.08	4.61	1.81	4.56	**6.19**	1.89	2.86
	SD	(1.933)	(1.888)	(2.060)	(1.582)	(2.076)	(2.340)	(1.326)	(1.854)
Winner Regret	Avg	1.72	4.94	1.66	6.19	2.31	**2.69**	4.75	1.38
	SD	(1.250)	(2.526)	(1.405)	(2.334)	(1.925)	(2.055)	(2.356)	(0.871)
No Regret (win)	Avg	1.25	5.64	1.25	7.14	1.57	**1.39**	5.39	1.07
	SD	(0.701)	(2.468)	(0.928)	(1.820)	(1.399)	(0.994)	(2.347)	(0.262)
No Regret (lose)	Avg	2.86	1.21	4	1.32	3	**3.89**	1.54	2.71
	SD	(2.206)	(0.499)	(1.905)	(0.772)	(2.000)	(2.558)	(1.644)	(2.016)

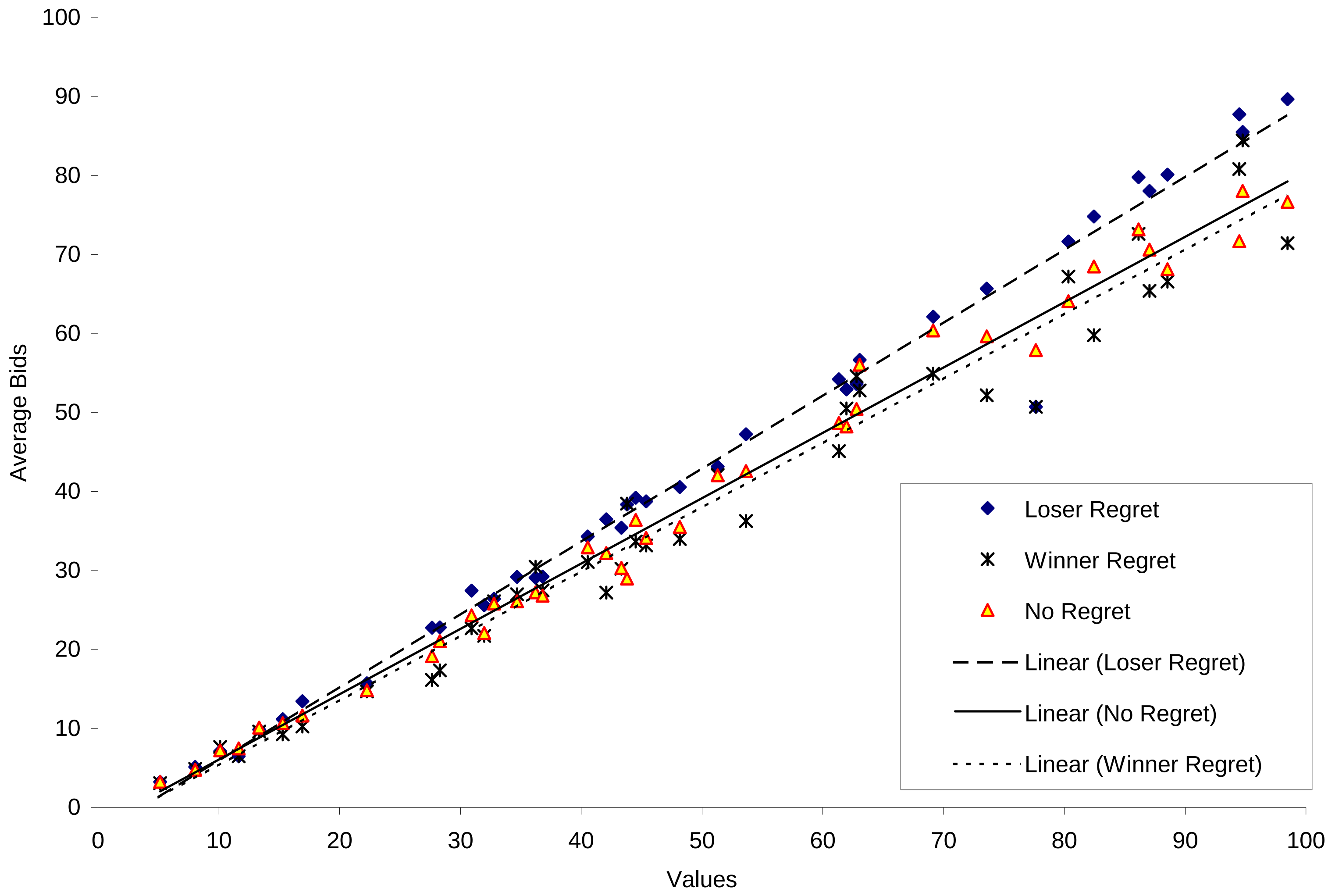

Figure 1. The Average Bids for the Corresponding Valuations for No Feedback, Winner Regret, and Loser Regret Conditions

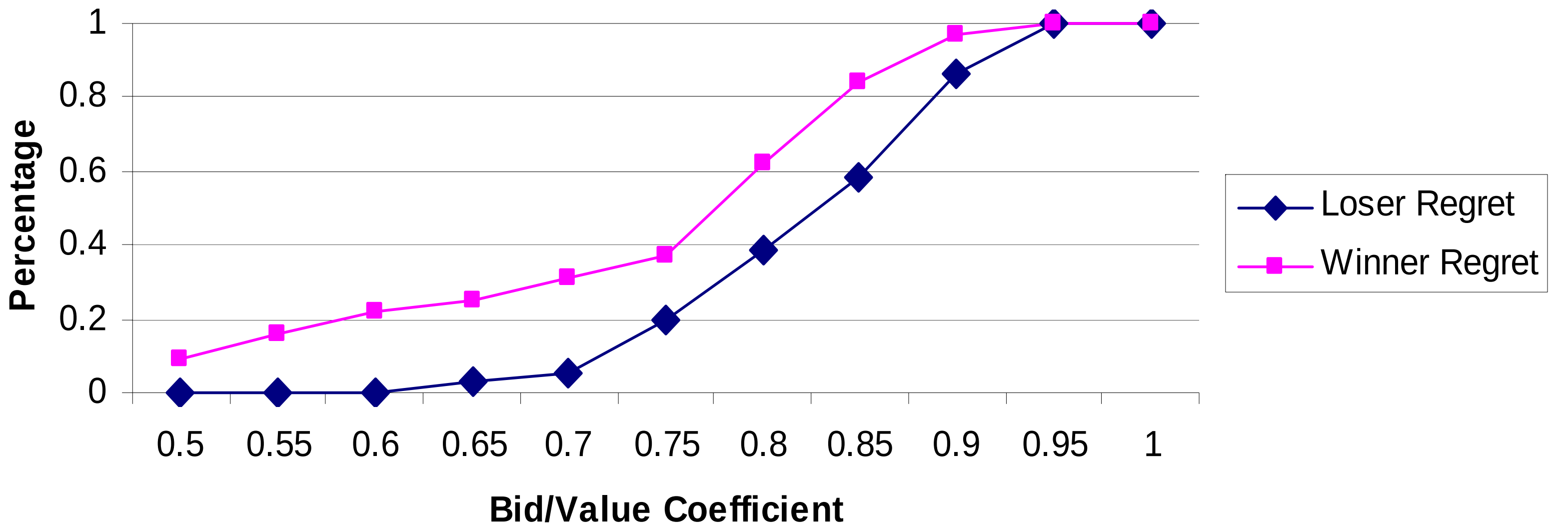

Figure 2. CDFs of Individual Bid/Value Coefficients