Auctions with Anticipated Regret: Theory and Experiment

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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, namely, anticipated regret.

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 the seminal papers of James C. Cox, Bruce Roberson, and Vernon L. Smith 1982 and Cox, Smith, and James M. Walker 1988; and the detailed survey of John H. Kagel 1995).

The underlying motive of this paper is that, in a game with incomplete information, what seems the best action ex ante may not turn out to be the best one ex post (after the information is revealed). This discrepancy may cause regret, and the decision maker reflects this regret concern in her decision if she can anticipate regret (see Graham Loomes and Robert Sugden 1982; and David E. Bell 1982).[1]

Auctions are a good way to observe such discrepancies. 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 that she lost because the highest bid was $901. Bidding $900 is not the best bid ex post because she could have won the object in a profitable way by bidding $902. 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 felt only by the losing bidders, we will call it "loser regret."

The scenario above is not the only way that regret can be felt in an auction. Consider the scenario again, but this time after she bids $900, the bidder learns not only that she is the highest bidder, but also that the second highest bid is $50. Again, bidding $900 is not the best bid ex post, e.g., she would still win with a bid of $51 but pay less. Since this regret may be experienced only by the winner, we will call it "winner regret."

In this paper we argue that if the bidders know they are going to receive some feedback, they may anticipate 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, they will overbid. First we theoretically show that these behaviors are observed in the equilibrium for 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 in their bids.

The relevance of feedback regarding the bids of the others in first price sealed bid auctions was initially studied by R. Mark Isaac and Walker (1985). They observed higher bids in the group that was informed about only the highest bid. Similarly, Axel Ockenfels and Reinhard Selten (2005) investigated the effect of feedback on bidding behavior in repeated first price auctions (see also Martin Dufwenberg and Uri Gneezy 2002). Further, they found that bids in the group that was informed about all the submitted bids were lower than those in the other group, which was informed only of the winning bid in every

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

period except the first one. They argued that the concept of weighted impulse balance equilibrium is capable of explaining the results, except behavior in the first period. In the concluding section of our paper, we will discuss that our model is capable of explaining their first period results as well.

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

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). Regret in auction settings was 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.

The most common explanation for the overbidding phenomenon in first price auctions is risk aversion (see Cox, Smith, and Walker 1988). However, there is no consensus on this explanation (see, e.g., Kagel and Dan Levin 1993 for overbidding in third-price auctions with respect to the RNNE, which goes against the implications of risk aversion in such a setting; see also Glenn W. Harrison 1989).[2] The reason for the wide acceptance of risk aversion, despite its problems, seems to be that other proposed explanations, such as the joy of winning, are not powerful enough to explain the experimental findings as compared 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 (2006) provided a theoretical analysis of overbidding in general first price auctions by using a level-k thinking model, but the implication of this theory coincides with RNNE for independent-private-value first price auctions with the uniform value distributions.

In Section I, we characterize the symmetric equilibrium bidding strategy under loser and winner regret in first price sealed bid auctions. In Section II, we conduct an experiment to check if bidders change their strategies in a first price auction depending on the information that can potentially make them anticipate regret. Unlike the standard lab auction experiments, ours is a one-shot design 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 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 consider other well-known auctions, namely second price, English, and Dutch auctions. Section V concludes. The proofs of all formal conclusions are available in Web Appendix A (http://www.e-aer.org/data/sept07/20050951_app.zip).

I. Model

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

Suppose the seller sells the object by a first price sealed bid auction (FP), i.e., 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.

A. *Loser Regret in a First Price Sealed Bid Auction*

Suppose, at the end of FP, the bidders learn not only their winning/losing position but also,

[2] Cox, Smith, and Walker (1992) and Daniel Friedman (1992) highlighted the theoretical problems in Harrison's critique (for additional shortcomings of Harrison's critique, see also Kagel and Alvin E. Roth 1992; and Antonio Merlo and Andrew Schotter 1992).

if they lose, they learn the winning bid. The utility of a losing bidder depends on the regret she feels. If the winning bid is less than the valuation of a losing bidder, then the ex post best action for this bidder is bidding a little more than the winning bid. Therefore, loser regret is defined as a function of the difference between her valuation and the winning bid if the winning bid is affordable.

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

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

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, and differentiable. The bigger the difference between her value and the winning bid, the more a bidder may feel loser regret. Moreover, assume $g(x) = 0$ for all $x \leq 0$ because if a bidder loses and learns the 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.

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 their too low 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 1: *In a first price sealed bid auction with loser regret, the symmetric equilibrium bidding strategy ($b^{FP_{lr}}(\cdot) : [\underline{v}, \bar{v}] \to [0, \infty)$) must satisfy the following condition:*

$$(1) \qquad E_X[X|X < v] = b^{FP_{lr}}(v) - E_X[g(X - b^{FP_{lr}}(X))|X < v],$$

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

REMARK 1: *The left-hand side of equation (1) 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 standard theory suggests, i.e., $b^{FP_{lr}}(v) \geq b^{FP}(v)$ for all $v \in [\underline{v}, \bar{v}]$ since $g(\cdot)$ is assumed to be nonnegative.*

REMARK 2: *Loser regret concerns of bidders increase the seller's expected revenue in FP since the equilibrium bidding strategy will be higher, as explained in Remark 1.*

B. *Winner Regret in First Price Sealed Bid Auctions*

Suppose at the end of the auction, bidders know not only their winning/losing position but also, if they win, the submitted second highest bid. 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. 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:

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

where b^2 is the second highest bid and $h(\cdot)$: $\mathbb{R}_+ \to \mathbb{R}_+$ is the winner regret function. 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 by bidding 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.

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, individuals may be afraid of bidding too aggressively.

THEOREM 2: *In a first price sealed bid auction with winner regret, the symmetric equilibrium* *bidding strategy* ($b^{FP_{wr}}(\cdot) : [\underline{v}, \bar{v}] \to [0, \infty)$) *must satisfy the following condition:*

$$(2) \qquad E_X[X|X < v] = b^{FP_{wr}}(v) + E_X[h(b^{FP_{wr}}(v) - b^{FP_{wr}}(X))|X < v],$$

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

REMARK 3: *The left-hand side of equation (2) 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 the RNNE, i.e.,* $b^{FP_{wr}}(v) \leq b^{FP}(v)$ *for all* $v \in [\underline{v}, \bar{v}]$ *since* $h(.)$ *is assumed to be nonnegative.*

REMARK 4: *Winner regret concerns of bidders decrease the seller's expected revenue in FP since the equilibrium bidding strategy will be lower, as explained in Remark 3.*

II. A First Price Auction Experiment

In Section I, we showed that winner regret and loser regret have different implications for 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 in 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 create three conditions that differ only in terms of information structures. In the no feedback condition, 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 those in the no feedback condition, and the bids in the winner regret condition will be lower than those in the no feedback condition.

Regret is a feeling one might experience after the action is taken and the uncertainty of the foregone actions is also resolved. Therefore, someone facing the same decision in a repeated fashion might reflect the regret of the previous round on the decision of the next round. Our theory relies, however, 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. In order to have more than one data point from each subject in a one-shot auction experiment, we propose a variation of the strategy method, which we call the "bid on list method." In this method, each subject reports bids for several different valuations. The details of this method will be explained later.

A. *Method*

The experiments were run at the New York University Center for Experimental Social Science (CESS). All participants were undergraduate students at New York University. The experiment involved six 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.[3]

In our auction experiment, we created groups of four bidders and gave each of them a list of ten possible valuations. Different lists were given to each of the four 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.[4] Additionally, the participants were informed that only one of those ten numbers in

[3] Web Appendix B gives instructions for the experiment, information structures, an example of a bidding list, and the survey.

[4] Drawing values independently and identically from a uniform distribution controls for "level-k" model explanation of any overbidding behavior (see Crawford and Iriberri 2006).

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 were the correct valuation of the object for them. The participants were told that after everyone submitted their bids, one valuation would be randomly selected[5] 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.[6]

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

Condition 1 (No feedback): Participants were told 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): Participants were told 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): Participants were told 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. In this survey, we listed a set of emotions and asked the subjects to rate the intensity of emotions that they felt after they received the relevant information. The ratings were between 1 and 9, where 1 indicated "not at all" and 9 indicated "very much." The survey did not include any other questions.

TABLE 1—LINEAR ESTIMATIONS OF BIDDING STRATEGIES UNDER EACH CONDITION

	Winner regret	Loser regret	No regret
Slope	0.77	0.87	0.79
	(0.011)	(0.01)	(0.007)
Lower 95 percent	0.745	0.852	0.775
Upper 95 percent	0.792	0.893	0.805

B. *Results*

For each condition, the averages of the bids corresponding to the same valuations were calculated. Figure 1 plots the average bids for the corresponding valuations for no feedback, winner regret, and loser regret. 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 0.87, which is significantly higher than that under winner regret, which is 0.77 (see Table 1, columns 1 and 2), 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 2 and 3), since the 95 percent confidence intervals of each estimate do not overlap. There is no significant difference, however, between the no feedback and winner regret conditions (see Table 1, columns 1 and 3).[7]

Additionally, the averages of the emotions under each condition are 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 define a typical variable for each individual to measure how she shades her value

[5] 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 fourth line in the lists became the true valuation of each participant.

[6] The conversion rate was 1USD = 2 Experimental Dollars.

[7] 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 0.77 (winner's regret), 0.88 (loser's regret), and 0.79 (no feedback). Figures demonstrating the individual bids for each treatment are available online.

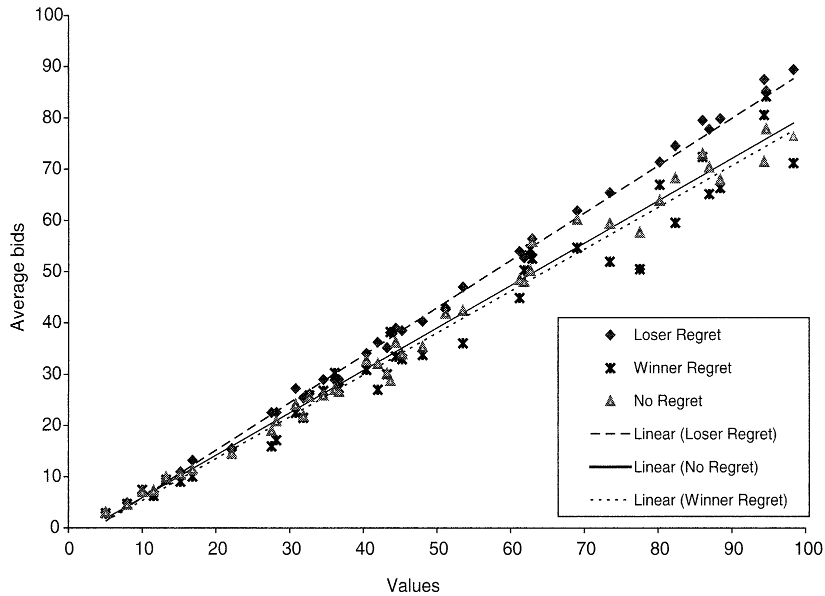

Figure 1. The Average Bids for the Corresponding Valuations for No Feedback, Winner Regret, and Loser Regret Conditions

while bidding. To generate this variable for a given subject, first we calculated the bid/value ratios for the subject's bid-value pair and then take the average of these ratios. We call this variable the individual bid/value coefficient. Figure 2 demonstrates the cumulative distribution functions (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 have the property that under the loser regret treatment the bid/value coefficients are higher than the winner regret coefficients. Observe from Figure 2 that in the winner regret condition, 31 percent of the subjects have bid/value coefficients below 0.7. In the loser regret condition, however, this percentage is 5. This means that the loser regret condition made most of the subjects bid aggressively. Additionally, these coefficients are dense around the estimated slope of the bidding function (0.87) for the loser regret condition (80 percent of the subjects have coefficients between 0.75 and 0.95). 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 vary quite a bit.

III. Combining Experimental Results with Theory

In this section, we will try to explain these experimental results using our theory. To do this, we need to determine the RNNE for FP in the traditional theory and use it as a benchmark to detect overbidding/underbidding behavior if there is any. 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 four bidders whose valuations are drawn from $[0,100]$ uniformly, this equilibrium bidding strategy corresponds to $b^*(v) = 0.75v$.

In the loser regret condition, the estimated bidding strategy is $\widehat{b}^{FP_{lr}} = 0.87v$, which is significantly above the RNNE bidding strategy. This is in line with our theoretical predictions (see Remark 1). In the winner regret condition, however, the estimated bidding strategy is $\widehat{b}^{FP_{wr}} = 0.77v$, 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

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	4.0	1.32	3.0	**3.89**	1.54	2.71
	SD	(2.206)	(0.499)	(1.905)	(0.772)	(2.000)	(2.558)	(1.644)	(2.016)

this anticipated loser regret in their bids, and hence overbidding in first price auctions can be explained by the loser regret concern of bidders. Bidders do not, however, anticipate winner regret, and they do not reflect this concern in their bids.

At this point it is important to look at the survey findings because Bell (1982) argues that regret has to be anticipated by a decision maker in order to be reflected in her decision. Table 2 indicates that the average intensity of anticipated regret under the 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. Hence, the absence of anticipation of winner regret, i.e., $h(\cdot) = 0$;, may be the reason for not observing underbidding.

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:

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

where $\alpha \geq 0$.

Applying Theorem 1 to $N = 4$ with valuations distributed uniformly on $[0,100]$, 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 of 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 ∞, i.e., the bidder is very 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 $\widehat{b}^{FP_{lr}} = 0.87v$. By solving $[(3 + 3\widehat{\alpha})/(4 + 3\widehat{\alpha})]v = 0.87v$, 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 nonnegative function.

Estimating the loser regret coefficient $\widehat{\alpha} > 1$ suggests that marginal effect of disutility from regret is higher in absolute value than marginal effect of monetary utility. Although it is a surprising finding, our estimate of the 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). In a theory that puts greater weight on an emotion than on monetary payoff in the utility, a money pumping argument can be developed in order to avoid the negative effect of that emotion. Perhaps with experience loser regret coefficient drops below 1, but as long as it is positive, overbidding will be observed.[8] It may be a fruitful exercise to look at how the loser regret coefficient evolves by experience.

[8] We are thankful to the coeditor and one of the referees for pointing this out.

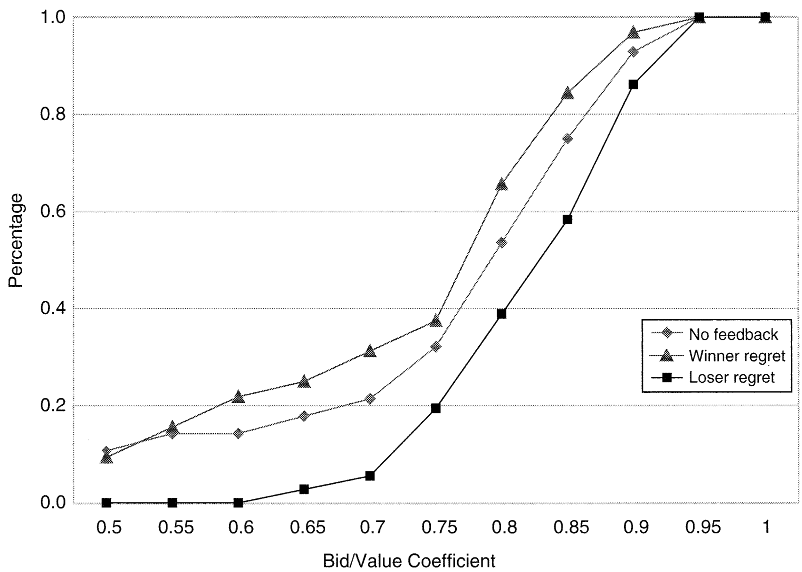

FIGURE 2. CDFs OF INDIVIDUAL BID/VALUE COEFFICIENTS

Some further analysis can be carried out in order to relate the survey data to individual bidding behavior. For the subjects in the loser regret treatment, the correlation between the intensity of regret they marked in the survey and their average individual bid/value coefficients is 0.26 (with $t = 1.559$, $p < 0.1$). Since one may think that the measure of intensity of an emotion can be a subjective issue, we created a dummy variable which is 1 for individuals who marked their regret level above the group average and 0 otherwise. This new variable is also found to be positively correlated with the individual bid/value coefficients. We found the correlation between these two to be 0.33 (with $t = 2.061$, $p < 0.05$). 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 0.43 (with $t = 9.084$, $p < 0.01$). 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. Additionally, for each individual in 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 0.33 (with $t = 2.058$, $p < 0$ $.05$). 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 the bidding function is 0.79, significantly higher than what the RNNE suggests (0.75). Perhaps a bidder in the no feedback condition feels loser regret *in expectation* because she can calculate the winning bid in expectation given that she lost. 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, they may also be capable of anticipating loser regret *in expectation*, and therefore still bid higher under the no feedback condition. It is worthwhile to note that the subjects in the no feedback condition reported in the survey that that they would feel more regret when they lose (3.89) than when they win (1.39).

IV. Further Discussion

Vickrey (1961) showed the revenue equivalence among four well-known auctions: first price, second price sealed bid, English, and Dutch. Now we 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., 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 affect only their winning/losing positions. So, winner regret will not change the form of utility.

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 at which no further price increases are made. Similar to SP, in an 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.

The Dutch auction is a descending price auction in which a public price clock starts out at a high level and falls until the first participant accepts to pay the price. 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. Here, we do not want to diverge from the regret theory in which information regarding the foregone alternative has to be realized in order to consider regret (see Bell 1982). It is possible, however, to consider regret *in expectation,* which would lead to similar analysis in the FP (recall the discussion at the end of Section III).

REMARK 5: *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 4, 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 the same in second price, English, and Dutch auctions.*

B. *Loser Regret in Other Auctions*

Unlike the winner regret, 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 lower than her bid. This does not happen in the equilibrium, however, 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* $v \in [\underline{v}, \bar{v}]$.

Unlike the analysis under winner regret, this time loser regret may be felt in a Dutch auction because information on the winning bid is known. 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 bid their true values, so the winning bid will not be affordable for the ones who lost the auction in the equilibrium.

REMARK 6: *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. The loser regret can, however, 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 auctions.*

C. *Combining Theory with Experiments in Other Auctions*

The experimental literature suggests that bids in English auctions 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 those of 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., findings.

In early Dutch auction studies, it has been found that bids are lower than those in first price auctions. Recently, however, 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 auctions become as high as those in first price auctions. 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 anticipation of loser regret in Kwasnica and Katok's experiment. In other words, as the bidders wait longer for the clock, they will have more time to anticipate loser regret. If, however, there is not enough time, they may not anticipate loser regret and may bid less in comparison to the first price auction.

V. Conclusion

In this paper, we argue that overbidding in first price auctions is derived from the anticipation of loser regret. Experimental results suggest that bidders can, indeed, anticipate loser regret. On the other hand, in the experiment, the bidders did not anticipate winner regret and hence did not reflect these feelings in their bids.

These results are indeed capable of explaining some other feedback experiments in the literature. For example, Ockenfels and Selten (2005) found that giving feedback on losing bids leads to lower bids, compared to no feedback on losing bids in every period of their repeated first price auction experiment. In the first period, however, 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 period results, but the first period result remains unexplained. If we interpret their treatments in terms of regret, loser regret is always in play since in their different treatments Ockenfels and Selten always tell the winning bid. However, winner regret is not always in play. Hence, (a) since loser regret is active in both treatments, our theory will predict overbidding under both treatments; and (b) 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 those in the 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.

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: (a) from missing out on a profitable transaction opportunity (error type m); and (b) from adversely affecting the price of a realized transaction (error type p). They found that the subjects reacted to the error type m more strongly than to the error type p. They posit their finding as a puzzle. The analysis of Cason and Friedman did not involve regret at all, but error types 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 externalities. Auctions with externalities have been discussed extensively in the literature. For example, John Morgan, Ken Steigletz, and George Reis (2003) considered externality 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 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 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 the 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.

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