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Information management and valuation: an experimental investigation

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Abstract

We explore the management of information and the response of market prices to such information. Sellers may be uncertain of dividends. We examine whether sellers anticipate buyers' pricing behavior and whether buyers' prices reflect correct inferences of the disclosure strategy of sellers. Buyers' inferences and sellers' anticipation require implicit Bayesian updating in solving for the equilibrium decision strategies of sellers and pricing behavior of buyers. Because of traditional problems in inducing Bayesian behavior we employ a manual technology. Our results show that if we split selling strategies into "information management" (sanitization), full disclosure, and randomization, then the information disclosed is consistent with sellers anticipating buyers' pricing functional. Furthermore, prices themselves are sensitive to the information environment (full certainty, intermediate certainty, and low certainty) in which information asymmetry is manipulated.

JEL classification: D800; D820

Keywords: Sanitized disclosure; Information management; Sophisticated bidders; Naive bidders; Experimental economics

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1. Introduction

Consider the seller of an asset who may observe imprecise and private signals about the value of the asset. Does she manage her private information in order to disclose the most favorable news about the asset? If the answer is yes, are buyers sophisticated enough to take this information management into account when they bid for the asset? Given that the seller's information is informative but imprecise, the following question arises. For the same disclosures by the sellers, do buyers' bids change when the probability that the seller observes private information changes?

The literature on disclosure has been concerned with the problem of the informed party misrepresenting the facts to the uninformed party. Grossman (1981) and Milgrom (1981) are the first papers to provide a framework for studying disclosure issues. These two seminal papers establish the conditions under which the so-called unraveling result is obtained. In its simplest form, the unraveling argument rests on the following three conditions:

(1) the informed party has perfect information concerning the payoff relevant state,
(2) cannot lie, and
(3) can costlessly disclose.

Given these assumptions, the pair of strategies in which the informed announces the most favorable report consistent with the truth and the uninformed assumes the worst given the announcement constitutes an equilibrium. Consequently, the informed party finds it in her best interest to disclose all her information given the buyer's extreme skepticism.

Much of the theoretical accounting literature on voluntary disclosure has relaxed the previous three conditions so that the unraveling result "unravels" and therefore full disclosure is not an equilibrium.[2] These theoretical models show that by relaxing one or more of these three conditions, partial disclosure can occur in equilibrium. Dye (1985) and Jung and Kwon (1988) relax condition (1) and show that when buyers are unsure of the information endowment of a seller, only relatively good news is disclosed in equilibrium. Shin's model (1994) provides the most general results on partial disclosure. In the Dye and Jung and Kwon studies, whenever a seller has private information about the asset's value, it is precise information. Shin (1994) relaxes condition (1) by introducing uncertainty and imprecision in the seller's private information about an asset.[3] As in

[2] The accounting disclosure literature has also examined other numerous interesting and complex disclosure issues such as disclosure regulation or the real effects of accounting disclosures; not all of which have been fully resolved. As a sample of the disclosure issues and the nature of differences among theorists, as well as between theorists and archival researchers we recommend the *Journal of Accounting and Economics* conference issue, volume 31, September 2001 and the *Journal of Accounting and Economics*, volume 32, December 2001, especially the paper on "Essays on disclosure" by Robert E. Verrecchia (2001) and the discussion on "Essays on disclosure" by Ronald A. Dye (2001).

[3] For example, consider an asset that pays S_i in state i where $i \in \{1, \ldots, N\}$. Suppose the true state of nature is k. If a seller receives precise private information about the asset, she knows for sure that the asset pays S_k. On the other hand, if the seller's private information about the true state of nature is not precise, she may only know that the asset's payoff lies in the partition element $\{S_j, \ldots, S_L\}$ where $1 \leqslant j < k < L \leqslant N$.

previous models, it is possible that the seller has no information at all. However, if the seller is informed, the nature of her informational advantage may be qualitatively different. This richer information structure enables us to ask the following empirical question. Given the information endowment of the seller (whether the news is good or bad), does she manage that information in order to disclose the most favorable news about the asset? Shin characterizes sequential equilibria in which the following are true: the seller discloses the most favorable information about the asset; the buyers rationally anticipate the seller's disclosure strategy and discount her disclosures. This anticipation is reflected in the price the buyers bid for the asset.[4]

Despite theoretical work in the disclosure area, direct empirical evidence testing theory has been relatively scarce.[5] Two major obstacles impede the empirical testing of disclosure theories. First, it is difficult to match the private information of sellers to their corresponding disclosures. Second, it is impossible for a researcher to know *a priori* the likelihood with which sellers are informed. Laboratory experiments can be used to overcome these two obstacles by controlling these two elements.

Our study differs from the previous experimental literature on information management because it presents a new challenge to both the buyers and the sellers of the asset. In the previous literature, if sellers receive a message, then they know with certainty the value of the dividend. Therefore, at most, when buyers receive no message from the seller, the buyers must only decide whether the seller received a message or not. In our study, the seller may receive, at most, two messages about the amount of the dividend, each of which contains the true dividend. If the seller receives both messages, then the seller knows the amount of the dividend with certainty. However, it is also possible that the seller will only receive one of the two messages, or none at all. In this case, the seller will not necessarily know the exact amount of the dividend, but instead some set that it is in. Therefore, when the seller sends a message to the buyers, she must not only decide if she wishes to send a message, but whether she wants to send both messages or just one of the two messages.

Of the previous experimental studies on disclosure, this paper relates primarily to Forsythe et al. (1989) and King and Wallin (1991a, 1991b). In both the Forsythe et al. and the King and Wallin (1991b) studies, an informed seller determines whether to disclose that information or to remain quiet. The buyers know that the seller is informed. Therefore, they must only determine how the seller is managing the information that they know the seller has.

In Forsythe et al.'s (1989) experiment a seller can either credibly disclose the exact value of her asset to potential buyers or choose to "blind bid" the asset by making no disclosure. Forsythe et al. generally find evidence consistent with the sequential equilibrium that

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4 It is conceivable that there could be some additional costs to truthful but partial disclosures. For example, if a buyer could observe the seller's information endowment ex-post, the buyer could penalize the seller in future transactions. Similarly, legal institutions could also impose penalties on the seller for partial disclosures. Shin (1994) does not consider such costs and we therefore deliberately abstract away such reputational and legal issues in our study.

5 There has, however, been an abundance of interesting *experimental* research on disclosure issues in accounting (see, for example, Dopuch et al. (1989), or King (1996), or more recently, Dopuch et al. (2001)). We have chosen to discuss and work with a small subset of the experimental disclosure research that is directly relevant to our current study.

sellers disclose their asset's value truthfully and completely. This evidence is consistent with Grossman's full disclosure result.

King and Wallin (1991b) has similarities to this paper. While the seller in King and Wallin knew the exact dividend with certainty and the buyers knew the seller had that knowledge, the seller was presented with a menu of disclosure options depending on the true dividend. The true dividend belonged to the set $\{15, 25, 35, 45, 55, 65, 75, 85\}$. A seller, knowing the dividend was 35, could, in one treatment, issue the disclosure $\{35\}$, $\{25, 35\}$, $\{35, 45\}$, $\{15, 25, 35, 45\}$, or remain silent, consistent with the imposed antifraud rule.

King and Wallin (1991a), a test of the Dye (1985) and the Jung and Kwon (1988) models, had a seller who may or may not be informed of the exact value of the dividend. If the seller was informed, she could only issue the exact dividend value, or no information at all. King and Wallin (1996) extend this to a situation where the probability of the seller becoming informed changes over time.

Our paper fills a gap in the literature. Like King and Wallin (1991b), it allows for imprecise disclosure even when the exact dividend is known. Like King and Wallin (1991a), the seller may be uninformed. And, unlike either, the seller may have imprecise information.[6]

By adding uncertainty to the knowledge of the seller, we increase the difficulty of the buyers' bidding decision. Therefore, when buyers receive a message, they may not know the amount of the true dividend. In the previous literature if the buyers received a message, they knew the seller knew the true value of the dividend. Thus they needed only to be concerned with the seller's disclosure strategy insofar as it changes the expected value of the dividend when no message was received. However, with the more extensive message space that we have employed, buyers must now also be able to compute the expected value of the dividend conditional on each possible message received. In doing so, they must revise their beliefs about the probabilities of each dividend conditional on the seller's strategies, and the probabilities of each message being received by the seller. For the fully rational buyer, this revision takes the form of Bayesian updating.

To implement a setting with severe probabilistic revision demands we employ several criteria of long standing in experimental economics. Davidson and Suppes (1957) were the first to advocate the use of physical objects to encourage beliefs by the subject in the nature of the apparatus. A major point was that if the subject could check the apparatus and actually observe it (even if only in practice rounds) there was a much better chance that the subject's perception of the setting would be consistent with what the experimenter was attempting to implement. In studying the "representative heuristic" Grether (1980) has implemented physical apparatus to ensure subject understanding before testing the predictive ability of Bayes theorem. Sedlmeier and Gigerenzeer (2001) suggest that individuals throughout life are exposed to naturally occurring frequencies. We argue that this makes the choice of a coin a good one. People have experience with coins and we hypothesize they are able to adjust their sensitivity based on the actual natural frequencies with which they occur. In addition, we believe the use of manual technology reduces the

[6] We thank the referees for helping us better relate our study to the relevant prior experimental literature.

skepticism of the subjects by allowing them to check the probabilistic mechanism anytime during the experiment.

It is in such a probabilistic world that we are concerned with how subjects are able to manage information. When sellers receive a message, do they always send this message?, or are there instances where they sanitize the information that they permit the buyer to observe? And, if the seller does omit some of the messages that she receives, do the buyers consider this when making their decisions? We now discuss how buyers and sellers might employ such probability revisions, and how these probability revisions affect the signals that the seller sends, and the prices that buyers bid.

For clarity, we will work backwards. When buyers observe a message that was sent by the seller, how do they decide what to bid? The buyers must decide what the message they receive tells them about the true dividend. They then calculate the expected value of the dividend given the message. This expected value depends on the probability of each state, given the messages received, and the seller's reporting strategy. Therefore, in order to calculate these probabilities, the buyers must form some beliefs about the seller's strategy for relaying messages. If the buyer believes that the seller is not sending all of the messages that she receives, then the buyer must use these beliefs, and the underlying probabilities of each state, given the message, to compute the price that she is willing to pay. Buyers then bid against each other in a first price sealed bid auction. The Bertrand nature of this pricing rule suggests that buyers' bids accurately reflect the expected (by the buyers) value of the dividend.

In addition, the sellers must choose which messages to send. Because of this, they must have some beliefs about the actions that the buyers will take in response to each message. Again, the seller must have some beliefs about the buyers' behavior when determining the optimal reporting strategy. While the seller's Bayesian revision may be slightly less complicated than that of the buyers, it is still important that the seller be able to compute the conditional price of the dividend for each message, given the beliefs of the buyer.

For these reasons, we attempt to follow the most widely accepted practice to ensure that subjects understand the probabilities of each of the messages being received by the seller. We used a coin to determine which messages were sent. We assume that people tend to have a belief that a coin, after inspection, is fair.

In our experiment, we study three different information treatments. Using a laboratory approach, we are able to control the amount of private information that a seller observes about the value of the asset. By analyzing the information that the seller discloses, we investigate the seller's disclosure strategies. By analyzing the buyers' bids we test whether the buyers are sophisticated bidders or naive bidders. If the buyers are sophisticated bidders, they understand the seller's reporting incentives and adjust their bids accordingly. If the buyers are naive bidders they believe the seller is making truthful and complete disclosures and ignore the adverse selection problem they face. We compare the bids across the three different information treatments to see if the bids are significantly different for the same disclosures made by the seller as the degree of information asymmetry between the seller and the buyers changes. If the buyers are sophisticated bidders, then theory predicts that bids will be different. This is not true for naive bidders.

2. Experimental design

2.1. Environment[7]

In our experiment a seller owns an asset that has payoffs in three equally likely states of nature.[8] The payoffs are 100, 200, or 300 francs. This prior distribution is common knowledge. The true dividend (100, 200, or 300) is privately drawn by the experimenter. Based on the true dividend selected, the seller may observe up to two messages about the true dividend. The probability with which the seller observes each message depends on the information treatment as shown in Table 1. The seller has two independent chances to observe messages about the true dividend. The lower partition element, the unfavorable message containing the true dividend, will be reflected in the first message. The upper partition element, the favorable message containing the true dividend, will be reflected in the second message. If she does not observe a message on either attempt, she observes a null message. Suppose the true dividend is 100 francs. The seller may observe a first message that is the lower partition element containing the true dividend, i.e., the message {100}. The seller may observe a second message that is the upper partition element containing the true dividend, i.e., the message {100, 200}.

The information treatments are identical except for the probability with which a seller observes a message about the true dividend. Sellers in the full certainty treatment always observe two messages about the true dividend and thus are perfectly informed about the true dividend. On the other hand, sellers in intermediate and low certainty treatments may observe zero, one, or two messages about the true dividend. The degree of information asymmetry between a seller and buyers is therefore the highest for the full certainty treatment, moderate for the intermediate certainty treatment, and lowest for the low certainty treatment. For each information treatment the messages that the seller may

Table 1
Probability of the seller observing messages for each information treatment

Probability of each message:	Suppose the true dividend is											
	100				200				300			
	messages observed				messages observed				messages observed			
	{100}	{∅}	{100, 200}	{∅}	{100, 200}	{∅}	{200, 300}	{∅}	{200, 300}	{∅}	{300}	{∅}
Full certainty treatment	1	0	1	0	1	0	1	0	1	0	1	0
Intermediate certainty treatment	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
Low certainty treatment	1/8	7/8	1/8	7/8	1/8	7/8	1/8	7/8	1/8	7/8	1/8	7/8

7 For an explanation of the main elements of Shin's (1994) model, see Appendix A.

8 We chose three states of nature to test the most parsimonious version of Shin's (1994) model. Using two states of nature would have been equivalent to testing the Dye and Jung, and Kwon models—see for example, King and Wallin (1991a, 1991b).

observe depend on the true dividend selected, but the messages are observed independently of each other. The message $\{100, 200, 300\}$ is always implicitly observed because the true dividend is always one of these three.

After the seller observes the messages, she decides which message(s) to disclose to the buyers. After observing the seller's disclosures, if any, three buyers bid for one unit of the asset in a first-price, sealed bid auction. We use a first-price, sealed bid auction to overcome the limitations of oral and second-price, sealed bid auctions, respectively. Oral auctions may lead buyers to adapt their behavior in response to the behavior of other buyers. Previous experimental work, e.g., Kagel et al. (1995) has shown that the second-price common value auctions provide noisier data compared to first-price common value auctions. Because of the Bertrand nature of pricing in this environment, and the common value of the asset, subjects' bids should, in principle, be arbitrarily close to their true value for the dividend.[9]

2.2. Procedures

Eighteen sessions were run in this experiment: 6 sessions for each of the three information treatments. Each session consisted of 6 subjects recruited from undergraduate economics courses at the University of Minnesota. Subjects were over-recruited for each session. Any subject bumped due to over-recruiting was paid $8. At the beginning of each session, each of the 6 subjects drew a poker chip without replacement from a bag. This chip determined their seat in the experiment. Each seat location was surrounded by a screen to maintain privacy. A no-talking rule was strictly enforced. Each buyer began the experiment with a balance of 1200 francs. During the experiment, payoffs were calculated in francs. The payoffs were converted back to dollars at the end of the experiment using a rate of 0.01 francs to the dollar.

Once subjects were seated, the instructions were read aloud to them. The instructions for the intermediate certainty treatment are reproduced in Appendix B. After the instructions were read and any questions answered, a practice round started. No cash was earned in the practice round. Each session consisted of a practice round and 10 trading rounds. In each round only one unit of the asset was traded. Three out of the five buyers were randomly pre-selected to bid for one unit of the asset in each of ten trading rounds thus making it difficult to identify who was bidding in that round. However, all buyers were required to submit a bid form whether or not they participated in a round. Those bidders not bidding in the current round submitted blank bid forms. We randomized the bidders' group composition from round to round in order to make it difficult for buyers to collude.[10]

[9] We do, however, acknowledge that there may be some problems with the first price auction. It is the case that it only requires one person to over bid, to distort prices compared to theory whereas the second price auction requires that at least two people overbid in order to obtain the same results. However, we have no evidence in this case that the results are driven by a single buyer's beliefs in any of the results.

[10] Though outright collusion among bidders has not been reported under standard experimental procedures, we felt that by using 5 players, and rotating, we would help ensure this did not happen. In fact, we did occasionally observe unusually low bids by individual buyers in some of our sessions as a message of a possible willingness to cooperate. However, this behavior was short lived. We do not formally test for collusion. The fact that individual buyers earned quite modest trading profits (approximately $2.50 for the entire experiment) is indirect evidence that behavior was close to competitive.

We will now describe the timing of the experiment for the intermediate certainty case because it is the most difficult to understand. We then require a small modification for the other cases.

First, the experimenter selected the true dividend for the round by privately drawing a poker chip from a bag. Each dividend (100, 200, or 300) was equally likely to be chosen. Next, the messages that the seller would receive were determined. The two possible messages that the seller might observe depended on the true dividend drawn in step 1 (see Table 1). To determine which of these messages the seller would receive, the experimenter tossed a coin twice behind a screen, once for the first message and once for the second message.

Once the box was received, the seller privately opened the message box and examined the messages. The message box might contain zero, one, or two messages. It was then up to the seller to decide how many messages to send back to the experimenter. The seller then returned some, all, or none of the messages in the message box.

After collecting the message box from the seller, the experimenter publicly disclosed the messages returned by the seller. After observing the disclosures, each buyer bid for one unit of the asset. The experimenter publicly announced the true dividend, the bid made by each buyer along with the buyer's identification number and the highest bidder. The highest bidder purchased the asset at the amount of her bid.[11] The profits or losses for the round were calculated for each player and were checked by the experimenter. The seller's profits equal the amount of the highest bid. The highest bidder's profit (or loss) equaled the true dividend less the amount of the highest bid. All other bidders earned zero profits. A new round was started.

To modify this procedure for the other treatments, all that was different was the determination of which messages the seller would receive. In the full certainty case, the experimenter always placed two message cards in the message box. The two message cards that the seller observed depend on the true dividend drawn in step 1 (see Table 1). For the low certainty case, to determine which messages the seller would see, the experimenter performed two series of coin tosses behind a screen. The messages were then delivered to the seller in a closed message box.[12]

Upon completion of each session, the seller's profits were added up for all the rounds and converted into dollars by using the exchange rate on the seller's personal history form. Each buyer's profits (or losses) were added to (or subtracted from) the beginning cash balance of 1200 francs and converted into dollars by using the exchange rate on the buyer's

[11] If two or more bidders tied for the highest bid, the winning bidder was determined by randomly choosing one of the highest bidders.

[12] Each series consisted of 3 coin tosses to reflect the probability, $1/8$, of the seller observing any message at all. If the coin landed on "Heads" all 3 times, a message card was placed in the message box. Otherwise, no message card was placed in the box. The coin was tossed 3 times in each series regardless of the outcomes; (e.g., even if the first toss landed on "Tails," the coin was still tossed the remaining two times). This was done to prevent the buyers from inferring whether or not the seller observed a message from a premature termination of the coin tosses.

personal history form. Each subject was paid her cash earnings privately at the end of the experiment.[13] Each session lasted approximately 90 minutes.

3. Equilibrium

3.1. Seller's disclosure strategies and buyers' pricing strategies

A disclosure strategy for the seller is a function from the set M_0 of messages that the seller observes to the set M_s of messages that the seller discloses. A pricing strategy for a buyer is a function from the set M_s of messages that the seller discloses to bidding decisions in $\mathbb{R}_+$.

3.2. Sanitization disclosure strategy

Shin (1994) establishes that there exist sequential equilibria in which the seller employs a sanitization disclosure strategy, and buyers rationally anticipate this strategy in pricing the asset.

Shin (1994) denotes a sanitization disclosure strategy as one in which a seller manages her information by selectively disclosing the most favorable information about the asset. This information management is accomplished by disclosing the message that provides the most favorable information about the true dividend and suppressing all other messages.

Formally, consider an asset that pays S_i in state i where $S_1 < \cdots < S_i < \cdots < S_N$. Suppose the seller observes messages which together reveal that the true dividend lies in the partition $\{S_i, \ldots, S_L\}$, where $1 \leqslant i \leqslant L \leqslant N$. Then the seller uses a sanitization strategy by disclosing only the message that provides the most favorable information about the true dividend: the message $\{S_i, \ldots, S_N\}$. Note that the information partition is such that the message disclosed always contains the true dividend, thus preventing the seller from lying.

Following Milgrom and Roberts (1986), if a bidder's pricing functional takes into account the seller's sanitization strategy, we call him a sophisticated bidder. Sophisticated bidders are capable of game-theoretic reasoning. A sophisticated bidder takes a seller's reporting incentives into account in forming posterior beliefs about the value of the asset. As compared to the prior probabilities, these posterior beliefs will discount a seller's disclosures by putting less weight on the higher states of nature. An alternative hypothesis is that buyers take the seller's disclosures at face value. Like Milgrom and Roberts, we call these naive bidders. A naive bidder is an unsophisticated bidder in the sense that he will form beliefs about the value of the asset using naive updating by Bayes' rule on the *ex-ante* probabilities. Naive bidders ignore the bias that adverse selection introduces into the seller's disclosures.

In our experiment, the sanitization disclosure strategy by a seller is always an equilibrium strategy, regardless of whether a bidder is sophisticated or naive. However,

[13] Sellers earned an average of $19.00 for each session. Buyers earned an average of $14.50 for each session. The exchange rate used was the same for buyers and the seller but each subject was privately informed about only his or her exchange rate. As stated before, the conversion rate is 0.01 dollars per franc.

Table 2
Messages disclosed by the seller as a function of messages observed by the seller depending on the disclosure strategy

Messages the seller may observe	Messages the seller discloses if the seller uses a sanitization disclosure strategy	Messages the seller discloses if the seller uses a full disclosure strategy
{Ø}	{Ø}	{Ø}
{100}	{Ø}	{100}
{100, 200}	{Ø}	{100, 200}
{100} and {100, 200}	{Ø}	{100}[b]
{200, 300}	{200, 300}	{200, 300}
{100, 200} and {200, 300}	{200, 300}	{100, 200} and {200, 300}
{300}	{300}	{300}
{200, 300} and {300}	{300}[a]	{300}

[a] Note that disclosing the messages {200, 300} and {300} is informationally equivalent to simply disclosing the message {300}. A seller who is sanitizing could then either disclose both messages {200, 300} and {300} or simply disclose the message {300}. Instead of writing {200, 300} and {300} for messages disclosed, we simply write {300} in the tables.

[b] Disclosing the messages {100} and {100, 200} is informationally equivalent to simply disclosing the message {100}. A seller who uses a full disclosure strategy could either disclose both messages {100} and {100, 200} or simply disclose the message {100}. Instead of writing {100} and {100, 200} for messages disclosed, we simply write {100} in the tables.

the sanitization disclosure strategy is not unique when the seller is fully informed as in the full certainty treatment. Full disclosure is also an equilibrium strategy in the full certainty treatment. This is because the inferences made by the buyer and therefore the information conveyed in equilibrium by the sanitization disclosure strategy or the full disclosure strategy are the same in the full certainty treatment. When a seller follows a sanitization disclosure strategy and buyers know that such a seller has perfect information about the true dividend, they put zero weight on all the states disclosed except for the lowest. Consequently, the seller then is indifferent between sanitizing the disclosures or making a full disclosure. Unlike the full certainty treatment, the sanitization disclosure strategy is unique in the intermediate and low certainty environments.

Table 2 lists the messages that the seller may observe and disclose if she uses a sanitization disclosure strategy. Note that in our environment the information content of the set {Ø} (or no message) is equivalent to that of the set {100, 200, 300}. Suppressing the message {100} and/or {100, 200} is, therefore, equivalent to employing a sanitization disclosure strategy since this would mean that the true dividend would be an element of the set {100, 200, 300}.

Table 2, column 2, shows that if the seller follows a sanitization disclosure strategy, only three messages will be disclosed by the seller in equilibrium: {Ø}, {200, 300}, and {300}. No other messages will be disclosed in equilibrium.

3.3. Full disclosure strategy

To focus on the bias introduced by the sanitization disclosure strategy, we illustrate the disclosures under another strategy: full disclosure. If the seller truthfully discloses all the information that she observes, then the buyers will observe the messages in the third column of Table 2.[14]

We first address the following question: Do the sellers manage the information that they observe by disclosing the most favorable message about the true dividend as predicted by the sanitization disclosure strategy? Alternatively, it may be that sellers use some other disclosure strategy, such as truthfully revealing all of their information to the buyers. It is also possible that sellers follow some random disclosure strategy.

Next, we ask that if sellers follow a sanitization disclosure strategy, are buyers sophisticated bidders so that they partially discount the seller's disclosures in bidding for the asset. Alternatively, buyers may naively bid for the asset with the belief that the seller is truthfully disclosing all of her information.

If buyers are sophisticated bidders, as is conventionally assumed in game theory, they will take the seller's information management (e.g., the use of the sanitization disclosure strategy) into account in forming posterior beliefs for each message disclosed by the seller. Given that the buyers are sophisticated bidders and the seller uses a sanitization disclosure strategy, the predicted prices for each treatment are shown in Table 3. In order to illustrate how the buyers form posterior beliefs in calculating the expected value of the asset, we next solve for the price in the case that the disclosure is the null message, $\{\emptyset\}$, for the intermediate certainty case.

If the seller follows a sanitization disclosure strategy, then only 3 messages will be disclosed in equilibrium: $\{\emptyset\}$, or $\{200, 300\}$, and/or $\{300\}$. The buyers form posterior beliefs π for each state, s, where $s \in \{100, 200, 300\}$ based on the message disclosed to calculate the expected value of the asset.

Suppose the seller follows a sanitization disclosure strategy and discloses the message $M_s = \{\emptyset\}$ (i.e., the seller does not disclose any message). Then the buyers will calculate the following posterior probabilities: prob$[100 \mid (M_s = \{\emptyset\})]$, prob$[200 \mid (M_s = \{\emptyset\})]$, and prob$[300 \mid (M_s = \{\emptyset\})]$.

To calculate each of the posterior probabilities, the buyers must first assess the following conditional probabilities: prob$[(M_s = \{\emptyset\}) \mid 100]$, prob$[(M_s = \{\emptyset\}) \mid 200]$, and prob$[(M_s = \{\emptyset\}) \mid 300]$.

Note first that prob$[(M_s = \{\emptyset\}) \mid 100] = 1$ because the true dividend is at least 100, and the seller is following a sanitization strategy. Suppose the true dividend is 200. Then the seller will disclose $M_s = \{\emptyset\}$ if she does not observe the message $\{200, 300\}$. Whether

Table 3
Predicted prices if a seller uses a sanitization disclosure strategy and buyers are sophisticated bidders

Message(s) disclosed by seller	Predicted price for each message disclosed in equilibrium under each information treatment		
	Full certainty	Intermediate certainty	Low certainty
$\{\emptyset\}$	100	157.14	191.12
$\{200, 300\}$	200	233.33	246.67
$\{200, 300\}$ and $\{300\}$	300	300	300

[14] The highest bid determines the price here as it did in the experiment.

Table 4
Predicted prices if a seller uses a sanitization disclosure strategy and buyers are naive bidders

Message(s) disclosed by seller	Predicted price for each message disclosed in equilibrium under each information treatment		
	Full certainty	Intermediate certainty	Low certainty
$\{\emptyset\}$	200	200	200
$\{200, 300\}$	250	250	250
$\{200, 300\}$ and $\{300\}$	300	300	300

or not the seller observes the message $\{100, 200\}$ is irrelevant because it will never be disclosed if the seller is following a sanitization disclosure strategy. Thus a buyer will assess that prob$[(M_s = \{\emptyset\}) \mid 200] = 1/2$. If the true dividend is 300, the seller will disclose $M_s = \{\emptyset\}$ if he or she does not observe either of the independent messages $\{200, 300\}$ and $\{300\}$. Thus a buyer will assess that prob$[(M_s = \{\emptyset\}) \mid 300] = 1/4$.

Using Bayes rule, prob$[100 \mid (M_s = \{\emptyset\})] = 4/7$, prob$[200 \mid (M_s = \{\emptyset\})] = 2/7$, and prob$[300 \mid (M_s = \{\emptyset\})] = 1/7$. So, the expected value of the asset given the buyer's beliefs, π, $E_\pi(s \mid M_s = \{\emptyset\}) = 100{*}4/7 + 200{*}2/7 + 300{*}1/7 = 157.14$.

Similar calculations show that if a seller follows a sanitization disclosure strategy, a sophisticated buyer will assess the expected value of the asset given the message $M_s = \{200, 300\}$ to be equal to 233.33.

On the other hand, if the buyers are naive bidders, they will simply update their beliefs in a purely statistical way using the prior probabilities of each state and ignoring the possibility of strategic behavior by the seller. Table 4 below shows the predicted prices for each information treatment given that the seller uses the sanitization disclosure strategy and the buyers are naive bidders.

Finally, we assess the following comparative static of Shin's model. As the degree of information asymmetry between the seller and the buyers *increases*, Shin's model predicts that buyers discount the seller's disclosures *more* for the *same* disclosures by the seller. The most symmetric environment is the one with the lowest probability of the seller receiving a message. The same message will, in general, have a different meaning in different treatments. This result occurs because the seller's ability to use her information strategically depends on her informational advantage, which is different for each treatment. This leads to the prediction that for sophisticated bidders, prices fall as the probability that the seller is informed increases. This occurs because the buyers put less and less weight on the higher states relative to the lower states for the same message. This is not true in the case of naive bidders.

4. Results

4.1. Discussion

Table 2 illustrates how the messages that the seller discloses depend on what messages she observes and on her disclosure strategy. If the seller is managing information according to the sanitization disclosure strategy, then the messages $\{100\}$ and $\{100, 200\}$ should never be disclosed in equilibrium. On the other hand, the full disclosure strategy predicts that the message {100} should always be disclosed when the corresponding message {100} is observed, and the message {100, 200} should always be disclosed when the message {100, 200} is observed. When both messages {100} and {100, 200} are observed, the full disclosure strategy predicts that either both messages are disclosed or only the message {100} is disclosed since they are informationally equivalent.

4.1.1. Descriptive analysis of the message data

Tables 5–7 summarize the empirical frequency with which each message is observed and disclosed by the sellers in the full certainty, intermediate certainty, and low certainty treatments, respectively.

From Table 5, it is clear that when the sellers are perfectly informed about the true dividend, they are not following a full disclosure strategy. When the true dividend is 100 and the sellers observe messages {100} and {100, 200}, the sellers suppress both messages 12 times and disclose the message {100, 200} 10 times. When the true dividend is 200 and the sellers observe messages {100, 200} and {200, 300}, the sellers suppress the message {100, 200} 24 times and disclose the message {200, 300} 21 times. The sellers are generally following a sanitization strategy. The notable exception occurs when the true dividend is 100. The message {100, 200} is disclosed 10 times. As discussed earlier, if the sellers are managing information, the message {100, 200} should never be disclosed in equilibrium.

Table 5
The empirical frequency of messages disclosed given messages observed by the sellers for the full certainty treatment

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{100} and {100, 200}	12		10					
{100, 200} and {200, 300}	4		2		20	1		
{200, 300} and {300}					1		8	2

Table 6
The empirical frequency of messages disclosed given messages observed by the sellers for the intermediate certainty treatment

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{Ø}	6							
{100}	6							
{100, 200}	6		4					
{100} and {100, 200}	7		2					
{200, 300}	1				7			
{100, 200} and {200, 300}	1		0		7			
{300}							6	
{200, 300} and {300}							7	

Table 7
The empirical frequency of messages disclosed given messages observed by the sellers for the low certainty treatment

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{Ø}	33							
{100}	4	1						
{100, 200}	7							
{100} and {100, 200}	4							
{200, 300}					4			
{100, 200} and {200, 300}					3			
{300}							3	
{200, 300} and {300}							1	

However, one plausible explanation for disclosing this message is that the seller believes that there is some slim chance that by putting the 200 explicitly before the buyer, rather than the null set, this may encourage the buyer to believe there is some slim chance that the value is 200 rather than 100. The disclosure of the null set may not frame the pricing decision for the buyer in this way. Thus, disclosing the message {100, 200} may still be consistent with sanitization. In addition, we find evidence of what has been described in previous literature as "gaming" on the part of the sellers. We have found that some sellers will disclose {100, 200} in the full certainty case early on in the experiment when the true dividend is 200. It seems that they take this early loss in order to gain later from a disclosure of {100, 200} when the true divided is 100.

From Table 6 it is clear that for the intermediate certainty treatment when the probability of observing a message is $1/2$, the sellers are managing the information that they observe; the message {100} is observed 6 times and is never disclosed. The message {100, 200} is observed 10 times but is disclosed only 4 times. The messages {100} and {100, 200} are observed together 9 times. The message {100} is not disclosed and the message {100, 200} is disclosed only twice. The messages {100, 200} and {200, 300} are observed together 8 times; the sellers suppress the message {100, 200} all 8 times and disclose the message {200, 300} 7 times.

For the low certainty treatment, (see Table 7) when the probability of observing any message is $1/8$, the frequency of observing any messages is much lower. However, we can still deduce sanitization by the sellers. The message {100} is observed 5 times and disclosed only once. The message {100, 200} is observed 7 times and never disclosed. The messages {100} and {100, 200} are observed together 4 times and never disclosed. The messages {100, 200} and {200, 300} are observed together 3 times. The message {100, 200} is not disclosed, and the message {200, 300} is disclosed all 3 times.

Overall, the results in Tables 5–7 lend qualitative support to the hypothesis that the sellers are following a sanitization disclosure strategy instead of a full disclosure strategy. However, the sellers occasionally deviate from the sanitization disclosure strategy by disclosing the message {100} or {100, 200} when they should have suppressed these messages in the equilibrium characterized by Shin. Another deviation occurs when sellers suppress the message {200, 300} or {300} when they should have disclosed these messages. We next present a formal statistical test of this hypothesis.

4.1.2. A Bayesian analysis of the message data

As discussed above the qualitative analysis of the data suggests that the sellers generally follow a sanitization disclosure strategy except for occasional deviations. We present a Bayesian analysis of the messages observed and disclosed by the seller using the techniques developed by Boylan and El-Gamal (1993). The use of this technique allows for the examination of strategies with errors. We start by specifying the probability of seeing a disclosure, given the messages received by the seller, if the seller is playing each of the possible strategies, a sanitization disclosure strategy (Table 8), a full disclosure strategy (Table 9), or a randomized strategy in which each message observed is equally likely to be disclosed (Table 10).

For each session we start with a prior likelihood at the beginning of the first round that a seller is equally likely to use each of the three disclosure strategies. We denote $p^0(S)$, the prior probability the seller is playing a sanitization strategy, $p^0(F)$, the prior probability that the seller is playing a full disclosure strategy, and, $p^0(R)$, the prior probability that the seller is playing a randomized disclosure strategy. In addition, we denote by $p_j^t(i)$, the probability at stage t that seller j is playing strategy i. Similarly, we will let $q_j^t(i)$ be the probability that a disclosure is made by seller j, given the messages at time t and the seller is playing strategy $i = S, F, R$. Then, we can calculate $p_j^T(i)$ for each seller and each strategy type using Bayes rule as follows:

$$p_j^T(i) = \frac{p^0(i)\prod_{t=0}^T q_j^t(i)}{p^0(S)\prod_{t=0}^T q_j^t(S) + p^0(F)\prod_{t=0}^T q_j^t(F) + p^0(R)\prod_{t=0}^T q_j^t(R)}.$$

Because in Tables 8 and 9 there are disclosures that occur with zero probability, this gives rise to the zero probability estimation problem. In order to avoid this problem, we assume that a seller makes errors at the rate ε in following a sanitization disclosure strategy or a full disclosure strategy. We assume a very specific form of this error model. If a disclosure strategy predicts that a seller should disclose a message with probability 1, we assume instead that she discloses it with probability $1 - \varepsilon$, and if there are k other feasible disclosures, she is equally likely to disclose each one of them, i.e., each is disclosed with probability ε/k. Using the above error model, Tables 8–10 show the conditional matrix

Table 8
Conditional probability matrix of disclosing a message given that it is observed under the hypothesis that the seller follows a sanitization disclosure strategy with an error rate of ε

Messages observed	Messages disclosed							
	{∅}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{100} and {100, 200}	$1-\varepsilon$	$\varepsilon/3$	$\varepsilon/3$	$\varepsilon/3$	0	0	0	0
{100, 200} and {200, 300}	$\varepsilon/3$	0	$\varepsilon/3$	0	$1-\varepsilon$	$\varepsilon/3$	0	0
{200, 300} and {300}	$\varepsilon/2$	0	0	0	$\varepsilon/2$	0	$(1-\varepsilon)/2$	$(1-\varepsilon)/2$

Full certainty treatment.

Table 9
Conditional probability matrix of disclosing a message given that it is observed under the hypothesis that the seller follows a full disclosure strategy with an error rate of ε

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{100} and {100, 200}	$\varepsilon/2$	$(1-\varepsilon)/2$	$\varepsilon/2$	$(1-\varepsilon)/2$	0	0	0	0
{100, 200} and {200, 300}	$\varepsilon/3$	0	$\varepsilon/3$	0	$\varepsilon/3$	$1-\varepsilon$	0	0
{200, 300} and {300}	$\varepsilon/2$	0	0	0	$\varepsilon/2$	0	$(1-\varepsilon)/2$	$(1-\varepsilon)/2$

Full certainty treatment.

Table 10
Conditional probability matrix of disclosing a message given that it is observed under the hypothesis that the seller follows a randomized disclosure strategy where each feasible message is equally likely to be disclosed

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{100} and {100, 200}	1/4	1/4	1/4	1/4	0	0	0	0
{100, 200} and {200, 300}	1/4	0	1/4	0	1/4	1/4	0	0
{200, 300} and {300}	1/4	0	0	0	1/4	0	1/4	1/4

Full certainty treatment.

Table 11
Conditional probability matrix of disclosing a message given that it is observed under the hypothesis that the seller follows a full disclosure strategy with an error rate of ε

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{Ø}	1	0	0	0	0	0	0	0
{100}	ε	$1-\varepsilon$	0	0	0	0	0	0
{100, 200}	ε	0	$1-\varepsilon$	0	0	0	0	0
{100} and {100, 200}	$\varepsilon/2$	$(1-\varepsilon)/2$	$\varepsilon/2$	$(1-\varepsilon)/2$	0	0	0	0
{200, 300}	$\varepsilon/3$	0	$\varepsilon/3$	0	$\varepsilon/3$	$1-\varepsilon$	0	0
{100, 200} and {200, 300}	$\varepsilon/3$	0	$\varepsilon/3$	0	$\varepsilon/3$	$1-\varepsilon$	0	0
{300}	ε	0	0	0	0	0	$1-\varepsilon$	0
{200, 300} and {300}	$\varepsilon/2$	0	0	0	$\varepsilon/2$	0	$(1-\varepsilon)/2$	$(1-\varepsilon)/2$

Intermediate certainty and low certainty treatments.

for the full certainty treatment if the seller uses a sanitization disclosure strategy, a full disclosure strategy or a randomized disclosure strategy, respectively.

Tables 11–13 show the conditional matrix for the intermediate certainty and low certainty treatments, under the above error model, if the seller uses a sanitization disclosure strategy, a full disclosure strategy or a randomized disclosure strategy, respectively.

Using an error rate of $\varepsilon = 0.1$ and an equal prior likelihood for the experimenter of $1/3$ for each disclosure strategy at the beginning of the first round, prior probabilities are updated over each round for all ten rounds for every session under each disclosure strategy.

Table 12
Conditional probability matrix of disclosing a message given that it is observed under the hypothesis that the seller follows a sanitization disclosure strategy with an error rate of ε

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{Ø}	1	0	0	0	0	0	0	0
{100}	$1-\varepsilon$	ε	0	0	0	0	0	0
{100, 200}	$1-\varepsilon$	0	ε	0	0	0	0	0
{100} and {100, 200}	$1-\varepsilon$	$\varepsilon/3$	$\varepsilon/3$	$\varepsilon/3$	0	0	0	0
{200, 300}	ε	0	0	0	$1-\varepsilon$	0	0	0
{100, 200} and {200, 300}	$\varepsilon/3$	0	$\varepsilon/3$	0	$1-\varepsilon$	$\varepsilon/3$	0	0
{300}	ε	0	0	0	0	0	$1-\varepsilon$	0
{200, 300} and {300}	$\varepsilon/2$	0	0	0	$\varepsilon/2$	0	$(1-\varepsilon)/2$	$(1-\varepsilon)/2$

Intermediate certainty and low certainty treatments.

Table 13
Conditional probability matrix of disclosing a message given that it is observed under the hypothesis that the seller follows a randomized disclosure strategy with each feasible message is equally likely to be disclosed

Messages observed	Messages disclosed							
	{Ø}	{100}	{100, 200}	{100} and {100, 200}	{200, 300}	{100, 200} and {200, 300}	{300}	{200, 300} and {300}
{Ø}	1	0	0	0	0	0	0	0
{100}	1/2	1/2	0	0	0	0	0	0
{100, 200}	1/2	0	1/2	0	0	0	0	0
{100} and {100, 200}	1/4	1/4	1/4	1/4	0	0	0	0
{200, 300}	1/2	0	0	0	1/2	0	0	0
{100, 200} and {200, 300}	1/4	0	1/4	0	1/4	1/4	0	0
{300}	1/2	0	0	0	0	0	1/2	0
{200, 300} and {300}	1/4	0	0	0	1/4	0	1/4	1/4

Intermediate certainty and low certainty treatments.

The final posterior probabilities of the experiment under each disclosure strategy in each information treatment are presented in Table 14. Similar results hold for $\varepsilon = 0.2$ and 0.3.

For 16 out of the 18 sessions, the final posterior probabilities support the hypothesis that the sellers are following a sanitization disclosure strategy rather than a full disclosure strategy or a randomized disclosure strategy. We conclude that the seller in session 4 of full certainty treatment is following a randomized disclosure strategy, while the seller in session 1 of the low certainty treatment is following a full disclosure strategy.

4.2. Buyers' bidding behavior

The results of the previous section indicate that the sellers are generally managing their information to disclose the most favorable message that they could send about the true dividend. Are the buyers sophisticated enough to take this information management into consideration? Do they partially discount the seller's disclosures in bidding for the asset, or do they naively bid for the asset? Comparing Tables 3 and 4, we notice that the predicted prices for the message {300} are the same under sophisticated and naive bidding behavior

Table 14
Terminal posterior probabilities at the end of each session using an error rate ε of 10% and starting with the experimenter's prior probability for each disclosure strategy of $1/3$

Session No.	Sanitization disclosure strategy	Full disclosure strategy	Randomized disclosure strategy
Full certainty treatment			
1	0.9999	0	0.0001
2	1	0	0
3	0.9028	0	0.0072
4	0.0063	0	0.9937
5	0.9027	0	0.0073
6	0.9994	0	0.0006
Intermediate certainty treatment			
1	0.9999	0.0001	0
2	0.9999	0.0001	0
3	0.9474	0.0526	0
4	1	0	0
5	0.9999	0.0001	0
6	0.9969	0.0031	0
Low certainty treatment			
1	0.0780	0.7043	0.2647
2	0.9993	0.0007	0
3	0.9959	0.0041	0
4	0.9939	0.0061	0
5	0.9027	0.0001	0.0972
6	0.9994	0	0.0006

for all three treatments. The difference in the predicted prices for the messages $\{\emptyset\}$ and $\{200, 300\}$ is the smallest for the low certainty treatment (less than 10 francs) and the largest for the full certainty treatment (at least 50 francs). The intermediate certainty and full certainty treatments therefore provide the sharpest contrasts in predicted prices for the messages $\{\emptyset\}$ and $\{200, 300\}$ for sophisticated versus naive bidders. If buyers are indeed sophisticated bidders, we should expect the actual bids for the messages $\{\emptyset\}$ and $\{200, 300\}$ to be, on average, much closer to their predicted prices in Table 3 than to their predicted prices in Table 4 for the full certainty and intermediate certainty treatments. Since the predicted prices in Tables 3 and 4 are so close to each other for the low certainty treatment, the actual bids could, on average, be close to either one of the predicted prices. The results in the next section confirm both observations.

4.2.1. Descriptive analysis of the price data

Table 15 summarizes the number of times that a particular message is disclosed, the average actual value of the asset for each message disclosed, the mean price for each message disclosed and the predicted prices of naive and sophisticated bidders.[15]

[15] The out-of-equilibrium price for the message $\{100, 200\}$ is obtained by deriving the posterior beliefs that assume the seller makes small mistakes in implementing the sanitization disclosure strategy, i.e., discloses an unfavorable signal with some positive probability but does not make any mistake in disclosing the favorable signal.

Table 15
Mean price for each message disclosed under each information treatment and the predicted prices for naive and sophisticated bidders

Message disclosed	Frequency of messages disclosed	Average actual value	Mean price	Predicted price naive bidders	Predicted price sophisticated bidders
Full certainty treatment					
{Ø}	16	125	119.63	200	100
{100, 200}	12	116.66	117.11	150	100
{100, 200} and {200, 300}	1	200	198	200	200
{200, 300}	21	204.76	211.96	250	200
{300}	10	300	291.19	300	300
Intermediate certainty treatment					
{Ø}	27	162.96	155.26	200	157.14
{100, 200}	6	133.33	125.50	150	133.33
{200, 300}	14	242.86	238.00	250	233.33
{300}	13	300	295.37	300	300
Low certainty treatment					
{Ø}	48	175.00	184.68	200	191.12
{100}	1	100	105	100	100
{200, 300}	7	242.86	261.71	250	246.67
{300}	4	300	291.67	300	300

Note that the following messages are out-of-equilibrium messages under the sanitization disclosure strategy: {100}, {100, 200}, and both messages {100, 200} and {200, 300}. Since the message {100} is disclosed only once and the messages {100, 200} and {200, 300} are disclosed together only once, we do not include them in any of the price analyses. The message {100, 200} is, however, included in the price analyses because it is disclosed 12 times out of the 49 times that the seller observes it in the full certainty treatment and 6 times out of the 27 times that the seller observes it in the intermediate certainty treatment.[16]

The mean bids for the message {Ø} in full certainty and intermediate certainty treatments are 119.63 and 155.26, respectively. They are much closer to their respective predicted prices of 100 and 157.14 under the sophisticated bidding hypothesis than to the predicted price of 200 under the naive bidding hypothesis. The mean bids for the out-of-equilibrium message {100, 200} in these two treatments are 117.11 and 125.50, respectively. They are also closer to their respective predicted prices of 100 and 133.33 under the sophisticated bidding hypothesis than to the predicted price of 150 under the naive bidding hypothesis. Similarly, the mean bids for the message {200, 300} in the full certainty and intermediate certainty treatments are 211.96 and 238.00, respectively. They are much closer to their respective predicted prices of 200 and 233.33 under the sophisticated bidding hypothesis than the predicted price of 250 under the naive bidding hypothesis.

[16] In addition, we partitioned our data to try to look for differences across time and find that subjects in general have similar bidding behavior over the time of our study. However, there are a couple of bidders who do react to the gaming that we discussed above. Furthermore, we note that while for some experiments adaptation may require some time due to different sets of instructions and procedures, the adaptation period can easily vary.

For the low certainty treatment, the mean bid for the message {Ø} is 184.68. The mean bid is lower than both predicted prices of 191.12 and 200 under the sophisticated bidding hypothesis and the naive bidding hypothesis, respectively. However, the mean bid is closer to the prediction of the sophisticated bidding hypothesis. The mean bid for the message {200, 300} is 261.71. The mean bid is higher than both predicted bids of 246.67 and 250 under the sophisticated bidding hypothesis and naive bidding hypothesis, respectively. The mean bid is however closer to the prediction of the naive bidding hypothesis.

Table 15 also shows that, for each message disclosed, the average actual values of the asset behave in a similar fashion to the mean prices. This occurs across all three treatments.

Notice that for the disclosure messages, {Ø}, {100, 200}, and {200, 300}, the predicted price for sophisticated bidders is increasing in the level of information uncertainty. However, for naive bidders, this is not true, and in fact, the predicted prices are constant. Thus, we show in Fig. 1 that as uncertainty increases, the prices do indeed fall. This can also be seen in Table 15.

As the probability that the seller is informed decreases, the sophisticated buyers discount the seller's disclosures less and less and therefore bid more and more for the asset given the same disclosures by the sellers. To see if the actual bids for the same messages are significantly different from one another across the three information treatments, we conduct a Kruskal–Wallis test. We reject the null hypothesis for both messages {Ø} and {200, 300} but not for the message {300} at a significance level of 0.05. A Kruskal–Wallis test also shows that for any two information treatments as the probability that the seller is informed increases, the actual bids significantly decrease for the messages {Ø} and {200, 300}. We therefore conclude that when the true dividend is not known, *given the same disclosures* by the sellers, the actual bids are significantly different from each other

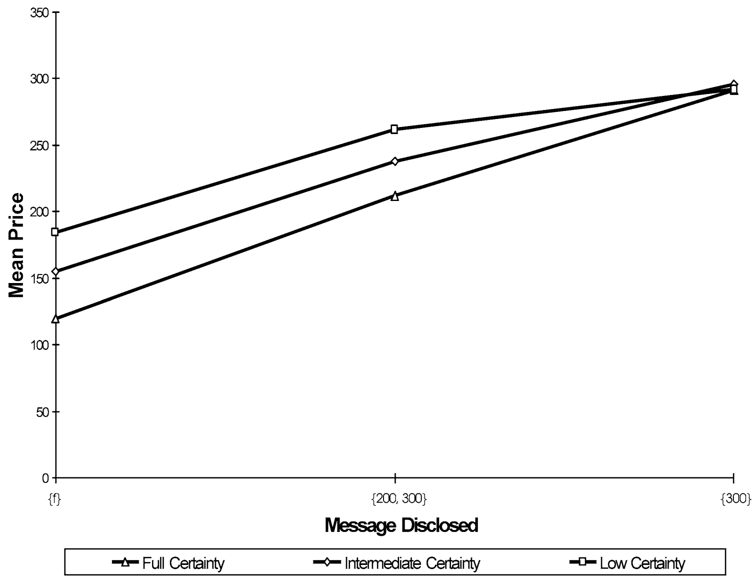

Fig. 1. Mean price for each equilibrium message disclosed in each information environment.

and decrease as the degree of information asymmetry between the seller and the buyers increases.

The overall results lend support to the hypothesis that whether buyers are sophisticated or naive bidders depends on the probability that the seller is informed about the true dividend. When the probability that the seller may be informed about the true dividend is relatively high, the buyers do not bid naively for the asset. They discount the seller's disclosures. On the other hand, when the probability of the seller being informed is relatively low, buyers do not discount the seller's disclosures and make bids according to the naive bidding hypothesis.

We do not control for the risk preferences of the subjects in our experiment. Risk aversion could be a plausible explanation for the difference between the theory and our data. Risk aversion is not a reasonable explanation for the bidding behavior of buyers in our experiment. This is best illustrated by a comparison of tables.

From Table 15, for the full certainty treatment, the mean prices for all but one of the messages sent by the seller, exceed the predicted prices for risk neutral sophisticated bidders. Overbidding would be inconsistent with risk aversion on the part of the buyers. For the one message, {300}, for which mean price (291.14 averaged over 10 observations) was lower than the predicted price (300) of the theory, it is hard to attribute the small shortfall of 8.86 cents to risk averse behavior on the part of the buyers. Risk averse buyers should not bid below 300 when they know with certainty that the true dividend is 300.

For the low certainty treatment, the mean prices for the messages {100} and $\{200, 300\}$ exceed the predicted prices for risk neutral sophisticated bidders. Overbidding would once again be inconsistent with risk aversion on the part of the buyers. For the null message and the {300} message, the mean prices of 184.68 and 291.67 are lower than their predicted risk neutral prices of 191.12 and 300 by 6.44 cents and 8.33 cents, respectively. These shortfalls are of about the same magnitude as the shortfall of 8.86 cents in the full certainty treatment for the message {300}. This therefore is hard to attribute to risk averse bidding behavior by the buyers.

5. Conclusion

This paper examines information management in a laboratory experiment. We show that sellers generally manage their information to disclose the most favorable information about an asset. When the probability that the seller is informed about the true dividend is relatively high, buyers behave as sophisticated bidders and discount the seller's disclosures in bidding for the asset. When the likelihood of the seller being informed about the true dividend is low, buyers do not discount the seller's disclosures. Furthermore, given the *same disclosures* by the sellers, the buyers discount the disclosures more as the degree of information asymmetry between the seller and the buyers increases.

This study adds to our understanding of the applicability of theory to the disclosure setting by placing more implicit demands on subjects' ability to revise beliefs. Such demands were not present in previous studies on disclosure. Given the heavy emphasis on Bayesian revision in most applications of economic theory in understanding the role of information structure, it is useful to have such studies especially in light of the long history that suggests that handling Bayesian revision is difficult. To ensure that we gave Bayesian revision a reasonable chance we followed the guidelines that go back to the work of Davidson and Suppes (1957) that have been part of the history of experimental economics. Namely we used physical objects as well as a manual experiment.

There are of course numerous additional possible questions that come out of this study. We believe that this paper contributes to the reasonableness of examining the more recent developments in the disclosure literature. In particular the so-called "real effects" models attempt to examine the impact of different disclosure settings on real production and investment decisions of firms. As with the earlier literature, one of the guiding economic forces in such "real effects" models is Bayesian probability revision. More specifically, these real effects studies assume that economic agents are able to extract all information from any disclosure regime and revise their beliefs about the firm's future cash flows and hence prices. Thus, it seems reasonable to ask if in environments where even more demanding Bayesian revisions are required, is it the case that the type of experiment developed here can serve as a basis for exploring even deeper questions about disclosure?

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Appendix A

A.1. Major elements of Shin's model

A seller owns an asset that pays dividends s_i in state i where $1 \leqslant i \leqslant N$ and s_i increases in i. The ex-ante probability of each state i is p_i. The dividends paid in each state and the ex-ante probability of each state is common knowledge.

Nature selects the true dividend s_k with probability p_k where

$$s_1 < s_2 < \cdots < s_k < s_{k+1} < \cdots < s_N.$$

Based on the true dividend, a seller may observe a set $M(s_k)$ of $N - 1$ messages about the true dividend.

$$m_i(s_k)\colon \quad s_k \geqslant s_i \quad \text{where } 2 \leqslant i \leqslant k,$$

$$m_i(s_k)\colon \quad s_k < s_i \quad \text{where } k+1 \leqslant i \leqslant N,$$

where, for example, the message $m_4(s_k)$: $s_k \geqslant s_4$ means that the true dividend belongs to the partition $\{s_4, \ldots, s_N\}$ and the message m_{k+3}: $s_k < s_{k+3}$ means that the true dividend belongs to the partition $\{s_1, \ldots, s_{k+2}\}$. The message m_1: $s_k \geqslant s_1$ is always implicitly observed since the true dividend is always at least s_1.

The seller observes each message m_i with probability θ_i and does not observe message m_i with probability $1 - \theta_i$. The messages are observed independently of each other, but they depend on the true dividend s_k.

The seller observes a random subset $M_0 \subseteq M(s_k)$ of these messages and discloses the set $M_s \subseteq M_0$ of messages to the buyers.

Risk Neutral buyers price the asset based on the seller's announcement of the set M_0 and their posterior beliefs about the seller's disclosure strategy.

Shin (1994) shows that in equilibrium the seller follows a sanitization disclosure strategy, i.e., discloses the most favorable information that she possesses about the true dividend and suppresses all other information. The buyers rationally take the seller's strategy into account in pricing the asset.

Using the above notation, the sanitization strategy means that the seller discloses the message in the subset M_0 that provides the most favorable information about the true dividend and suppresses all other messages. Suppose that the seller observes messages in the set M_0 that inform the seller that $s_k \in \{s_i, \ldots, s_L\}$ where $1 \leqslant i \leqslant L \leqslant N$. She sanitizes her disclosure by disclosing the message that $s_k \in \{s_i, \ldots, s_N\}$ where $1 \leqslant i \leqslant N$. The set M_s thus, contains the message with the most favorable information about the true dividend. The set M_s could be empty (no messages are disclosed at all) therefore, implicitly disclosing the message $m_1\colon s_k \geqslant s_1$.

Buyers price the asset at V where $V = E_\pi(s \mid M_s)$ where π are the posterior beliefs of the buyers given the seller is using a sanitization disclosure strategy.

Appendix B. Instructions[17]

General instructions

This is an experiment in the economics of decision-making. Various research foundations have provided funds for this research. The instructions are simple. If you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in cash, privately, immediately after the experiment ends today. Before we proceed to describe the experiment, we would like to establish some simple rules:

1. It is very important that you do not talk at any time during the experiment. The screens between the participants are to maintain privacy.
2. If you have any questions during the experiment, please raise your hand and an experimenter will answer your questions.

In this experiment, you will be either a seller or buyer of an asset. There will be 5 buyers and 1 seller participating in this experiment. Whether you are a seller or a buyer will be randomly determined at the beginning of the experiment. At this stage, please note that your identification number is at the top of this page.

- If you are a seller, you will find your personal history form in your folder.
- If you are a buyer, you will find your personal history form and a set of bid forms in your folder. The bid forms are ordered by round number. Each buyer will begin the experiment with a balance of 1200 francs in your account.
- Each form has your ID number and the round number printed on it.

For each round, 3 out of the 5 buyers have been randomly pre-selected to bid for one unit of the asset. The other two buyers will not bid in that round. If you are not bidding in a round, your bid form and your personal history form for that round have a large "*X*" marked through them. There will be a practice round followed by 10 rounds in this experiment. All 5 buyers will participate in the practice round. However, no cash will be earned in the practice round. We will now describe what will happen in each round.

Drawing a poker chip to select a dividend

At the beginning of each round, the experimenter will privately draw one poker chip from a bag. The bag contains 15 poker chips altogether (5 red, 5 blue, and 5 white). Each red poker chip is marked with the number "100" on it. Each blue poker chip is marked with the number "200" on it. Each white poker chip is marked with the number "300" on it. The numbers 100, 200, or 300 represent the dividends in francs that the asset pays in each round. The number that the experimenter privately draws for each round is called the *true dividend.* The 3 dividends (100, 200, or 300) are equally likely to be selected.

[17] These instructions are for the intermediate certainty treatment.

Picking the messages that will be sent to the seller

After the true dividend has been determined, the experimenter will randomly draw the two messages that will be privately observed by the seller. Each message will be written on a message card and consists of a list of one or two numbers enclosed in brackets. *The true dividend is always one of the numbers on the message card.*

These messages will provide information to the seller about the true dividend that was selected.

Examples

- The message {100, 200} means that the true dividend is either 100 or 200 francs.
- The message {100} means that the true dividend is 100.
- If the true dividend is 200, then the seller may observe the message {100, 200} or the message {200, 300}; but the seller will *not* observe the message {300} or the message {100}.

The message cards that the seller observes are determined as follows:

First coin toss

First, the experimenter will toss a coin privately behind a screen to determine whether the seller will observe the 1st message.

- If the coin lands "Heads," the experimenter will place a message card in the box.
- If the coin lands "Tails," the experimenter will *not* place a message card in the box.

Second coin toss

Second, the experimenter will toss the coin again behind a screen to determine whether the seller will observe the 2nd message.

- If the coin lands "Heads," the experimenter will place a message card in the box.
- If the coin lands "Tails," the experimenter will *not* place a message card in the box.

Tables B.1–B.3 below show how the 2 messages that the seller may receive depend on the true dividend.

Table B.1
Suppose the true dividend is 100

1*st Coin Toss*, if the coin lands on		2*nd Coin Toss*, if the coin lands on	
Heads	Tails	Heads	Tails
The message card will say: {100}	The seller receives **NO** message card	The message card will say: {100, 200}	The seller receives **NO** message card

Table B.2
Suppose the true dividend is 200

1*st Coin Toss*, if the coin lands on		2*nd Coin Toss*, if the coin lands on	
Heads	Tails	Heads	Tails
The message card will say: {100, 200}	The seller receives **NO** message card	The message card will say: {200, 300}	The seller receives **NO** message card

Table B.3
Suppose the true dividend is 300

1*st Coin Toss*, if the coin lands on		2*nd Coin Toss*, if the coin lands on	
Heads	Tails	Heads	Tails
The message card will say: {200, 300}	The seller receives **NO** message card	The message card will say: {300}	The seller receives **NO** message card

After the experimenter has tossed the coins twice, he or she will place the message cards in a message box. *If no messages are drawn, the message box will be empty*. The experimenter will then deliver the message box to the seller who will open it and examine its contents behind a screen.

Seller's decision

After the seller has seen the contents of the message box, he or she will decide what messages to disclose. The seller makes a disclosure by choosing which of the message cards he or she will return to the experimenter and which of the message cards he or she will retain. *The seller may return some, all, or none of the message cards that he or she receives.* After collecting the message box from the seller, the experimenter will write on the blackboard exactly the messages that were returned by the seller. If the seller sends back no cards, the experimenter will write "No Messages" on the blackboard. In every round, the seller will place the cards that he or she wants to retain in a box marked "Retain" behind his or her screen. The experimenter will collect that box at the end of the last round.

Reminder
- In every round, the seller may only return some, all, or none of the message cards that he or she receives.
- The message cards that the seller retains in a round cannot be used for any other rounds.

Buyer's decision

After the experimenter has written the messages that were returned by the seller on the blackboard, the buyers will be asked to fill out a bid form for that round.

Reminder
- If you are not bidding in a round, your bid form will have an "*X*" marked through it. Whether you are bidding in a round or not, the experimenter will still collect your bid form.

After the buyers have made their bids, the experimenter will collect all of the bid forms.

Updating your personal history sheet and payoffs

The experimenter will then announce and write the true dividend on the blackboard. He or she will also announce and write down all of the bids along with the buyer's ID on the blackboard. The highest bid will be circled. The asset will be sold to the highest bidder at the price equal to his or her bid. If two or more buyers submit the same highest bid, the experimenter will resolve this tie by a random choice of the buyer. The other bidders will pay zero.

The seller and all buyers will then be asked to update their personal history forms for that round.

- The seller and the buyers will write down the true dividend on their personal history form.
- Each buyer will write down the amount of his or her bid.
- The seller and buyers will calculate their respective profits for the round as follows:

Computing the seller's profits

- Seller's Profits = Amount of the highest bid

Computing the buyer's profits

- Winning bidder's profits = True dividend − Amount of the highest bid
- All other bidders should record a profit of zero.

An experimenter will check the calculations of the seller and the buyers.

Other rounds

After the first round, the experimenter will repeat the process and begin another round by drawing a poker chip from the bag again. This will continue for ten rounds.

Determining your cash earnings for the experiment

Seller's cash earnings

At the end of the experiment, the experimenter will add up the profits the seller has earned in each round. This amount in francs will be converted into dollars by using the exchange rate on the seller's personal history form. This is the seller's total cash earnings for the experiment. An experimenter will pay the seller his or her cash earnings privately at the end of the experiment.

Buyer's cash earnings

If the true dividend for a round is higher (or lower) than the price the buyer paid for the asset, the buyer will make a profit (or loss) on the purchase. The profits (or losses) earned by the buyer for a round will be added to (or subtracted from) the beginning cash balance of 1200 francs. At the end of the experiment, the ending balance in francs will be converted into dollars by using the exchange rate on the buyer's personal history form. This is the buyer's total cash earnings for the experiment. An experimenter will pay each buyer his or her cash earnings privately at the end of the experiment.

Summary of steps in each round

Step 1. The experimenter privately draws a poker chip from a bag that determines the true dividend.

Step 2. The experimenter tosses a coin twice behind a screen to determine whether the seller will see the two message cards about the true dividend. The two messages cards that the seller may receive are in Tables B.1, B.2, or B.3 depending on the true dividend. The messages card(s) that are drawn are put in a message box and delivered to the seller.

Step 3. The seller opens the message box and privately examines the message cards, if any, in the message box. The message box may contain 0, 1, or 2 message cards. The seller may not see the true dividend. However, the message cards the seller receives may provide information about the true dividend. It is up to the seller to decide how many message cards to send back in the message box to the buyers. The seller may return some, all, or none of the message cards in the message box. The seller places the message card(s) that he or she wishes to retain in the box marked "Retain." These message cards cannot be used in any other rounds.

Step 4. After collecting the message box from the seller, the experimenter opens the message box and writes the messages returned by the seller on the blackboard or writes "No messages" if he or she receives an empty message box. After observing the messages, buyers will be asked to bid for the asset.

Step 5. The experimenter collects the bid forms. He or she then announces and writes on the blackboard: the true dividend, the bid made by each buyer, and the highest bidder. The highest bidder purchases the asset at the amount of his or her bid. The personal history forms for the round are updated. A new round is started by going back to Step 1.

To ensure that you understand the instructions, please answer the following questions. An experimenter will check your answers.

(1) If the seller gets the message {100}, what is the true dividend?
   (a) 100,
   (b) 200,
   (c) 300,
   (d) do not know.
(2) Suppose the true dividend is 300 francs. Write down all the messages the seller may receive.
(3) Suppose the seller receives the message cards {100, 200} and {200, 300}. Then the true dividend can only be ______.
(4) Suppose the seller receives the message cards {100, 200} and {200, 300}. Circle the correct answer.
   (a) The seller may return the message card {100, 200} and retain the message card {200, 300}.
   (b) The seller may return the message card {200, 300} and retain the message card {100, 200}.
   (c) The seller may retain both message cards and send an empty box.
   (d) The seller may return both message cards.
   (e) All of the above.
(5) In a particular round, buyer 1 bid 50 francs, buyer 2 bid 100 francs and buyer 3 bid 150 francs. The true dividend was 200 francs. Calculate the profits for buyer 1, buyer 2, buyer 3 and the seller for that round?

   Profits: Buyer 1 =; Buyer 2 =; Buyer 3 =; Seller =.

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