Feedback triggered Beliefs Distortions: Theory and Evidence from an Auction Application

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Abstract

The focus of this paper is on the effect of different types of feedback on bidders’ bidding behavior in the first-price sealed-bid auction. We present a new theoretical explanation that can account for some empirical regularities that have been observed in the lab and have been previously explained by anticipated regret or impulse balance equilibrium. These existing explanations are silent regarding the effect of other types of feedback that we consider and that might be relevant if the seller is interested in the revenue-maximizing type of feedback. We also propose a novel type of feedback that is, according to our explanation, predicted to generate a higher amount of revenue than any of the standard types of feedback considered in the literature. In the second part of the paper, we empirically test the effect on bids and revenue of this alternative type of feedback as well as several other types of feedback.

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1 Introduction

Consider the environment of first-price sealed-bid auctions with independent private values. After bidders submit their bids, they always receive a feedback on whether they won or not, which we label as “minimal feedback.” Bidders routinely receive richer feedback types, though, of which they know even before they start bidding. The most typical of those are: (1) conditional on losing, the realization of the highest competitor bid, i.e., the winning bid, which we label as “full loser feedback;” (2) conditional on winning, the realization of the highest competitor bid, i.e., the second highest bid, which we label as “full winner feedback;” (3) the realization of the highest competitor bid irrespective of the outcome of the auction, which we label as “full feedback.” The traditional theoretical view on the revenue-maximizing design of auctions with independent private values (Myerson (1981)) assumes that bidders are attempting to maximize their \textit{ex ante} expected payoff (or expected utility, in case of risk-averse preferences, see Riley and Samuelson (1981)) and the presence or absence of any \textit{ex post} feedback, except for the minimal feedback, is immaterial to this bidding decision. However, there is experimental evidence (Isaac and Walker (1985); Ockenfels and Selten (2005); Neugebauer and Selten (2006); Ozbay and Ozbay (2007); Engelbrecht-Wiggans and Katok (2008)) that, conditional on value, bidding in first-price sealed bid auctions is affected by what feedback is provided to bidders \textit{ex post}. There are in essence two findings. First, the addition of the full loser feedback (to the baseline of minimal feedback or full winner feedback) increases bid/value ratios. Second, the addition of the full winner feedback (to the baseline of minimal feedback or full loser feedback) decreases bid/value ratios. Such differences in the bidding behavior translate into corresponding changes in expected revenue in analogous directions. In particular, they suggest that if a designer of an auction is interested in maximizing the expected revenue, the bidders should be provided with the full loser feedback, but should not be provided with the full winner feedback.

These findings, however, leave open the question of what type of feedback is revenue maximizing in the first price auction. Apart from minimal or full loser/winner feedback, one can imagine many other types of feedback. Consider just a few examples: (1) conditional on losing, a bidder is informed of the highest competitor bid if this bid is within some pre-specified range above the bidder’s own bid; (2) conditional on losing, a bidder is informed
about whether the highest competitor bid is below or above some pre-specified threshold; (3) conditional on losing, a bidder is informed about the highest competitor bid with some probability that depends on his bid; (4) irrespective of the auction outcome, a bidder is informed about the highest competitor bid if this bid is in some pre-specified range.

The aim of this paper is to explore revenue consequences of such alternative types of feedback. This research question has both theoretical and empirical aspects. On the theoretical side, we need some alternative theory to expected payoff (utility) maximization, since this traditional theory cannot account for even the existing empirical evidence, let alone provide guidance for bidding and revenue consequences of alternative forms of feedback. On the empirical side, this paper provides experimental implementation of the first price sealed bid auction with several alternative types of theoretically-motivated feedback and identifies their expected revenue consequences.

The existing literature proposes two explanations for the empirical regularities discussed above. One stream of literature (Ozbay and Ozbay (2007); Engelbrecht-Wiggans and Katok (2008)) proposes an equilibrium-based explanation that builds on the theory anticipated regret first introduced into auction theory by Engelbrecht-Wiggans (1989). Regret is an ex post feeling of loss in that a different feasible course of action chosen ex ante would have generated a better ex post outcome. There are two potential kinds of bidder regret in the first-price auction. First, a bidder who lost, upon learning about the highest competitor bid, may realize that he could have profitably won the auction by bidding more. This is referred to as loser regret. Second, a bidder who won, upon learning the highest competitor bid, may realize that he could have won the auction with a higher profit by bidding less. This is referred to as winner regret. This theory on its own is, however, insufficient to make bids sensitive to the type of feedback. The reason is that whatever the form of such feedback is and conditional on own bid, the expected posterior belief about the highest competitor bid is equal to the prior belief due to the martingale property of beliefs. The theory of anticipated regret is therefore augmented by a verbal salience assumption that anticipated loser (winner) regret enters the ex ante objective of the bidder when the full loser (winner) feedback is provided, but not when the minimal or the winner (loser) feedback are provided. We therefore refer to the resulting theory as “feedback-salient anticipated regret theory.” Under this additional assumption, this theory is capable of accounting for the empirical findings that concern these
type of feedbacks. Note, however, that, being a verbal assumption, it cannot help distinguish whether alternatives forms of feedback should be considered more or less salient and therefore to predict the effect on bids and revenue. To give an example, the assumption does not give a guidance as to whether full looser feedback is more salient than promising feedback on the winning bid only if the latter one is within a 10% range of the bidder’s bid. One might argue that full feedback is a finer feedback but in principle this might not coincide with what makes the undesirable events of loosing more salient.

Another stream of literature (Ockenfels and Selten (2005); Neugebauer and Selten (2006)) proposes a quasi-learning-based explanation known as “impulse-balance equilibrium.” Under this theory, bidders balance off expected upward and downward impulses, possibly with weights. Under full feedback, these impulses coincide with the realizations of loser and winner regret, respectively. As a result, equilibrium bid coincides with balancing of expected winner and loser regret, possibly with weights. Under minimal feedback or full loser or winner feedback, because exact realizations of impulses defined in this way are not always known, upward and downward impulses are defined as events of losing and winning the auction, respectively. Equilibrium bidding then balances off probabilities of losing and winning, possibly with weights.

These existing theories are hard to generalize to other types of feedback that we would like to examine. In addition, each theory postulates that the behavioral criterion used to decide on a bid changes across forms of feedback. Under the feedback-salient anticipated regret theory, anticipated loser/winner regret enters the bidder’s \textit{ex ante} expected payoff only if full loser/winner regret is provided. Under the impulse balance equilibrium theory, the definition of what an impulse means changes depending on whether full feedback is available or not. From the traditional modeling point of view, we believe it would be more desirable to have a given model of decision-making that can be applied to any kind of provided feedback.\footnote{Also note that the impulse balance equilibrium theory is based purely on \textit{ex post} rationality (ignoring \textit{ex ante} expected payoff maximization as a rationale behind bidding) and it is therefore completely non-strategic.}

In the first part of the paper, we therefore propose an alternative theory for how \textit{ex post} feedback may influence bidding behavior. Our theory is also based on anticipated regret and assumes that, for the purpose of computing \textit{ex post} and \textit{ex ante} expected regret, bidders systematically bias their \textit{posterior beliefs} (after receiving the feedback) about the highest com-
petitor bid upward, hence reducing expected regret both \textit{ex post} and \textit{ex ante}. For the types of feedback considered in the existing experimental literature (minimal vs. full loser/winner feedback), our proposed theory is observationally equivalent to the feedback-salient anticipated regret theory and the impulse balance equilibrium theory in that it can account for the existing empirical evidence. In addition, however, it allows modeling other types of feedback and predicting their impact on bidder behavior and, ultimately, on expected revenues. We also propose a feedback mechanism that, according to the model we propose, increases bids more than the standard types of feedback discussed above.

In the second part of the paper, we implement an experimental design that includes several novel forms of feedback and investigate implications of these feedback types on bidding behavior, revenue and efficiency. Note that we do not attempt to empirically distinguish between the theory we propose and the feedback-salient anticipated regret theory or the impulse balance equilibrium theory since for the restricted set of feedback types for which the latter theories have predictive power, they are observationally indistinguishable from the model we propose.

The paper is structured as follows. Section 2 reviews existing experimental findings together with the feedback-salient anticipated regret theory. Section 3 outlines the alternative theory that we propose. Section 4 presents our experimental design. Section 5 presents experimental results. Section 6 concludes.

2 Existing Literature

2.1 Empirical Findings

There are several experimental papers in the literature that document the impact of the type of feedback on bidding in the first-price auction. Isaac and Walker (1985), using groups of four human bidders, and Ockenfels and Selten (2005), using pairs of human bidders, conduct an auction experiment with two feedback conditions: full feedback and full loser feedback. Both studies find that bid/value ratios are statistically significantly smaller in the full feedback treatment.

Ozbay and Ozbay (2007) conduct an auction experiment using groups of four human bidders and three feedback treatments: minimal feedback, full loser feedback and full winner
feedback. Compared to the minimal feedback treatment, the bid/value ratios are statistically significantly higher in the full loser feedback treatment, and lower, but not statistically significantly so, in the full winner feedback treatment. Also, the absolute value of the effect on the bid/value ratio of the full loser feedback is larger than that of the full winner feedback.

Engelbrecht-Wiggans and Katok (2008) conduct an auction experiment using individual human bidders bidding against two computerized opponents who use the risk-neutral symmetric Bayesian-Nash equilibrium bidding strategy of two-thirds of the value (this is framed to subjects as computers “using a strategy that would maximize their expected profit under the assumption that all of the opponents follow the identical strategy.”) They implement four feedback conditions: minimal feedback, full loser feedback, full winner feedback, and full feedback. In addition, in the latter three treatments, subjects also receive as feedback the amount of maximum foregone payoff and the \textit{ex ante} probability of winning conditional on a particular bid (in some treatments). Full loser regret has a positive and statistically significant effect on bid/value ratios, whereas full winner regret has the opposite effect. Also, similarly to the findings of Ozbay and Ozbay (2007), the effect of the former is stronger in absolute value than the effects of the latter.\footnote{There is no statistically significant effect of displaying the probability of winning.}

In a similar spirit, Neugebauer and Selten (2006) conduct an auction experiment using individual human bidders bidding against $N \in \{3, 4, 5, 6, 9\}$ computerized opponents whose bids are independently drawn from the uniform distribution. They implement three feedback conditions: minimal feedback, full loser feedback and full feedback. There is no statistically significant effect of the feedback type on bids in the first round. Overall, however, bid/value ratios are higher under full loser feedback than under the other two feedback treatments.

To summarize, based on a multitude of studies, one can conclude that full loser feedback has a positive and statistically significant marginal (relative to the baseline minimal feedback or full winner feedback) effect on bid/value ratios. On the other hand, full winner feedback has a negative, but statistically borderline significant marginal (relative to the baseline minimal feedback or full loser feedback) effect on bid/value ratios.

In most of the studies, bidding datasets are generated by having subjects bid sequentially many times. This opens up a possibility that later bid observations may be affected by
outcomes of earlier auctions. The literature implements two ways of controlling for this potentially confounding impact. Neugebauer and Selten (2006), apart from analyzing all data jointly, also separately analyze bids in the initial round. This method, however, provides the experimenter with only one bid observation for each subject. To improve upon this, Ozbay and Ozbay (2007) generate multiple bid observations in the single-round auction design via the strategy method in which each subject submits bids for ten different values. In this respect, this study differs from all the other ones reviewed above. In our experimental implementation, we also adopt the strategy method to elicit multiple initial bids for every subject.

2.2 Theoretical Explanation

In this section, we briefly formally review the two theories that we briefly discuss in the Introduction. Regarding the feedback-salient anticipated regret theory, assuming bidder risk neutrality, Ozbay and Ozbay (2007) propose to modify the usual expected payoff bidder objective to

\[
u(v, b) = \begin{cases} 
v - b & \text{if winning and receiving minimal feedback} \\
v - b - w(b - \hat{b}) & \text{if winning and receiving full winner feedback} \\
0 & \text{if losing and receiving minimal feedback} \\
-l(v - \hat{b}) & \text{if losing and receiving full loser feedback} \end{cases}
\]  

(1)

In this specification, \(v\) and \(b\) are the bidder’s value and bid, respectively, \(\hat{b}\) is the highest competitor bid, \(l(\cdot)\) captures loser regret and \(w(\cdot)\) captures winner regret. It is assumed that \(l(x) = w(x) = 0\) for \(x \leq 0\) and both \(l(\cdot)\) and \(w(\cdot)\) are monotonically increasing, weakly convex and everywhere differentiable. Under a simple parametrization given by

\[
l(x) = \alpha^l \max\{x, 0\}, \ \alpha^l \geq 0
\]

\[
w(x) = \alpha^w \max\{x, 0\}, \ \alpha^w \geq 0
\]

(2)

and a uniform distribution of valuations on \([0, 1]\), it is easy to show that the symmetric equilibrium bidding function is linear with the slope given by (with \(n\) being the number of bidders)

\[
\gamma^0 \equiv \frac{n - 1}{n}
\]

(3)

\[3\text{In fact, this is the purpose of the design in Neugebauer and Selten (2006).}\]
under minimal feedback,

\[ \gamma^l \equiv \frac{1 + \alpha^l}{n - 1 + \alpha^l} \]  

(4)

under full loser feedback,

\[ \gamma^w \equiv \frac{1 - \alpha^w}{n - 1 - \alpha^w} \]  

(5)

under full winner feedback, and

\[ \gamma^{lw} \equiv \frac{1 + \alpha^l - \alpha^w}{n - 1 + \alpha^l - \alpha^w}, \]  

(6)

under “full feedback,” defined as learning about the highest competitor bid irrespective of the auction outcome. It follows immediately that

\[ \gamma^w \leq \gamma^0 \leq \gamma^l \]  

(7)

and

\[ \gamma^w \leq \gamma^{lw} \leq \gamma^l, \]  

(8)

with the inequalities being strict if \( \alpha^l \) and \( \alpha^w \) are strictly positive. Furthermore,

\[ \gamma^0 \precsim \gamma^{lw} \text{ as } \alpha^l \precsim \alpha^w. \]  

(9)

It then follows from (7) that, relative to minimal feedback, bid/value ratios are higher under full loser feedback and lower under full winner feedback. This accounts for empirical findings of Ozbay and Ozbay (2007) and Engelbrecht-Wiggans and Katok (2008). In addition, it follows from (8) that, relative to the full feedback, bid/value ratios are higher under the full loser feedback, accounting for the empirical findings of Isaac and Walker (1985). Hence the feedback-salient anticipated regret theory is capable of accounting for the existing empirical findings.

Let us now turn to the impulse balance theory proposed by Ockenfels and Selten (2005). As already briefly outlined, this theory is essentially a learning theory based on an ex post rationality principle that bidders react to the feedback they receive after the auction adjusting their bid upwards (upward impulse) or downwards (downward impulse). More precisely, the idea behind this theory is that bidders play repeatedly in the same auction game, that they start with some linear bidding function \( b(v) = av \), and after each time they get feedback from the auction they re-evaluate their bidding function by adjusting to a bigger value of \( a \) in case
of upward impulse, and to a lower value of $a$ under a downward impulse. The equilibrium is essentially the steady state of this learning process, and it is given by the linear (a restriction) bidding function that balances the upward impulse and downward impulse. The two impulses can receive unequal weights from the bidders and in fact the theory can explain overbidding compared to RNNE only if the upward impulse receives more weight. Two types of feedback are analyzed NF, which corresponds to our minimal feedback and F, which corresponds to our full winner feedback. Formally, let $x$ be the value of the bidder we consider and $y$ the highest value of the $n$ opponents. Values are uniformly distributed and independently drawn so that the density associated to $y$ is $f(y) = (n - 1)y^{n-2}$. Ex post a bidder can find out if he has lost or won. This defines three regions: region 1, $\Delta_1$, for which $x > y$, so that the bidder wins, which produces a downward impulse; region 2, $\Delta_2$, for which $y > x$, but $x > ay$ so that the bidder looses and his value is higher than the winning bid, which produces an upward impulse; region 3, $\Delta_3$, for which $x < ay$, for which no impulse is generated. The expected downward impulse and the expected upward impulse for the F feedback are respectively defined as follows: $E_- = a \int_{\Delta_1} (x - y) f(x) f(y) dx dy$, and $E_+ = \int_{\Delta_2} (x - ay) f(x) f(y) dx dy$. The weight that balances these two impulse is denoted by $\lambda$, such that $E_+ = \lambda E_-$. The parameter $a$ that defines the equilibrium bidding function is then derived a function of $\lambda$ and $n$. For feedback F then in equilibrium the expected amount of the downward and upward impulse are balanced. For the NF feedback the same procedure cannot be applied directly because the loosing bid is not available for the winner. The way out for this theory is to assume that in this case instead of the expected amount of the impulses, what is balanced is the expected number of them. These are given by $P_- = \frac{1}{n}$ (ex ante all bidders are equally likely to win in a symmetric equilibrium) for the downward impulse and $P_+ = \int_{\Delta_2} f(x) f(y) dx dy$ for the upward impulse. As before then $\lambda$ is defined such that $P_+ = \lambda P_-$, and $a$ derived as a function of $\lambda$ and $n$. By comparing $a$ so derived with the RNNE, it is possible to figure out for which values of $\lambda$ the theory is compatible with overbidding. For both types of feedback it is required that downwards impulse receive more weight. In particular for the F treatment, we need $\lambda < \frac{1}{2}$. The estimate for $\lambda$ from the experimental data are .32 for feedback F and .37 for feedback NF.
3 A Model of Anticipated Regret with Biased *Ex Post* Beliefs

As we discussed before, as a behavioral model of decision-making, feedback-salient anticipated regret theory and the impulse balance equilibrium theory are vague as to the impact of alternative types of feedback, such as announcing a range of possible realizations of the winning or the second highest bid. This is an important drawback since it is impossible to use either of the theories to answer questions such as what sort of feedback is revenue-maximizing. Because we aim to answer such questions, in this section we introduce our alternative model of anticipated regret with biasing of *ex post* beliefs. This model can account for the existing empirical evidence, is structurally stable and can make predictions across any type of feedback. The underlying idea is that an individual, when considering *ex post* what alternative choices he could have made *ex ante*, tends to bias the objective Bayesian posterior beliefs about the highest bid of the competitors in a way that makes the *ex ante* chosen alternative look relatively better in terms of experienced expected regret. If no further decisions are based on these biased posterior beliefs, the biasing process has little opportunity cost. The bidder is in turn aware of this biasing process when deciding on his action *ex ante*.

3.1 Model

Formally, suppose that the highest bid \( \hat{b} \) of the competitors is distributed on the support \([0, \overline{b}]\) according to the cdf \( F(\cdot) \) with a continuous and strictly positive density \( f(\cdot) \). Let \( B[0, \overline{b}] \) be the Borel sigma-field on \([0, \overline{b}]\) and let \( \Psi \) be the set of Borel-measurable partitions of \([0, \overline{b}]\). In general, suppose that upon submitting a bid \( b \in [0, \overline{b}] \) (it never makes sense to bid more than \( \overline{b} \)), the bidder is promised a feedback \( \Theta(b) \), where \( \Theta : [0, \overline{b}] \to \Psi \). We require that any provided feedback at least informs the bidder about whether he won or lost the auction, i.e., the sets within \( \Theta(\hat{b}) \) can be grouped into the intervals \([0, b]\) (winning the auction) and \((b, \overline{b}]\) (losing the auction). For any set \( A \in B[0, \overline{b}] \) of strictly positive measure, let \( F_A(\hat{b}) \) be cdf of a Bayesian posterior on \( \hat{b} \) conditional on \( \hat{b} \in A \). We postulate that for the purpose of computing expected posterior regret when deciding on his bid, the bidder biases his beliefs within any such set \( A \) from the objective Bayesian posterior \( F_A(\cdot) \) to a subjective posterior \( F^\rho_A(\cdot) \), with \( \rho > 0 \). The case \( \rho = 1 \) corresponds to no biasing, \( \rho > 1 \) corresponds to upward biasing, and \( \rho < 1 \) corresponds to downward biasing of beliefs about \( \hat{b} \), respectively. In line
with the intuition discussed above, we hypothesize that \( \rho > 1 \) for most of the bidders, even though we do not rule out that \( \rho \leq 1 \) for some bidders. As a result, upon realized feedback \( A \in \Theta(b) \), if \( b < \inf(A) \) or \( b = \inf(A) \) and \( b \notin A \), i.e., the bidder is losing the auction, the expected posterior amount of loser regret is given by

\[
\int A l(v - \hat{b})dF_A^\rho(\hat{b}),
\]

and if \( b \geq \sup(A) \), i.e., the bidder is winning the auction, the expected posterior amount of winner regret is given by

\[
\int A w(b - \hat{b})dF_A^\rho(\hat{b}),
\]

where the properties of \( l(\cdot) \) and \( w(\cdot) \) are as specified in the previous section. We also assume that the bidder has an objective prior about different possible realizations of \( \hat{b} \) when it comes to computing the expected payoff and probabilities of different feedback outcomes.

Then, analogously to utility specification in (1), the bidder’s expected utility when having a valuation \( v \) and submitting a bid \( b \) is given by

\[
EU(v, b) = F(b)(v - b) - \int_{\{A \in \Theta(b) : A \subset [0, b]\}} w(b - \hat{b})dF_A^\rho(\hat{b})dF(A) - \int_{\{A \in \Theta(b) : A \subset (b, \infty]\}} l(v - \hat{b})dF_A^\rho(\hat{b})dF(A).
\]

In what follows, we are going to use a simple parametrization given in (2). Under this assumption, (12) becomes

\[
EU(v, b) = F(b)(v - b) - \alpha w \int_{\{A \in \Theta(b) : A \subset [0, b]\}} (b - \hat{b})dF_A^\rho(\hat{b})dF(A) - \alpha l \int_{\{A \in \Theta(b) : A \subset (b, \infty]\}} (v - \hat{b})dF_A^\rho(\hat{b})dF(A).
\]

**3.2 Accounting for Empirical Evidence**

Now consider how this theory, if \( \rho > 1 \), can account for the empirical findings in the literature that we discussed above. Suppose, initially, that the distribution of the highest bid of the
other bidders is exogenously given by the cdf $F(\cdot)$. Define

$$EU(v, b, \rho^w, \rho^l) \equiv F(b)(v - b) - \alpha^w F^1 - \rho^w (b) \int_0^b F\rho^w (\hat{b})d\hat{b} - \alpha^l [1 - F(b)]^{1 - \rho^l} \int_b^v \left[ F(\hat{b}) - F(b) \right]^{\rho^l} d\hat{b}. \quad (14)$$

**Case 0: minimal feedback.** In this case $\Theta(b) = [0, b] \cup (b, \bar{b}]$ and the bidder *ex ante* objective is given by

$$EU^0(v, b) = EU(v, b, \rho). \quad (15)$$

**Case L: full loser feedback.** In this case $\Theta(b) = \{[0, b] \cup (b, \bar{b}]$ and the bidder *ex ante* objective is given by

$$EU^L(v, b) = EU(v, b, \rho, 1). \quad (16)$$

**Case W: full winner feedback.** In this case $\Theta(b) = [0, b] \cup \{(b, \bar{b}]$ and the bidder *ex ante* objective is given by

$$EU^W(v, b) = EU(v, b, 1, \rho). \quad (17)$$

**Case F: full feedback.** In this case $\Theta(b) = [0, \bar{b}]$ and the bidder *ex ante* objective is given by

$$EU^F(v, b) = EU(v, b, 1, 1). \quad (18)$$

Since

$$\frac{\partial}{\partial b} EU(v, b, \rho^w, \rho^l) = f(b)(v - b) - F(b) - \alpha^w F(b) + \alpha^w (\rho^w - 1) f(b) \int_0^b \left[ F(\hat{b}) \right]^{\rho^w} d\hat{b} + \alpha^l f(b) \int_b^v \left\{ \rho^l \left[ \frac{1 - F(\hat{b})}{1 - F(b)} \right]^{\rho^l - 1} + \left[ \frac{F(\hat{b}) - F(b)}{1 - F(b)} \right]^{\rho^l} \right\} d\hat{b}, \quad (19)$$

it follows for $\rho^w > 1$ and $\rho^l > 1$ that

$$\frac{\partial}{\partial b} EU(v, b, 1, \rho^l) < \frac{\partial}{\partial b} EU(v, b, \rho^w, \rho^l). \quad (20)$$
\[
\frac{\partial}{\partial b} EU(v, b, \rho, \rho_l) < \frac{\partial}{\partial b} EU(v, b, \rho, 1). \tag{22}
\]

As a result,

\[
\frac{\partial}{\partial b} EU^W(v, b) < \frac{\partial}{\partial b} EU^F(v, b) < \frac{\partial}{\partial b} EU^L(v, b) \tag{23}
\]

and

\[
\frac{\partial}{\partial b} EU^W(v, b) < \frac{\partial}{\partial b} EU^0(v, b) < \frac{\partial}{\partial b} EU^L(v, b). \tag{24}
\]

It follows that when bidding against an exogenous distribution of the highest bid of the other bidders given by \(F(\cdot)\), bidders in the full loser feedback scenario are going to bid more than bidders in the full winner feedback scenario, with bids in the other two scenarios being in between. In a symmetric equilibrium context with endogenous \(F(\cdot)\), these bid shifts are translated into the bidding behavior of other bidders and get even magnified into \(F(\cdot)\) via competition. As a result, our theory is capable of explaining findings in the previous literature within the equilibrium context (Isaac and Walker (1985); Ozbay and Ozbay (2007)) as well as in the context of bidding against exogenously behaving computers (Ockenfels and Selten (2005); Neugebauer and Selten (2006); Engelbrecht-Wiggans and Katok (2008)).

To understand this intuitively, consider the comparison of Case 0 and Case L. When submitting a bid, a bidder is considering how much to shade compared to his value. He is aware that the more he shades, the higher is the probability of losing and feeling regret for having bid too little. However, if there is no feedback on the value of the winning bid, the bidder, upon losing, is at liberty to form whatever beliefs he wants about the value of the winning bid. By biasing his beliefs about the winning bid upward, he will reduce his expected \textit{ex post} regret both in total and on the margin just above his bid. In fact, the marginal loser

\footnote{To see this latter comparison, fix any \(b \in (b, v)\), denote}

\[
a \equiv \frac{F(b) - F(b)}{1 - F(b)}
\]

and note that \(a \in (0, 1)\). The integrand in the last term on the right-hand side of (19) then has a form

\[
\rho'(1-a)a^{\rho'-1} + a^{\rho'}. \tag{22}
\]

By Fermat’s theorem, for any \(a \in (0, 1)\) and \(\rho' > 1\),

\[
\rho' a^{\rho'-1} < \frac{1-a^{ho'}}{1-a},
\]

implying that (22) is less than 1.
regret is reduced to zero. Concerns about anticipated loser regret thus become unimportant on the margin relative to expected payoff in the *ex ante* objective of the bidder. Compared to that, if knowing that there will be a precise feedback about the winning bid if losing, the bidder understands that he will not be able to use biasing of beliefs to reduce his *ex post* regret, in total or on the margin. As a result, concerns about anticipated loser’s regret become important on the margin in the *ex ante* objective of the bidder under full loser regret. This comparison implies that, in an attempt to reduce anticipated regret on the margin, the bidder bids more under full loser feedback in comparison to how much he bids under minimal feedback.

Analogously, consider the comparison of Case 0 and Case W. When submitting a bid, a bidder is considering how much to shade his bid compared to his value. He is aware that the less he shades, the higher is the probability of winning and feeling regret for having bid too much and also the amount of the regret. However, if there is no feedback on the value of the second highest bid, then the bidder, upon winning, is at liberty to form whatever beliefs he wants about the value of the second highest bid. By biasing his beliefs about the second highest bid upward, he will reduce his expected *ex post* regret in total, but increase it on the margin. Concerns about anticipated winner regret thus become more important on the margin relative to the case of full winner feedback, because in the latter case the bidder understands that he will not be able to use biasing of beliefs to affect his *ex post* regret, in total or on the margin. This comparison implies that, in an attempt to reduce anticipated regret on the margin, the bidder bids less under full winner feedback in comparison to how much he bids under minimal feedback.

### 3.3 A Proposal for Feedback That Would Further Improve Revenue

Based on the existing empirical evidence discussed above, it may seem that if the designer of the auction is interested in maximizing expected revenue, he should employ full loser feedback. Intuitively, employing the theory we propose above, if the bidder is not given the opportunity to distort his beliefs about the winning bid in case of losing, anticipated loser regret kicks in with a full force, leading the bidder to increase his bid the most.

We do not dispute this intuition when it comes to deterministic feedback. However, our theory also suggests that, for a given bid, bidders dislike receiving feedback since they can
no longer distort their posterior beliefs. Based on this observation, consider the following stochastic feedback rule: in case of losing, bidders are promised to receive minimal feedback with probability \( p(b) \) and to receive full loser feedback with probability \( 1 - p(b) / \), where \( p(\cdot) \) is strictly increasing. Under this feedback rule, the \textit{ex ante} objective of the bidder is given by

\[
EU(v, b) = \int_b^v \left[ \frac{F(\hat{b}) - F(b)}{1 - F(\hat{b})} - \frac{F(\hat{b}) - F(b)}{1 - F(b)} \right] \rho \ d\hat{b}. \tag{25}
\]

and

\[
\frac{\partial}{\partial b} EU^\alpha(v, b) = \frac{\partial}{\partial b} EU^L(v, b) + p'(b)\alpha \int_b^v \left[ \frac{F(\hat{b}) - F(b)}{1 - F(\hat{b})} - \frac{F(\hat{b}) - F(b)}{1 - F(b)} \right] \rho \ d\hat{b} \nonumber
\]

\[
+ p(b)\alpha f(b) \left[ -(v - b) + \int_b^v \left\{ \rho \frac{F(\hat{b}) - F(b)}{1 - F(\hat{b})} \left[ \frac{F(\hat{b}) - F(b)}{1 - F(\hat{b})} \right]^{\rho - 1} + \frac{F(\hat{b}) - F(b)}{1 - F(b)} \right\} d\hat{b} \right]. \tag{26}
\]

We conjecture that

\[
\frac{\partial}{\partial b} EU^\alpha(v, b) > \frac{\partial}{\partial b} EU^L(v, b),
\]

suggesting higher bids under the proposed feedback rule. We are working on the proof of this result at the moment.

4 Experimental Design

We plan to run an experimental auction in which a bidder bids against a computerized opponent that bids uniformly on \([0, 1]\). Bidder values are distributed uniformly on \([0, 1]\) too. Bidders are informed about the type of feedback they are going to receive. Using between-subject design, these feedback types are going to be: (1) minimal feedback; (2) full loser feedback; (3) stochastic feedback discussed above. We plan to have about 20 subjects in each feedback treatment. We are going to compare bids and revenues under the three feedback types, testing the conjecture we described in the previous section. This part of the project is under development at the moment.
References


