Fair Market Value Could Have Contributed to the Crash

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Abstract

This article argues that fair-market value accounting could have played a significant role in the recent financial crisis, by causing a drop in demand for the structured finance products that were central to the market collapse. The culprit is the discretion inherent in the use of "mark-to-model" reports, in which firms report fair values that they calculate internally, rather than actual market prices. In equilibrium, discretion in mark-to-model reports leads to aggressive reporting of asset values, compared with a conservative reporting regime. Aggressive reporting weakens demand and increases financial market frictions, resulting in illiquidity. We demonstrate these effects in a laboratory experiment with a matched pairs design, and find that adopting a mark-to-model regime causes drops in prices and reduces the frequency of trade.

Keywords: Fair value, mark-to-model, financial crisis, experiments, ambiguity

JEL Classifications: G01, M41, C92, M48, D82, G02, D02

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1 Introduction

In the immediate aftermath of the 2008 collapse of Lehman Brothers, attention focused on the role that fair-value accounting may have played. We argue that fair value could have contributed to the recent crisis, by causing a drop in demand for the financial assets that were central to the market collapse. This downward shift in demand leads to falling prices and illiquid markets, matching the pattern seen in the crisis.

Our focus is on the reporting of asset values that a firm calculates from formulas, rather than taking fair values directly from market prices. This practice, referred to as "mark-to-model," was almost always used in reporting the fair values of the collateralized debt or mortgage obligations (CDOs/CMOs) at the heart of the crisis (see, for example Laux and Leuz 2010, for discussion).

Mark-to-model accounting gives a firm discretion on how to value its assets, at least within limits. If the model uses publicly available market data as inputs, these data constrain the possible reports. But within some bounds, a firm can choose the model, and hence the value, it reports for its assets.

Discretion has important consequences. Under very general conditions, reporting a higher value to the market is better news, making it a dominant strategy for a firm to report as aggressively as permissible under a mark-to-model regime. Potential investors, after observing a mark-to-model report, learn an upper bound on an asset's value, but do not receive any information about a lower bound. So although the market for CDOs and CMOs is over-the-counter, and in most respects like a first-price sealed-bid auction, the presence of mark-to-model accounting gives the CDO/CMO market some of the features of a Dutch auction.

By contrast, under a conservative reporting regime, firms are required to disclose a lower bound on an asset's value, but do not receive any information about an upper bound. Conservative reporting thus gives the CDO/CMO market features similar to an English auction.

The tradeoff between adopting a mark-to-model or a conservative regime is therefore as follows: under mark-to-model, because a seller reveals an upper bound on the asset's value, potential investors are protected against paying an information rent. This benefit comes at the cost of keeping investors uninformed about how much to discount the reported value. As the seller has no credible way of disclosing a lower bound, it will sometimes be the case that the highest bid is lower than a rational seller would consider. This friction, which leads to market illiquidity, does not arise in a conservative reporting regime. But because potential investors are not protected against potential information rents in a conservative regime, prices will tend to be lower under mark-to-model than under conservative reporting.

Summing up, from a comparative statics viewpoint, we have the following observations: compared with a conservative reporting regime, a mark-to-model regime leads to the market discounting reported values, an overall drop in market prices, and a decrease in market liquidity—exactly the pattern observed during the crisis. The potential information rent that exists under a conservative reporting regime is, in some sense, the price of keeping markets active.

To test whether these claims are behaviorally observable, we ran a laboratory experiment, using a matched pairs design. For the participants assigned to a conservative reporting treatment, we made a lower bound on an asset's value public information, giving the asset's initial owner a private upper bound on the asset's value. For those assigned to a fair value treatment, we made an upper bound on the asset's value public, and gave the initial owner a private lower bound on the asset's value. Each group of subjects in a conservative treatment was matched with a group of subjects in the fair value treatment. In other words, a given set of realizations was shown to both a fair value group of participants and a conservative group. We assigned other participants to a third treatment, called our discretionary treatment. Sellers in the discretionary treatment were informed of a lower and an upper bound on an asset's value, and were allowed to choose a to report to the buyers, with the only restriction being that the report had to be between the seller's private bounds. In all three treatments, after the participants received their information about the asset's value, trade took place in a first-price sealed bid auction.[1]

This design enables us to separate two aspects of mark-to-model accounting. The discretionary treatment tests whether the prediction of aggressive reporting is observable in the laboratory. The fair value treatment tests whether, given aggressive reporting, demand is lower than under a conservative reporting regime.

In the discretionary treatment, the distribution of reported values first-order stochastically dominates the distribution of sellers' private reserve prices.[2] So the sellers reported aggressively, and this behavior was not merely due to sellers having high private values. The median reported value was roughly 7/8 of the seller's upper bound on the asset's value, compared with a median reserve price of roughly 3/8 of the upper bound. The top quartile was at 97% of the upper bound. These results support the prediction of aggressive reporting, and are consistent with findings in earlier experiments on disclosure (e.g., King and Wallin 1991, Forsythe et al. 1999).

Secondly, we find that both the bid distribution and the highest bid were lower under fair value than under conservative reporting. Drops in prices or in bidding behavior were not driven by changes in seller reserve prices, which were indistinguishable across treatments.

[1]For reasons related to the nature of the structured finance market, which we describe below in Section 2 the auction we consider is one with ambiguously distributed asset values. This softens the adverse selection in the market. See Condie and Ganguli (2011), Dickhaut et al. (2011), de Castro and Chateauneuf (2011). A thorough review of the literature on ambiguity and asset pricing is in Guidolin and Rinaldi (2010).

[2]In our design, it was incentive compatible for sellers to report their reserve prices truthfully.

Instead, the effects all arose from changes in demand.

Third, we find that the market is significantly less liquid under fair value than under conservatism. Participants in fair value treatment traded in just under half of the rounds. Their counterparts in the conservative treatment traded in nearly 3/4 of the rounds.

Overall, the results of the experiment are consistent with our predictions and with what was observed in the crisis: aggressive reporting, lower prices, and illiquidity under a mark-to-model regime, compared with what occurs under conservative reporting.

The remainder of the paper is organized as follows. Section 2 discusses the institutional background and prior literature. Section 3 provides the theory, with technicalities deferred to an appendix. Section 4 presents the experimental design. Section 5 discusses the results. Section 6 concludes with a discussion and extensions. Appendix A spells out the details on the theory. Appendix B shows the experiment's instructions.

2 Background

Fair market value accounting is the practice of adjusting a reported items on a company's balance sheet or income statement in order to reflect current market conditions. Critics have asked whether fair value accounting could have played a role in the financial crisis. Former Federal Deposit Insurance Corporation (FDIC) Chairman expressed this concern as follows:

> The SEC has destroyed $500 billion of bank capital by its senseless marking to market of these assets for which there is no marking to market, and that has destroyed $5 trillion of bank lending. That's a major issue in the credit crunch

we're in right now.[3]

In other words, Chairman Isaac's concern is over mark-to-model accounting, and may in part be a reaction to changes in financial standards on fair value accounting that took place shortly before the crisis. Although the practice of listing most securities at their current market prices was established well beforehand,[4] the Financial Accounting Standards Board (FASB) had largely been agnostic on the issue of how to record the "market values" of securities that are not actively traded—assets for which no market exists.

That changed with the FASB's issuance of SFAS 157, which took effect in 2007. The statement defined criteria for Level 2 fair market value accounting, which consists of a company using market data as an input to a model, which in turn is used to calculate an asset's fair value. The amount listed on the balance sheet is then adjusted to this estimated value. SFAS 157 also created Level 3 fair market value reports, under which a firm internally generates both its valuation model and the inputs to the model. Both Level 2 and Level 3 reports are known as mark-to-model. This is in contrast to a Level 1 report, which is a value based on the price in a market with active trading.

The change in the standard appears to have had an effect on the amount of mark-to-model accounting, at least at large bank holding companies and investment banks. For instance, in the last quarter of 2006, before SFAS 157 went into effect, JP Morgan Chase reported $458 billion in trading and available-for-sale securities, which are marked to their market values on the balance sheet under SFAS 115. In the first quarter of 2007, just after SFAS 157 took effect, JP Morgan Chase reported $803 billion in Level 2 assets, making up 57% of the total assets on its balance sheet. By the end of 2007, the total amount of Level 2 assets had risen

[3]Interview with CNBC on October 9, 2008. See http://www.cnbc.com/id/27100454.

[4]In 1993, the FASB issued Statement of Financial Accounting Standards 115, which stated that, other than some debt securities, most financial securities would be listed at fair values. See Beatty et al. (1996) for a discussion of the history and the role of the Securities and Exchange Commission (SEC) in the development of the standard.

to \$1.099 trillion, just over 70% of total assets. By quarter 1 of 2008, Level 2 assets totaled \$1.572 trillion, corresponding to 96% of JP Morgan's total assets.[5]

JP Morgan Chase is an extreme example, but the use of mark-to-model reporting is the norm for the CDOs/CMOs that collapsed during the crisis. Laux and Leuz (Table 2, 2010, p. 108) report that, for large investment banks, mark-to-model reports accounted for 72% of fair value asset values (which in turn were around half of total assets) at the beginning of 2007. By the end of the first quarter of 2009, mark-to-model reports were around 87% of total fair value assets. For large bank holding companies, the pattern was similar, with Level 2 and 3 reports growing from 66% of total fair value assets (around 1/3 of the overall total assets) at the beginning of 2007 to around 81% at the end of the first quarter of 2009. Laux and Leuz also observe, from the notes to banks' financial statements, almost all of the mortgage-related assets were reported using Levels 2 or 3.

Given this market response to SFAS 157, it seems plausible that mark-to-model accounting received so much attention because the crisis was post hoc. Was it propter hoc? We argue there is cause to think so, because of the effects of mark-to-model accounting on the demand side of the CDO/CMO market.

Our demand-side argument is, to the best of our knowledge, largely unexplored in the discussion of the role of accounting in the crisis.[6] Other researchers, along with the SEC (2008), have focused on the supply side of the CDO/CMO market. Prior to the crisis, theoretical work on fair value accounting had raised concerns about interactions with bank regulations or coordination on equilibria with panic selling (Allen and Carletti 2008, Plantin et al. 2008). These models focus more on Level 1 reports; notably, in Allen and Carletti's model,

[5]Data from the SNL Finance database.

[6]The chief exception is Easley and O'Hara (2010), who model investors with maxmin-expected utility representations of their preferences. Their focus is more on the role of ambiguous asset value shocks, in contrast to our emphasis on the market's reaction to strategic mark-to-model reports.

an exogenous drop in market prices forces banks to sell more assets in order to maintain regulatory capital. This puts excess supply of assets on the market, causing a downward spiral. Although these types of models raise valid concerns, the SEC report and the academic literature (e.g., Barth and Landsman 2010, Laux and Leuz 2010, Badertscher et al. 2012)[7] persuasively show that excess supply was unlikely to have played much of a role. As noted above, the vast majority of the debt-based assets were reported using Levels 2 and 3, making impairment in an active market less of a concern. Moreover, when assets reported using a Level 2 or Level 3 valuation were later sold, the price reflected a significant discount, with trading prices averaging 63% of stated values for Level 2 assets and only 49% for Level 3 assets (Goh et al. 2009; see also Song et al. 2010). The apparent aggressiveness of the mark-to-model reports does not support a case for low reported values prompting selling pressure.

Aggressive reports are, however, consistent with a demand effect. Investors, correctly anticipating that mark-to-model reports are overly rosy, discount the listed values when deciding how much to bid for an asset. If the amount of discretion in mark-to-model reports is difficult to estimate and potentially large, then the discounting can close down the market. The reason is that mark-to-model reports provide an upper bound on an asset's value, telling investors to discount, but do not give any information on a lower bound. Without this knowledge, investors will sometimes discount more heavily than sellers of an asset are willing to accept. Specifically, when a seller has a small amount of reporting discretion, he or she cannot credibly signal that only a small discount is acceptable.

This market for debt-based securities is especially vulnerable to this type of liquidity friction. Coval et al. (2009) illustrate how tranching makes the payoff distribution of CDOs, CMOs,

[7]But for a different viewpoint, see Heaton et al. (2010), Khan (2012). Even so, as Heaton et al. point out, if the issue is the interaction of bank regulation with accounting rules, it may be preferable to change the bank regulations, rather than abandon fair value accounting. For further discussion on policy issues related to regulatory-induced fire sales, see Diamond and Rajan (2011).

and more exotic structured finance products highly sensitive to small estimation errors in the covariance structure of underlying debt instruments. And this covariance structure would have been difficult to estimate accurately during the run-up to the crisis: Keys et al. (2010) show that the distribution of the debt instruments changed endogenously with the growth in the market for structured finance products in the lead-up to the crisis, and that the payoff distributions on debt-backed securities were highly idiosyncratic, due to the way securitization works.

There are two important consequences of these difficulties in estimation. First, as Acharya et al. (2011, p. 1205) point out, traders who have limited information about the nature of the risks they face are effectively in a market with ambiguity. Second, the idiosyncratic nature of each securitized asset's payoff distribution prevents sellers from using a Level 1 report, as there are no comparable assets priced in actively traded markets. The ambiguity causes the liquidity friction, and the idiosyncratic nature prevents sellers of these assets from trying to find an objective market price as a way to commit to avoiding aggressive reporting.

3 Theory

This section gives a high-level theoretical overview of the setting we study. We limit ourselves here to enough detail to allow us to explain our hypotheses and our experimental design, and provide technical details in Appendix A.

3.1 Agents, endowments, and timing of events

There are two types of agents, a single seller and $n \geq 2$ buyers, who meet in a first-price sealed bid auction. This represents the over-the-counter structure of the market for the debt-based securities that were central to the crisis. The seller is endowed with one indivisible unit of a financial asset, with a value $\widetilde{v}$ that is realized at the end of the only period in the economy. The buyers have cash, which they can keep or use to bid on the asset. No one may borrow or sell the asset short.

Initially, there are commonly known bounds on the asset's end-of-period value, $\widetilde{v} \in [\underline{a}, \overline{b}]$. The distribution of $\widetilde{v}$ is ambiguous, corresponding to the difficulties in estimating the payoff distribution on CDOs, CMOs, and related securities that Coval et al. and Keys et al. point out. Before the market opens, the seller receives a private signal, in the form of a refinement to the set of possible terminal values. That is, the seller learns $\widetilde{v} \in [a', b'] \subset [\underline{a}, \overline{b}]$.

The seller publicly reports $\widehat{v} \in [a', b']$. This reflects the fact that the report is audited. The seller is therefore unable to lie. Nevertheless, the values $[a', b']$ represent those which the seller could justify, and the auditor has no grounds for objecting to a report that is within this permissible range. This corresponds to the fact that Level 2 reports are discretionary, but with some bounds, as their inputs are verifiable.

After the seller reports $\widetilde{v}$, the seller chooses a private reserve price v^*, and the buyers submit their bids $\{p_i\}_{i=1}^n$. If the highest bid $p^* := \max_{i=1 \ldots n} p_i \geq v^*$, then there is trade, and the price is p^*. Otherwise, the seller keeps the asset, and the buyers keep their money. The value of asset $\widetilde{v}$ is realized and paid to its owner, and then the game ends. The timeline is summarized in Figure 1.

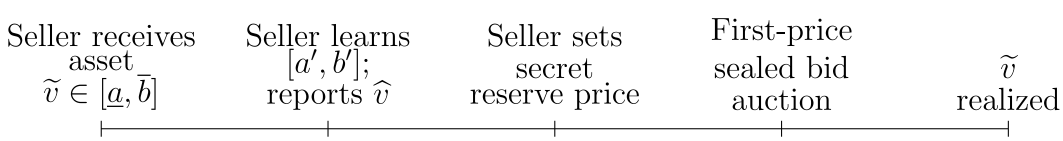

Figure 1: Timeline.

3.2 Preferences and Aggressive Reporting

Following Bewley (2002), we allow preferences to be incomplete, as a way to weaken the Savage axioms enough to allow for ambiguity. Our strategy, pursued in detail in Appendix A, is to provide axioms on preferences that are necessary and sufficient conditions to guarantee aggressive reporting (i.e., that the uniquely optimal report is $\widehat{v} = b'$). This gives us the largest class of preferences consistent with aggressive use of mark-to-model reports. Most standard examples, such as α-maxmin-expected utility with pessimism parameter $\alpha > 0$ and the smooth ambiguity model of Klibanoff et al. (2005) are consistent with our axioms.[8]

Our first axiom is a weak form of monotonicity. Agents' preferences are an *interval order* (Fishburn 1985, Bogart 1993): given two assets with ambiguous values in the ranges $[a_0, b_0]$ and $[a_1, b_1]$, if $b_0 \leq a_1$, then $[a_0, b_0] \precsim [a_1, b_1]$. If the inequality is strict, then so is the preference. Intuitively, agents always prefer an asset whose payoff is guaranteed to be higher to one that it dominates.

We also need two other axioms, in order to account for the fact that the seller can give the same report $\widehat{v}$ whenever $a' \leq \widehat{v} \leq b'$. This means that, before considering the seller's reporting strategy, buyers learn from $\widehat{v}$ a set of possible ex post bounds the seller may have:

$$\widehat{v} \text{ is a feasible report iff } [a', b'] \in \{[a, b] | \underline{a} \leq a \leq \widehat{v} \leq b \leq \overline{b}\}$$

Our first additional axiom is a dominance condition, which we call *witnessed strict dominance*. Given two disjoint sets of possible ranges for the value of $\widetilde{v}$, say S and T, suppose that every interval in S is strictly worse (in the interval order sense) than some interval in T, and that nothing is T is strictly worse than anything in S. Then we assume an agent

[8] The main exception is maxmin-expected utility, which results in a babbling equilibrium.

prefers an asset where the seller's report reveals that $[a', b'] \in T$ to one where the report reveals that $[a', b'] \in S$.

The other additional axiom, which we call *disjoint union betweenness*, is a replacement for the sure-thing principle, related to the averaging and impartiality conditions in Bolker (1967). Given three pairwise disjoint sets R, S, T, suppose the agent prefers an asset where $[a', b'] \in T$ to one where $[a', b'] \in S$. Further, suppose R is between S and T, in the sense that the agent does not prefer an asset with $[a', b'] \in S$ to one with $[a', b'] \in R$; similarly, the agent does not prefer an asset with $[a', b'] \in R$ to one with $[a', b'] \in T$. Then we require that the agent prefers an asset with $[a', b'] \in R \cup T$ to one with $[a', b'] \in S \cup R$.

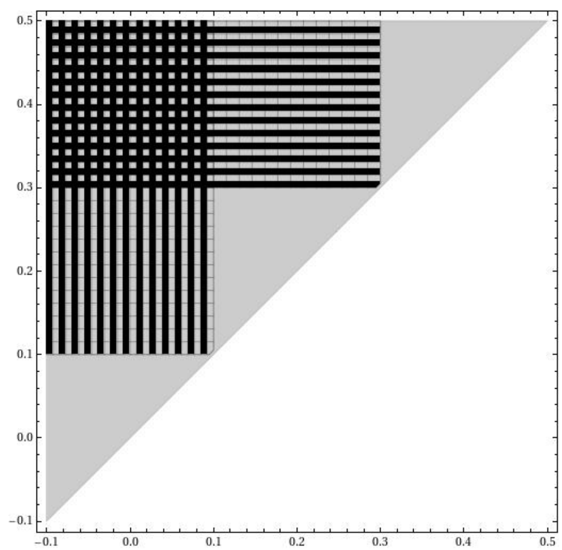

Figure 2: Preferences over sets of intervals. The x-axis represents the ex post lower bound a' on the asset's value. The y-axis represents the ex post upper bound b'. The gray triangle is the set of possible ranges of the seller's private information. The witnessed strict dominance axiom requires that agents prefer an asset with $[a', b']$ in the horizontally striped region to one with $[a', b']$ in the vertically striped region. The disjoint union betweenness axiom requires that adding the checked region to both the striped regions preserves the agents' preference ordering.

Figure 2 illustrates the idea behind these two axioms. Let S be the vertically striped region, R the checked region, and T the horizontally striped region. Assume all boundaries belong to R. Given a report of $\widetilde{v} = 0.1$, the agents know that $[a', b'] \in S \cup R$. Similarly, given a report of $\widetilde{v} = 0.3$, the agents know $[a', b'] \in R \cup T$. The witnessed strict dominance axiom requires that an agent prefers an asset with $[a', b'] \in T$ to one with $[a', b'] \in S$. The disjoint union betweenness axiom says that the agent must then prefer $R \cup T$ to $S \cup R$. If the buyers satisfy these axioms,[9] then a higher report to the market is always better news.

We therefore have the following:

Theorem 3.1 (Aggressive Reporting). *If the seller's private information is $[a', b']$, then the uniquely optimal report is $\widehat{v} = b'$.*

3.3 Effects on Demand

We now illustrate how Theorem 3.1 affects the bid distribution in the auction and leads to illiquidity. Because the seller can justify any value in $[a', b']$, we require only that the reserve price is in this range.[10] Buyers, however, know only that $\widetilde{v} \in [\underline{a}, b']$, which means that any bid above b' is a dominated strategy. See Figure 3.

Bids below $\underline{a}$ are deliberate decisions to stay out of the auction. The region of interest is therefore $[\underline{a}, b']$, where buyers offer a bid that, from their viewpoint, is potentially credible.[11]

An investor with maxmax preferences would care only about the upper bound, and therefore would always bid b'. For any other investors, the decision on how to set a credible bid

[9] A technical continuity axiom guarantees that the checked region R is not worse than the horizontally striped region T and not better than the vertically striped region S.

[10] Although maxmin preferences among buyers would give a babbling report rather than an aggressive report, it is possible to have aggressive reporting if the seller has maxmin preferences. Hence, we cannot rule out a reserve price at the ex post lower bound a'.

[11] Because the distribution of $\widetilde{v}$ is unknown to all parties, the seller cannot choose a reserve price at the expected value of $\widetilde{v}$. This expectation is not uniquely defined. Under risk, the market would shut down completely, due to the adverse selection. With ambiguity, the lemons problem (Akerlof 1970) is not as severe. Buyers remain at an informational disadvantage, but the seller can rationalize a reserve price at or arbitrarily close to a'. See Dickhaut et al. (2011).

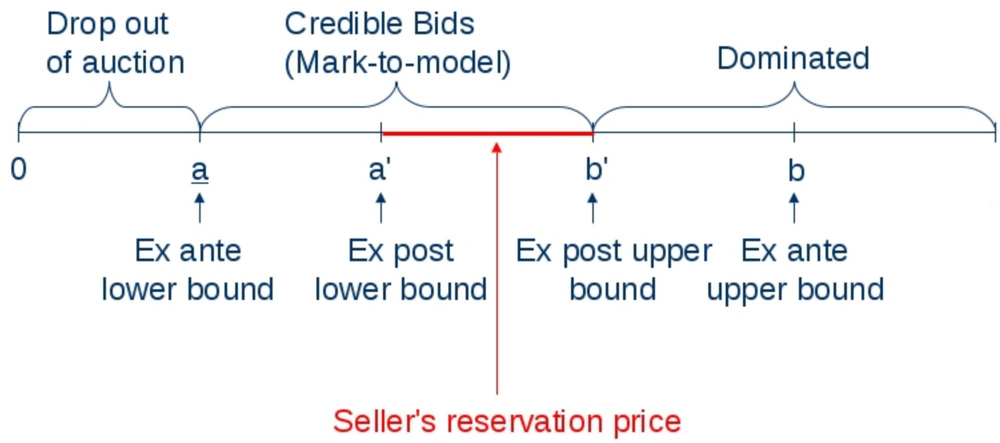

Figure 3: Bids and reserve prices under mark-to-model. The seller will always choose a reserve price in $[a', b']$. A buyer who wishes to stay out of the market can bid anything in $[0, \underline{a}]$. Because the seller optimally discloses b', no buyer with monotone preferences ever bids above b'. The buyers do not know a', and therefore any buyers wishing to make a credible bid must choose a value in $[\underline{a}, b']$.

amounts to one of estimating how much to discount the report from b'. If the highest bidder discounts the report below a'—which the bidders have no reliable way of estimating, given the ambiguity—then the market shuts down. Fixing the values of $\underline{a}$ and b', it is easy to see that the higher a' is, the greater the illiquidity from a given level of discounting. This is because the amount that the highest bidder discounts the report $\widehat{v} = b'$ can depend only on $\underline{a}$ and b'.

A conservative reporting regime, in which the seller is required to report $\overline{b}$, shifts the range of credible bids to the right. See Figure 4.

The buyers wishing to make a credible bid in a conservative reporting regime choose a bid in $[a', \overline{b}]$. This interval is shifted to the right of the corresponding interval under mark-to-model. The problem in choosing how to bid is also changed: rather than deciding on how much to discount the reported value, buyers must now decide how aggressively to bid above the reported value. A bid that is above b'—which the buyers cannot estimate—gives the

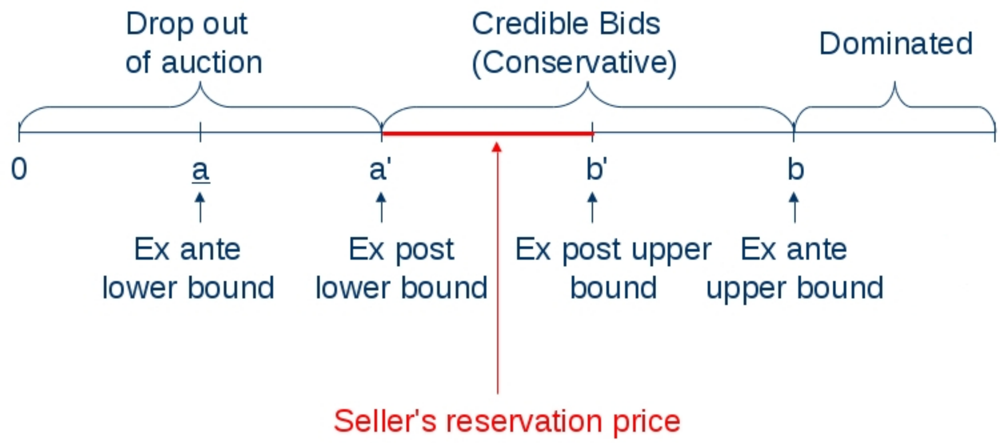

Figure 4: Bids and reserve prices under conservative reporting. The seller's reserve price is in $[a', b']$. A buyer who wishes to stay out of the market can bid anything in $[0, a']$. The buyers do not know b', and therefore any buyers wishing to make a credible bid must choose a value in $[a', \bar{b}]$.

seller an information rent. For fixed a' and $\bar{b}$, as b' decreases, a buyer at a given level of aggressiveness in bidding will be more likely to pay this information rent, which cannot arise under mark-to-model.

3.4 Remarks on Predictions

The above discussion suggests that prices, bids, and liquidity are higher under conservatism than under mark-to-model reporting. However, because we have deliberately kept our axioms on preferences as general as possible, these predictions are not the only ones consistent with our setting.

Because our preference axioms are consistent with α-maxmin expected utility, buyers who choose their bids as a weighted average of their known bounds will make higher bids under a conservative reporting regime than under a mark-to-model regime: for any $\alpha \in (0, 1]$, it is necessarily true that $\alpha \underline{a} + (1 - \alpha)b' < \alpha a' + (1 - \alpha)\bar{b}$ whenever there is at least one strict inequality in $\underline{a} \leq a' \leq b' \leq \bar{b}$.[12]

Our axioms, however, are deliberately made consistent with incomplete preferences. Consequently, there need not be a strong prediction of how or whether a buyer bids. Incomplete preferences are helpful in justifying ambiguity, but they leave some indeterminacy in the predictions. Whether the intuition from Figures 3–4 is observable is an issue we believe best settled in the laboratory.

4 Description of the Experiment and Hypotheses

To test the predictions described in Section 3, we ran a laboratory experiment. We recruited participants from the Carnegie Mellon Tepper School of Business/Social and Decision Sciences subject pool, using an online recruiting program. The experiment was coded in z-Tree (Fischbacher 2007).

Participants in the experiment were grouped together in groups of 5 for 16 rounds. Each group was assigned to one of three conditions: a fair value condition, a discretionary reporting condition, or a conservative reporting condition. The purpose of the discretionary condition was to test whether, given flexibility in reporting, sellers of a financial asset would report aggressively, as Theorem 3.1 predicts. The fair value treatment, on the other hand, imposes the aggressive reporting that occurs in equilibrium. This structure enables us to separate our tests of the predicted reporting behavior from our tests of trading behavior under mark-to-model reporting.

In each treatment, the computer privately and randomly selected one participant in each

[12] More generally, mark-to-model generates illiquidity, relative to conservatism, whenever $Pr(p^* < a'|[\underline{a}, b']) < Pr(a' \leq p^* < v^*|[\underline{a}, b']) - Pr(a' \leq p^* < v^*|[a', \bar{b}])$. That is, the probability of the highest bidder discounting too heavily must offset any added willingness to bid aggressively when b' is public.

round as the seller for that round. The other four participants in the group were the buyers for that round. The choice of the seller in each round was made independently, from a discrete uniform distribution with replacement, and this was explained to the participants in the instructions.[13]

In each round, the seller was endowed with an asset whose value was commonly known to be between \$0.50 and \$1.50. The buyers would receive an endowment of \$1.50, which they could use only in the current round. After all trading for a given round was completed (as described below), the asset's value was revealed to all the participants, along with an indication of whether trade occurred and, if so, at what price. All money that a participant held at the end of a given round was deposited into the participant's bank account, used to determine the participant's earnings but unavailable for trading in any subsequent round.

The setting of the experiment was a first-price sealed bid auction, with a privately informed seller. The timeline, common to all treatments, follows Figure 1 from Section 3, with $\underline{a}$ set to \$0.50 and $\bar{b}$ to \$1.50. In the conservative treatment, $\widehat{v}$ was always set to a'. In the fair value treatment, $\widehat{v}$ was always set to b'. The discretionary treatment allowed the seller to choose $\widehat{v}$.

To generate the values for (a', v, b') in each of the 16 rounds, we used the ambiguity generator of Stecher et al. (2011). This draws numbers from a nonstationary, nonergodic process, giving us a set of realizations where each draw came from a new distribution, and where the way the distribution was changing between draws is unknowable. We partitioned the realizations into triples and sorted, making a' the lowest realization in the triple, v the median realization, and b' the highest.

[13]Keeping the subjects grouped together was necessary for us to rule out subject heterogeneity as the sole source of differences in behavior across treatments. However, grouping creates the possibility of order effects, where behavior in one round affects decisions in subsequent rounds (e.g., learning, attempts at repeated play). We ran several tests for order effects, which we describe below in 5.6.

In total, we generated five blocks of 16 realized triples (a', v, b'), and used a matched pairs design. We ran one conservative session and one fair value session for each block of 16 triples, and ran two discretionary sessions using two of the blocks of realized triples.

Our main hypotheses stated in alternative format, were as follow:

$\mathbf{H_A^1}$**:** In the discretionary treatment, the distribution of reports first-order stochastically dominates the distribution of reserve prices.

$\mathbf{H_A^2}$**:** The bid distribution in the conservatism treatment first-order stochastically dominates the bid distribution in the fair-value treatment.

$\mathbf{H_A^3}$**:** The maximum bid under conservatism is higher than the maximum bid under fair value.

$\mathbf{H_A^4}$**:** Fair value reduces liquidity. That is, Pr[trade | Fair Value] $<$ Pr[trade | Conservatism].

The first hypothesis is based on Theorem 3.1. If buyers report aggressively, then they should disclose values that systematically exceed their reserve prices. The second and third hypotheses are related to demand and prices (or, if there is no trade, the latent price). H_A^2 states that the overall level of demand is shifted downward under fair value compared with the conservative treatment. H_A^3 states that this downward shift affects the highest bids, and hence is significant enough to affect prices in a first-price auction. The last hypothesis states that fair value reduces liquidity.

Additionally, we test whether reserve prices are affected by the reporting regime, in order to rule out supply-driven factors. We also conduct several robustness checks. For the results on liquidity, we test whether our repeated measures design drives the results. That is, we check whether differences in liquidity across matched sessions could be driven by the same behavior of individual subjects. For the results on the bid distribution, we test whether any shifts in demand are due to aggressive reporting being common knowledge. To do this, we compare the bid distributions of the discretionary sessions with those of the corresponding fair value and conservative sessions. To rule out order effects, we test whether reserve prices and maximum bids differ between the first eight and the last eight rounds of the experiment.

5 Results

5.1 Participants

We recruited 60 participants for a total of twelve sessions. An additional four participants were turned away and did not return to a subsequent session. The median participant age was 24.5 years, with an interquartile range of 21–29 years. All participants were at least 18 years old, and 45% identified themselves as full-time students (though some were pursuing graduate or professional degrees). Approximately 40% of participants self-identified as white, and another 45% self-identified as Asian. The remaining 15% either listed themselves as black, Hispanic or Latino, other, or two or more races. Roughly 40% were female.

For the discretionary reporting treatment, there were two groups of participants, giving 32 rounds of discretionary report and reserve price observations. For the conservative and fair value treatments, there were five groups each, with each conservative group matched to a fair value group. This provided us with a total of 80 matched pairs of rounds, with 160 reserve price observations and 640 bid observations.

Among the 80 matched pairs of conservative and fair value rounds, in 59/80 (74%), all participants in both groups made decisions that were rationalizable given an objective of profit maximization. In the remaining 21 rounds, at least one participant either made a bid that was guaranteed to lose money or chose a reserve price that was a dominated strategy. Among these, 13 were driven by a single subject, who consistently bid more than the commonly known upper bound on the asset's value.

Each session took approximately 45 minutes, including time to seat participants, read and quiz the participants on the instructions, and pay the participants at the end of the session. Earnings ranged from \$19.60 to \$24.02.

5.2 Aggressive reporting

In the two sessions with discretionary reporting, sellers provided both a reserve price and a report to the market. Because the private lower bound a' and the private upper bound b' varied across rounds, we calculate a normalized value $\frac{\widehat{v}-a'}{b'-a'}$, representing how far the report $\widehat{v}$ is along the line segment from a' to b'. We use a similar normalization to scale the seller's reserve price v^*. Because the reserve price is chosen privately, it is a weakly dominant strategy for the seller to truthfully report v^*.[14] If the distribution of $\widetilde{v}$ first-order stochastically dominates the distribution of v^*, then there is evidence that the seller is issuing a report that is aggressive from the seller's viewpoint. Including this comparison is crucial, because it allows us to distinguish between high reports arising from optimistic beliefs from aggressive reports.

Figure 5 shows the cumulative empirical histograms of seller reserve prices and reported values. The x-axis gives the normalized distance along the line segment from a' to b'. The y-axis shows the cumulative proportion of observations at or below a given level on the

[14] If the seller's preferences are incomplete, as is commonly assumed in models with ambiguity (e.g., Bewley 2002), then v^* is optimally chosen at a value where the seller is not worse off by selling and not better off by buying. See Appendix A.

x-axis.

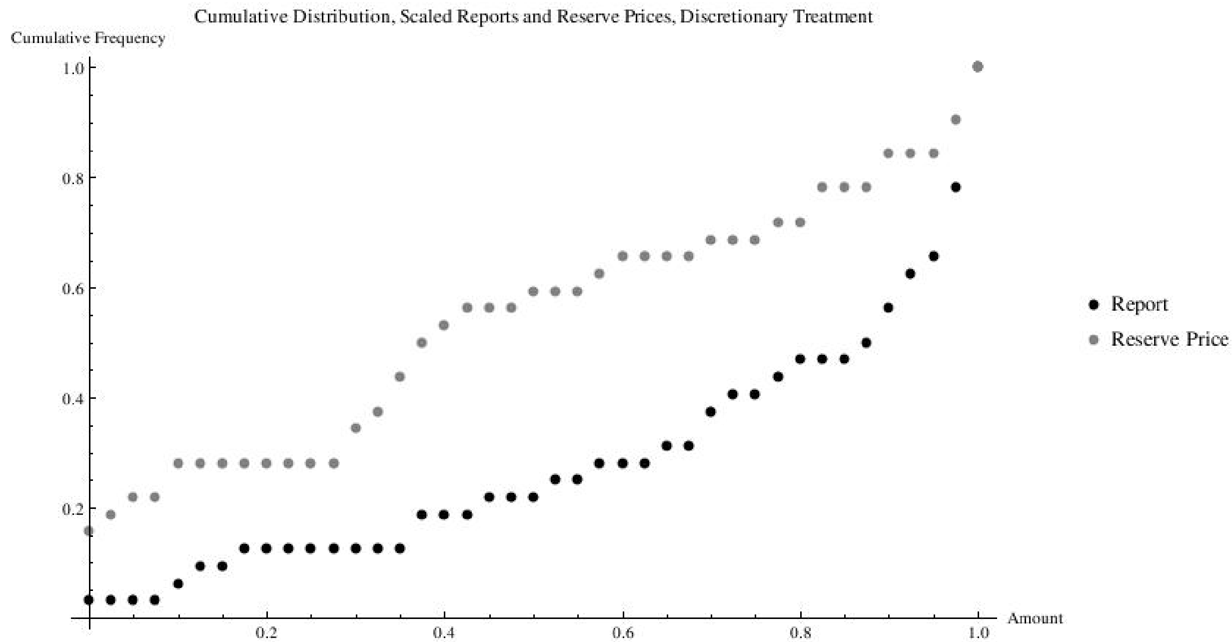

Figure 5: CDFs of scaled reported values (dark) and reserve prices (light) in baseline treatment.

Figure 5 shows that the distribution of reports is shifted to the right of the distribution of reserve prices. The difference between the two cumulative distributions is significant at the 0.05 level under a Kolmogorov-Smirnov test and at the 0.01 level under Anderson-Darling, Cramér-von Mises, and Mann-Whitney tests. We therefore strongly reject the null that the distribution of reports does not dominate that of reserve prices.

In absolute terms, the median scaled reported value was 0.87, compared with a median scaled reserve price of 0.37. That is, the median report was roughly 7/8 of the distance along the line segment from a' to b', while the median reserve price was only 3/8 of this distance. The 75%ile of scaled reports was 0.97, meaning that roughly one-fourth of sellers reported approximately at the upper bound b'. As is apparent from the figure, upper quartile of scaled reserve prices is considerably lower, at 0.82.

Overall, it appears uncontroversial that the discretionary treatment leads to aggressive reporting.

5.3 Bid distribution

Given that discretion leads to aggressive reporting, we now address whether the effects on the market of aggressive reporting originate in a downward shift in demand—that is, whether the results are the "crunch" that Chairman Isaac suggests.

Figure 6 shows the cumulative empirical histograms of bids in the conservative and fair value treatments.[15]

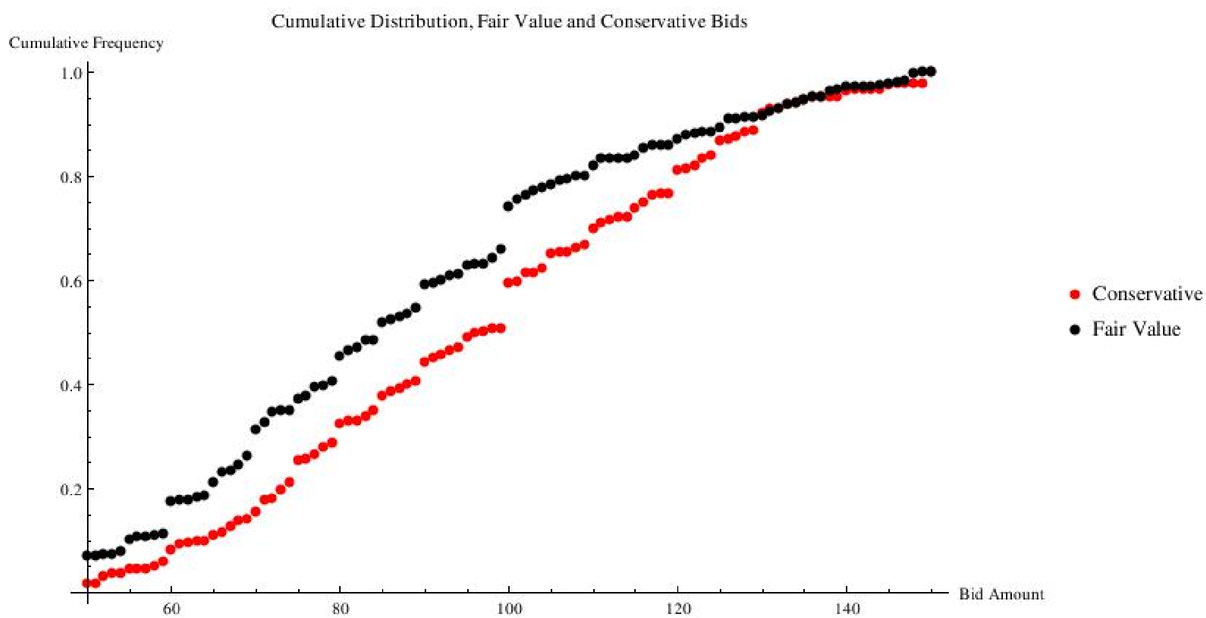

Figure 6: CDFs of bids under the conservative and fair value reporting.

Figure 6 shows that the bid distribution under conservatism is to the right of the distribution

[15]For the bid distributions, we do not scale the values between 0 and 1. This is because participants in the fair value treatment know the ex ante lower bound a and the ex post upper bound b', whereas participants in the conservatism treatment know the ex post lower bound a' and the ex ante upper bound b. The raw bid amounts are comparable, and the subjects are matched across sessions, so unscaled data are more directly comparable. This contrasts with Figure 6, where sellers always know both a' and b', and in any case face the same information when choosing their reserve prices and their reports.

under fair value. The difference between the two empirical CDFs is significant at the 0.001 level under Anderson-Darling, Cramér-von Mises, Kolmogorov-Smirnov, and Mann-Whitney tests. We strongly reject the null that the fair value does not weaken demand.

In a first-price auction, however, it is the highest bid that matters, not the entire bid distribution. Table 1 compares the average values of the maximum bids across treatments.

Conservative	Fair Value
112.8¢	105.3¢

Table 1: Average value of highest bid across treatments

Under a Wilcoxin signed-rank test, the difference in the maximum bids was significant at the 0.01 level.[16]

To test whether supply could also have played a role, we compared the distribution of reserve prices across treatments. Figure 7 shows the cumulative empirical histograms.

The CDFs of reserve prices did not differ significantly at any conventional levels. The p-values were 0.27, 0.30, 0.30, and 0.46, respectively, under the Kolmogorov-Smirnov, Cramér-von Mises, Anderson-Darling, and Wilcoxin signed-rank tests. We therefore fail to reject the null that reserve prices are independent of the reporting regime.

Combining these results, we find that supply is not affected by the adoption of fair value, but demand is significantly weakened.

[16] As noted in subsection 5.1, there were 21 rounds in which either the seller or the highest bidder made a decision that was a dominated strategy. These included 14 rounds when the highest bid was above a commonly known upper bound (in the other 7, the seller's reserve price was outside $[a', b']$). All but one of the 14 rounds with an inexplicably high bid were due to a single subject. If we restrict attention to the 59 rounds in which all subjects choose a rationalizable strategy, the difference between bid distributions becomes more significant, with a p-value below 0.001.

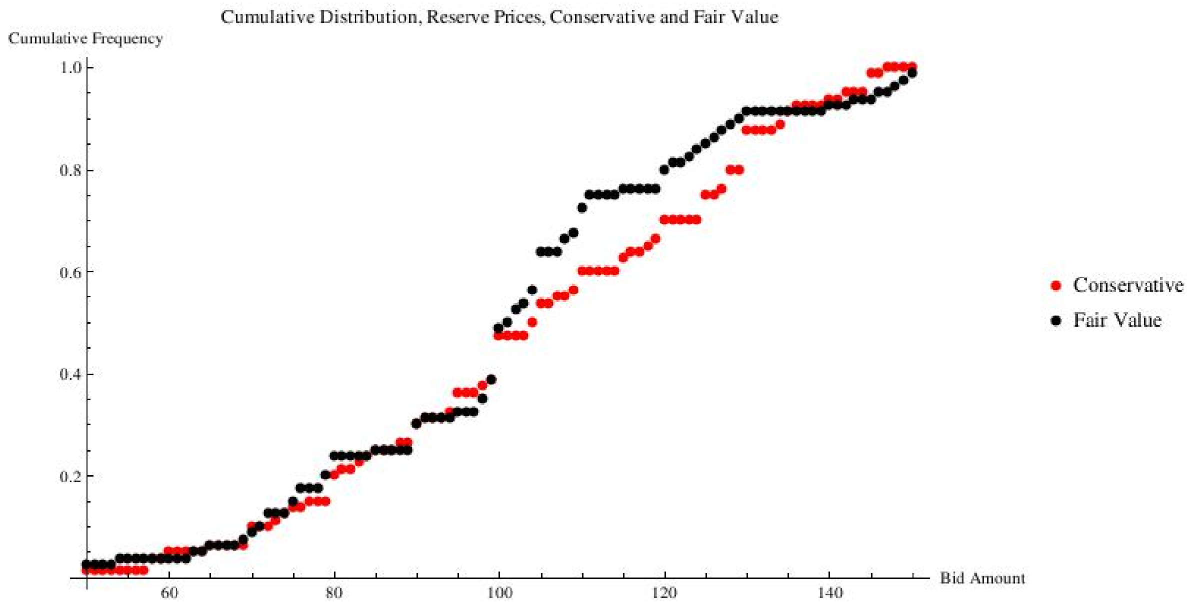

Figure 7: CDFs of reserve prices under conservative and fair value treatments.

5.4 Liquidity

Having established that the fair value regime lowers demand and maximum bids, we now address whether fair value also leads to a drop in prices. Table 2 summarizes the frequency of trade under both regimes.

Conservative \ Fair Value	Trade FV	No Trade FV
Trade C	31.3%	**36.3%**
No Trade C	**23.8%**	8.8%

Table 2: Frequency of trade, cross tabulated across treatments.

An exact form of a McNemar test, which compares the off-diagonal entries with a binomial(80,1/2), gives a p-value of 0.0279 against a one-sided alternative.

This result, however, is too strong, because the McNemar test does not adjust for the repeated measures inherent in our design. To correct for this, we use the procedure of Eliasziw and Donner (1991), who first adjust estimate the amount of correlation among the discordant pairs (i.e., among the off-diagonal elements in Table 2), then adjust the approximate McNemar test statistic for the estimated correlation.

The Eliasziw-Donner procedure gives an estimated correlation among discordant pairs of 0.183, which, though seemingly low, is enough to make the difference in frequencies of discordant pairs insignificant. However, this correlation is driven almost entirely by a single subject, whose bids were above the commonly known upper bound in 13 rounds. To adjust for the effects of non-maximizing behavior, we re-ran our tests, focusing on the 59 rounds in which the sellers and buyers in both treatments made rationalizable decisions. The results are in Table 3.

Conservative \ Fair Value	Trade FV	No Trade FV
Trade C	30.5%	**42.4%**
No Trade C	**15.3%**	11.9%

Table 3: Frequency of trade, cross tabulated across treatments, consistent rounds only.

Although the numbers in the cells of Tables 2 and 3 are similar, the Eliasziw-Donner correlation among discordant pairs changes dramatically, dropping to 0.048. This indicates that the participants who did not maximize wealth, and in particular the single participant who consistently made bids that were assured of losing money, generated almost the entire clustering effects. The difference between the frequencies of discordant pairs in Table 3 is now significant, with a p-value of 0.009.

In practical terms, the difference in trade frequency across treatments is quite large. From Table 3, trade occurred in **72.9%** of rounds under the conservative treatment, compared with **45.8%** of rounds under the fair value treatment. If we include the rounds with non-maximizing participants, trade occurs in 67.5% of rounds under conservatism versus 55.0% under fair value. This gives a likelihood ratio of 1.59 for subjects whose behavior is rationalizable and 1.23 overall.[17]

[17]Could switching from a sealed-bid to an open bid auction help improve liquidity? It seems unlikely in our setting: the friction is caused by information that none of the buyers have and that the seller cannot

5.5 Discretion vs. aggressive reporting

The analysis so far establishes our results in a piecemeal fashion. In subsection 5.2, we show that discretion leads to aggressive reporting. Making use of this result, we show in subsections 5.3 and 5.4 that the consequence of aggressive reporting is a drop in prices and liquidity, driven by a fall in demand.

To test the robustness of our predictions, we look at bidding behavior in the discretionary treatment. This is a more complex setting than the fair value treatment, because it requires participants to anticipate aggressive reporting from others, and adjust their bids accordingly. By contrast, in the fair value setting, all participants are informed that the reports will be aggressive. An initial analysis suggests that participants do not anticipate aggressive reporting from the sellers: in our discretionary sessions, we observed an astoundingly high frequency of trade, occurring in 93% of the rounds!

A more careful analysis, however, shows that the discretionary treatment is less anomalous than it initially seems. Figure 8 shows the bid distribution in the discretionary sessions and the matched fair value and conservative reporting sessions.

Figure 8 shows that the bid distribution in the discretionary treatment is shifted leftward from the conservative treatment, though not as far leftward as the fair value treatment (in which the optimal aggressive report is imposed and commonly known).

The driving force is the right tail of the bid distribution. The top quartile of bids are nearly identical under conservatism and under the discretionary treatment. So while demand in general falls when moving from a conservative to a discretionary treatment, the highest bid

credibly disclose. Also, Athey et al. (2011) find, in a different setting, that open bidding shifts the highest bid downward. This would seem more likely to amplify the amount of illiquidity in the market.

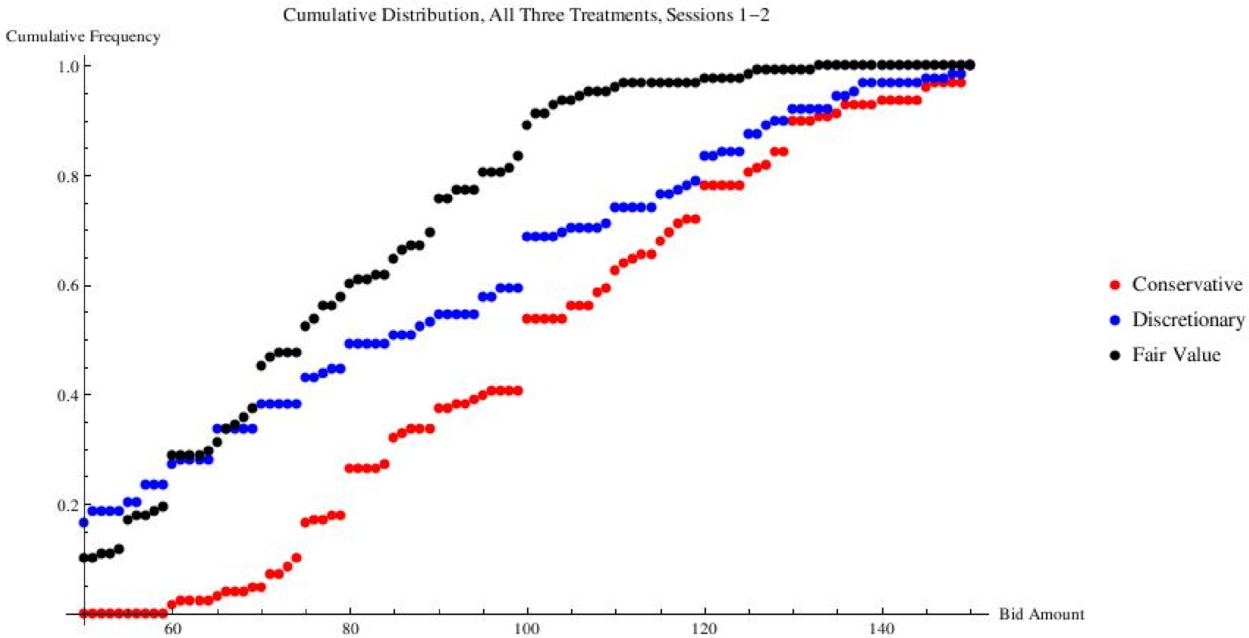

Figure 8: CDFs of reserve prices under conservative all three value treatments.

does not soften enough to eliminate trade.[18] So even with the high frequency of trade in the discretionary treatment, the bids move in the predicted direction, and the same forces are in play as in our fair value sessions.

5.6 Order effects

Our design makes reputation building difficult, as the seller's identity is private, and a participant's expected number of times as a seller is only 3.2 rounds. Nevertheless, participants may anticipate repeated interaction, or may alter their decisions due to learning. If so, then the decisions in the early rounds would not be comparable to those in the late rounds.

We provide two tests of order effects. First, we check whether the reserve price distribution varied between the first and last half of the experiment. Second, we check whether the

[18]The reserve price distribution did not differ significantly across any of the three treatments.

highest bid varied in the first and last half of the experiment.

For the fair value groups, the difference between reserve price distributions in the first and last half of the experiment differed with p-values of 0.54, 0.59, 0.64, and 0.90, respectively, under Mann-Whitney, Anderson-Darling, Cramér-von Mises, and Kolmogorov-Smirnov tests. For the conservatism group, the corresponding p-values were 0.73, 0.91, 0.93, and 0.92. So we find no evidence of an order effect on reserve prices.

Among the maximum bids, the p-values for differences between the first and last half of the experiment for the fair value group were 0.48, 0.56, 0.57, and 0.76, respectively, under Mann-Whitney, Anderson-Darling, Cramér-von Mises, and Kolmogorov-Smirnov tests. For the conservatism group, the corresponding p-values were 0.29, 0.41, 0.37, and 0.40.

In sum, we find no evidence of order effects in our participants' decisions.

6 Discussion and Conclusion

Our analysis highlights the consequences of choosing between a conservative and a mark-to-model reporting regime, in settings where there is over-the-counter trade in idiosyncratic assets, and where there is uncertainty over the distribution of asset returns. Our experiment has similar features to the structured finance market, and produces similar results to those seen in the crisis. We find that a mark-to-model regime leads to aggressive reporting, lower asset prices than under conservative reporting, and market illiquidity—exactly the "credit crunch" that former FDIC Chairman Isaac identifies, and for exactly the reasons he suggest.

The lower prices in the mark-to-model regime, however, are not the result of a panic or the popping of a bubble, but are informationally more efficient than the prices observed in a conservative regime. The reason is that, faced with a mark-to-model regime, a seller optimally discloses the ex post upper bound on the asset's value. If the highest bid is below the seller's ex post lower bound, then the seller optimally rejects the highest bid and keeps the asset. Therefore, whenever trade occurs, the price reflects all of the seller's private information. Under a conservative reporting regime, investors learn the asset's ex post lower bound, but have no way of learning the ex post upper bound. The tradeoff is, therefore, between informationally inefficient pricing in the conservative regime and inefficiency due to illiquidity in the mark-to-model regime.

A potentially fruitful direction for future work is to investigate the macroeconomic consequences of greater financial market frictions arising from adopting a mark-to-model regime. Bernanke and Gertler (1989, 1990) and Bernanke et al. (1996, 1999) have shown that the multiplier effect of frictions in lending markets can quite large; a good overview of this literature is in Hall (2010). It would be useful to know whether the multiplier effects from the illiquidity associated with marking to model overwhelm the benefits of reducing information rents.

There is good reason to expect frictions in the structured finance market played a large role in the wider crisis. Mian and Sufi (2009, 2010) and Demyanyk and van Hemert (2011) show that the demand to create mortgage-backed securities led to the rapid growth in subprime lending in the lead-up to the crisis, and that demand from subprime borrowers was not a major factor. Fostel and Geanokoplos (2012) and Gorton and Metrick (2012) document how the collapse in the market for innovative financial assets such as credit default swaps subsequently amplified the market collapse. It is important to understand the extent to which adopting a mark-to-model regime forced a halt to the credit expansion that Mian and Sufi and that Demyanyk and van Hemert identify, and whether this switch set in motion or exacerbated the collapse that Fostel and Geanokoplos and that Gorton and Metrick describe. The work of Ivashina and Scharfstein (2010), which shows how the collapse of Lehman Brothers led to frictions in the market for short-term loans, is suggestive.

From a public policy viewpoint, it is natural to wonder if there is an easy fix. Why not require firms to disclose both a conservative and a mark-to-model estimate? This idea has established precedent in financial reporting. Some employee stock options are recognized in the income statement at their immediate exercise value, ignoring the time value of the option. In the footnotes to the financial statements, the firm issuing these options discloses a fair value estimate. Several studies have found that firms use the fair value disclosure strategically (e.g., Aboody et al. 2006, Bartov et al. 2007, Dechow et al. 2010, Blacconiere et al. 2011). As another example, firms using LIFO to measure inventory flow also disclose in the notes to the financial statements a LIFO reserve, which is calculated as if the firm had used FIFO.

Reporting two numbers, for instance by requiring a conservative asset value for the balance sheet and a mark-to-model disclosure in the footnotes, may seem to give us the best of both worlds. The conservative report could safeguard the market against illiquidity, while the fair value disclosure could protect potential investors against an information rent. But there is cause for skepticism.

The difficulty is in assuring that firms would continue to disclose an aggressive mark-to-model estimate when they are required to report a conservative valuation. This is far from obvious, for reasons similar to those in Shin (1994). A firm may be better off with a pessimistic mark-to-model estimate that simply restates the conservative valuation, along with a note declaring the mark-to-model disclosure to be pessimistic. In this way, the firm discloses only the lower bound on its asset values, thereby protecting its potential information rent.

An alternative is to mandate explicitly that the firm provide a conservative and an aggressive estimate. Because one number would be declared to be aggressive, firms would no longer have incentive to underreport. The main concern associated with this approach is the additional costs of providing (and having audited) both a best-case and a worst-case scenario. Whether these costs are justifiable depends on how large they are, compared with the costs of potential information rents. Future research studying this trade-off would provide useful information for standard setters and regulators.

A Axioms and Theoretical Development

The central tenet of our argument is that the discretion in mark-to-model accounting leads to aggressive reporting. In this appendix, we elaborate on the axioms on preferences that are necessary and sufficient for aggressive reporting to be the seller's unique optimal reporting strategy. Because the market of interest to us is characterized by ambiguity, as discussed in Section 2, we allow preferences to be incomplete; see Bewley (2002) or the recent model of Easley and O'Hara (2010).

We require that all agents prefer an asset that is guaranteed to have a higher value to one that is guaranteed to be lower. Letting

$$X = \{[a, b] | \underline{a} \leq a \leq b \leq \bar{b}\},$$

we have the following.

Axiom A.1 (Interval Order). *All agents have preferences that are monotone in the range of values, in the interval order sense of Fishburn (1985): if asset x has value in $[a, b]$ and asset y has value in $[c, d]$, then*

$$b \leq c \Rightarrow x \precsim y,$$

and if there is at least one strict inequality among $a \le b \le c \le d$, then $x \prec y$.

For convenience, we will write preferences as if directly on X. Thus, we will henceforth write $[a,b] \precsim [c,d]$ instead of writing $x \precsim y$ for asset x with values in $[a,b]$ and asset y with values in $[c,d]$.

Violations of Axiom A.1 lead to counterexamples to the unique optimality of always reporting the private upper bound. If buyers have a bliss point, then there is nothing to be gained by reporting that a value above the bliss point is feasible. Note that A.1 implies a full support condition.

Because a report $\widehat{v}$ is feasible if and only if $a' \le \widehat{v} \le b'$, buyers learn from the seller's report that $a' \in [\underline{a}, \widehat{v}]$ and $b' \in [\widehat{v}, \overline{b}]$. We therefore extend preferences to *rectangular* subsets of X ("rectangles"), which are sets of the form

$$R(w,x,y,z) := \{[a,b] \in X | w \le a \le x \le y \le b \le z\}.$$

In this notation, the report $\widehat{v}$ is feasible if and only if $[a',b']$ is in the rectangle $R(\underline{a}, \widehat{v}, \widehat{v}, \overline{b})$.

Our next axiom is monotonicity with rectangular sets.

Axiom A.2 (Witnessed Strict Dominance)**.** *Let S, T be nonempty rectangular subsets of X. Suppose that*

$$(\forall [a',b'] \in S)(\exists [a'',b''] \in T) \quad [a',b'] \prec [a'',b'']$$

and

$$(\forall [c'',d''] \in T)(\forall [c',d'] \in S) \quad \neg([c'',d''] \precsim [c',d']).$$

Then $S \prec T$.

A.2 is weaker than strict dominance. It says that, if every element of S is strictly dominated by something in T, and nothing in T is strictly dominated by anything in S, then $S \prec T$. That is, given a possible range of values in S, there must be a witness in T willing to testify that T offers something better. If this condition holds, then the agent must prefer T to S. Referring Figure 2, Axiom A.2 requires that the horizontally striped region, excluding the left boundary, is strictly better than the vertically striped region, excluding the top boundary. If this does not hold, and our next axiom does, then the seller would be better off issuing a lower report than an higher report.

Axiom A.2 compares regions that are feasible under one report and infeasible under another. That is, A.2 addresses the symmetric difference of feasible regions for distinct reports. The next axiom, which we call *disjoint union betweenness*, compares the intersection of feasible regions.

Axiom A.3 (Disjoint Union Betweenness)**.** *Let S, T, U be nonempty rectangular subsets of X. Suppose $S \prec T$, $\neg(U \prec S)$, and $\neg(T \prec U)$. Then*

$$U \cup S \prec U \cup T.$$

It is important to restrict attention to rectangles that are no worse than a preferred rectangle and no better than the dominated rectangle. To see why, assume $S \prec T$ and U, S, and T are pairwise disjoint. Suppose $U \prec S$, and that T is a small region, say a single identified point $[v, v]$. Suppose U is a larger region than T, but a much smaller region than S. Then $U \cup T$ is almost identical to U, and $U \cup S$ is almost identical to S. This would suggest that very small changes to regions being compared could drastically alter preferences. The restriction of Axiom A.3 to regions U that are not worse than S or better than T avoids this difficulty.

Although violations of Axioms A.1–A.3 can provide examples where aggressive reporting is not uniquely optimal, these axioms alone are insufficient to guarantee aggressive reporting. The reason is that none of Axioms A.1–A.3 assures that the checked region in Figure 2 is neither better than the horizontally striped region nor worse than the vertically striped region. To fix this, we need a closure condition. We first define a notion of distance.

Definition A.1. Let $[a,b],[a',b'] \in X$, and let $U \subseteq X$. Define

$$\begin{aligned} d([a,b],[a',b']) &:= \|(a,b)-(a',b')\| \\ d([a,b],U) &:= \inf_{[a'',b'']\in U} d([a,b],[a'',b'']) \end{aligned}$$

If $U = \varnothing$, then set $d([a,b],U) := -\infty$.

Definition A.1 says the following: associate the interval $[a,b] \in X$ with the point $(a,b) \in \mathbb{R}^2$, as in Figure 2. Define the distance between two intervals be the Euclidean distance between the associated points in $\mathbb{R}^2$, and let the distance from an interval $[a,b] \in X$ to a subset $U \subseteq X$ be the distance from $[a,b]$ to the closest point in X.

Axiom A.4 (Closure)**.** *Let S,T be rectangular subsets of X, with $S \prec T$. Then for all $[a,b],[a',b'] \in X$, if $d([a,b],S) = d([a',b'],T) = 0$, $\{[a,b]\} \precsim \{[a',b']\}$.*

Lastly, we impose a consistency condition.

Axiom A.5 (Consistency)**.** *Let $S,T \subseteq X$. Suppose $(\forall[a,b] \in S)(\forall[c,d] \in T)$, we have $[a,b] \precsim [c,d]$. Then $S \precsim T$.*

Lemma A.6. *Let* $\underline{a} < v' < v'' < \bar{b}$. *Define the rectangles*

$$\begin{aligned} S &= R(\underline{a}, v', v', v'')\backslash\{[a,b] \in X | \underline{a} \leq a \leq v' \textit{ and } b = v''\} \\ T &= R(v', v'', v'', \bar{b})\backslash\{[a,b] \in X | a = v' \textit{ and } v'' \leq b \leq \bar{b}\} \\ U &= R(\underline{a}, v', v'', \bar{b}) \end{aligned}$$

Then $\neg(U \prec S)$ *and* $\neg(T \prec U)$.

Remark. In Lemma A.6, the regions S, T, and U correspond to the vertically striped, horizontally striped, and checked regions in Figure 2.

Proof. First, note that, for every $[a_0, b_0] \in S$ with $a_0 < v'$, the points $\{[a,b] \in X | a = v' \text{ and } v'' \leq b \leq \bar{b}\} \subset U$ strictly dominate $[a_0, b_0]$. On the other hand, no point in S strictly dominates any point in U. So again by witnessed strict dominance, $S\backslash\{[a,b] \in S | a = v'\} \prec U$.

Next, observe that for any $[v', b] \in S$ and any $[c, d] \in U$, we have $d([v', b], S) = d([c, d], U) = 0$. So by the closure axiom A.4, $[v', b] \precsim [c, d]$. We therefore have, for all $[a, b] \in S$ and for all $[c, d] \in U$, $[a, b] \precsim [c, d]$, and hence by the consistency axiom A.5, $S \precsim U$.

An analogous argument shows that $U \precsim T$. $\square$

We can now prove Theorem 3.1.

Proof of Theorem 3.1. Let S, T, U be as in the proof of Lemma A.6. We will show that $S \cup U \prec T \cup U$. Since $S \cup U$ is the information the buyer receive from report v' and $T \cup U$ is the information the buyers receives from report $v'' > v'$, this will imply that a higher report is always better news. Consequently, the seller's uniquely optimal strategy is to choose the highest admissible report, $\widehat{v} = b'$.

Observe that $S \prec T$; this is an immediate consequence of the interval order axiom A.1 and the witnessed strict dominance axiom A.2. Lemma A.6 then guarantees that $S \precsim U$ and $U \precsim T$. By the disjoint union betweenness axiom A.3, the result follows. □

B Instructions

We provide the instructions and the review questions for the conservative treatment. The instructions for other treatments are shown in brackets.

Instructions

This is an experiment in the economics of decision-making. This experiment will last approximately one hour. Do not talk to others at any time during the experiment. If you have any questions during the experiment, please raise your hand.

To make a profit, you will trade a financial asset. At the end of the experiment, we will pay you a show-up fee of $5 plus any profits you will have made.

The experiment will last for 16 rounds. In each round, the computer will randomly select one person as the seller. The other four participants will be buyers for that round. Everyone has an equal chance of being the seller in any given round. The computer will tell you whether you are a seller or a buyer. The computer will not tell the buyers who the seller is.

At the beginning of each round, the seller will receive an asset, and the buyers will receive 150 cents. The computer will determine the asset's value at the end of the round.

Your Information [*Discretionary treatment:* Your Information and the Seller's Report]

If you are the seller, the computer will tell you a minimum and maximum value of the asset for that round. The minimum will be at least 50 cents, and the maximum will be at most 150 cents. The asset's value will be between the minimum and maximum. [*Discretionary treatment:* The computer will ask you to enter a possible value of the asset, which must be between the minimum and the maximum.] If you are a buyer, the computer will tell you the minimum, and will remind you that maximum is at most 150 cents. [*Fair value treatment:* If you are a buyer, the computer will tell you the maximum, and will remind you that minimum is at least 50 cents.] [*Discretionary treatment:* If you are a buyer, the computer will tell you the possible value the seller entered.]

The Auction

If you are a seller, the computer will ask you to enter the lowest price for which you are willing to sell the asset. None of the buyers will see the minimum price you enter.

If you are a buyer, the computer will ask you to enter the amount you are willing to pay for the asset. We call this amount your bid. You may enter any amount from 0 to your 150 cents. None of the other participants will see your bid.

If the highest bid is at least the minimum price the seller is willing to accept, then the computer will sell the asset to the buyer who made the highest bid. The price will be the amount of the highest bid. If two or more buyers tie for the highest bid, then the computer will randomly select one of these buyers and sell the asset to the selected buyer. The computer will then determine the asset's value. If trade does not occur, the seller will receive the asset's value. If trade occurs, the buyer who bought the asset will receive the asset's value. After the computer determines the asset's value, your money for the current round will be deposited into your account.

At the end of the experiment, we will pay you the balance in your account. If your account balance is negative, we will still pay you the full $5 show-up fee.

If you have any questions, please raise your hand now.

Review Questions

Please answer the following questions. Your answers will not affect your payment.

1. The computer tells the seller that the asset is at least 59 cents and at most 120 cents. The computer will also tell the buyer that the asset is worth at most 120 cents. [*Discretionary Treatment:* The computer tells the seller that the asset is worth at least 59 cents and at most 120 cents. The computer will also tell the buyers the possible value the seller enters.]

   True **False**

2. The computer tells the seller that the asset is at least 59 cents and at most 120 cents. The computer will also tell the buyer that the asset is worth at least 59 cents. [*Discretionary treatment:* The computer tells the seller that the asset is worth at least 59 cents and at most 120 cents. The seller may enter a possible value of 125 cents.]

   True **False**

3. The lowest price for which the seller is willing to sell the asset is 76 cents. The highest bid is 87 cents. Trade will occur.

   True **False**

4. The lowest price for which the seller is willing to sell the asset is 87 cents. The highest bid is 76 cents. Trade will occur.

True **False**

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