

Online Appendix for  
A Procurement Auction for Toxic Assets  
with Asymmetric Information

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## 1. Historical Notes

### 1.1 The Environment in which the TARP Auction was Conceived

In early September of 2008, the adverse consequences of the subprime crisis spread and deepened at an alarming pace.<sup>1</sup> On September 7, *Fannie Mae* and *Freddie Mac*, two cornerstones in the securitization of mortgages, were placed under conservatorship by their regulator (the Federal Housing Financial Agency). Half of the remaining U.S. investment banks ceased to exist on September 15, as *Merrill Lynch* was sold to *Bank of America*, while *Lehman Brothers* filed for bankruptcy protection. The *Lehman Brothers* bankruptcy, the largest in U.S. history,<sup>2</sup> set off what had been described as a devastating tidal wave that immediately sliced through the entire financial system.<sup>3</sup> Two days later, the Federal Reserve loaned \$85 billion to *AIG*. In spite of a record injection of \$180 billion in liquidity by central banks around the world, the situation became critical on September 18: interbank credit markets nearly collapsed, money market funds experienced an unprecedented run which was reported to exceed half a trillion dollars,<sup>4</sup> while the commercial paper market was on verge of dislocation

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<sup>1</sup> For an inside view of the events that led to the creation of the TARP, see the account by former Assistant Treasury Secretary Philipp Swagel (2009).

<sup>2</sup> “Lehman folds with record \$613 billion debt,” *Marketwatch*, Sept 15, 2008 (<http://www.marketwatch.com/news/story/story.aspx?guid={2FE5AC05-597A-4E71-A2D5-9B9FCC290520}&siteid=rss>).

<sup>3</sup> “President Obama Goes to Wall Street,” *Nightly Business Report*, PBS, Sept 14, 2009 ([pbs.org/nbr/site/onair/transcripts/president\\_obama\\_sends\\_a\\_message\\_to\\_wall\\_street\\_090914](http://pbs.org/nbr/site/onair/transcripts/president_obama_sends_a_message_to_wall_street_090914)).

<sup>4</sup> Congressman Paul Kanjorski, Capital Market Subcommittee Chair, *C-Span* interview on Jan 27, 2009. (<http://www.cspan.org/Watch/Media/2009/01/27/HP/A/14757/Rep+Paul+Kanjorski+DPA+Chairman+of+the+Capitol+Markets+Subcmte.aspx>).

(Kacperczyk and Schnabl 2010).<sup>5</sup> At this point, some observers felt that the financial system was on the edge of a precipice and could completely melt down in a matter of days.<sup>6</sup>

On the evening of September 18, then Treasury Secretary Henry Paulson and Federal Reserve Chairman Ben Bernanke met with members of Congress. The atmosphere in the meeting has been described as grave and somber.<sup>7</sup> Secretary Paulson presented a plan aimed at creating a “firewall” to stop the crisis from spreading from the weakest financial institution to the next. Instead of acting on a case-by-case basis, the plan called for a bold, comprehensive approach to attack what was perceived to be the root of the crisis.<sup>8</sup> More specifically, Secretary Paulson proposed to purchase \$700 billion in mortgage related securities that were believed to clog the overall flow of credit to financial institutions, corporations, and consumers. The rationale was that the virtual collapse of the market for mortgage related securities had made it extremely difficult to value these securities, and by extension, the financial institutions that owned them. This increased uncertainty was perceived to be the main reason behind the reluctance of market participants to loan and trade with one another. The hope was that removing these illiquid assets from banks’ balance sheets would restore confidence and jumpstart financial markets.<sup>9</sup>

On September 20, the Treasury submitted a three page draft proposal which, after being substantially amended, was rejected in the House of Representatives on September 29.<sup>10</sup> The Dow Jones Industrial Average immediately lost \$1.2 trillion in market value (1.7 times more than the TARP bill), or 777 points (the largest single-day point drop in its history).<sup>11</sup> Congress then further amended the bill, which swelled to more than 400 pages and \$850 billion. When the Emergency

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<sup>5</sup> Commercial paper is used by corporations to meet short term funding needs to finance (e.g.) payroll or rent. For a reference see “As Credit Crisis Spiraled, Alarm Led to Action,” *NY Times*, October 2, 2008 (<http://travel.nytimes.com/2008/10/02/business/02crisis.html>).

<sup>6</sup> See e.g. Paul Krugman’s *PBS* interview on January 17, 2009 (<http://www.pbs.org/wgbh/pages/frontline/meltdown/interviews/krugman.html>).

<sup>7</sup> Chairman Bernanke was reported as saying to a member of Congress: “If we don’t do this, we may not have an economy on Monday” (“As Credit Crisis Spiraled, Alarm Led to Action,” *NY Times*, Oct 2, 2008). Senator C. Dodd, the chairman of the Banking, Housing and Urban Affairs Committee remarked: “We are literally maybe days away from a complete meltdown of our financial system”. Senator C. Schumer recounted: “When you listened to him describe it, you gulped.” See “Congressional Leaders Stunned by Warnings,” *NY Times*, Sept 20, 2008, (<http://www.nytimes.com/2008/09/20/washington/19cnd-cong.html>).

<sup>8</sup> Testimony by Secretary H. Paulson before the Senate Banking Committee on Turmoil in U.S. Credit Markets: “Recent Actions regarding Government Sponsored Entities, Investment Banks and other Financial Institutions,” Sept 23, 2008 ([www.ustreas.gov/press/releases/hp1153.htm](http://www.ustreas.gov/press/releases/hp1153.htm)).

<sup>9</sup> Statement by Secretary H. Paulson, Sept 19, 2008 ([www.ustreas.gov/press/releases/hp1149.htm](http://www.ustreas.gov/press/releases/hp1149.htm)).

<sup>10</sup> The initial proposal may be found here: <http://www.nytimes.com/2008/09/21/business/21draftcnd.html>, and various drafts of the bill may be found here: <http://www.govtrack.us/special/econstimbill/changes.xpd>.

<sup>11</sup> “U.S. House Rejects \$700 Billion Financial-Rescue Plan,” *Bloomberg*, September 29, 2008 (<http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aeqvQcX6sRe4>).

Economic Stabilization Act was finally signed into law on October 3,<sup>12</sup> however, it was unclear how the mortgage related securities would be acquired from banks and at what price. For MBS, a reverse (“low bids win”) auction had been mentioned (e.g. in the September 29 bill), as it was perceived to be an efficient and transparent mechanism for determining prices when markets are not functioning. Such an approach had been successfully adopted in the late 1980’s during the “Saving and Loans Crisis” to purchase distressed real estate.<sup>13</sup> As many noted, however, MBS are complex securities that are different from real estate, and doubts were immediately expressed about the effectiveness of such a straightforward reverse auction in the current context.<sup>14</sup> Since there was no ready-to-use procedure that would fit the Treasury’s needs, a new type of auction needed to be designed without delay.

On Saturday, September 20, a team at the Federal Reserve Bank of New York proposed to the Treasury a basic structure for government purchases of large numbers of MBS through a procurement auction based on reference prices (Armantier and Vickery 2008). In the week that followed, the Treasury also contacted academics with experience in designing auctions from the ground up. These experts were grouped into four teams that developed separate proposals. The Treasury selected a reference price design submitted by Jacob Goeree and Charles Holt (2008b), and decided to associate them with Charlie Plott to refine their design and incorporate elements he had suggested.<sup>15</sup>

Although it did not have what economists would characterize as a well defined objective function, the Treasury had specific priorities and concerns when designing the new TARP auction. Starting from the first draft submitted to Congress on September 29, the TARP bill stated that the objectives of the purchase program were i) stabilizing financial markets, and ii) protecting the taxpayer. So, although the primary objective was first and foremost to remove the illiquid MBS from the banks’ balance sheets, the Treasury also realized it needed to strike a delicate balance between overpaying for the securities (which would harm taxpayers) and underpaying (which would harm financial institutions).<sup>16</sup> The goal was therefore to design an auction yielding a price between what was described as the “fire sale price,” at which some of these assets were traded at the

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<sup>12</sup> The bill may be found here: <http://financialservices.house.gov/media/pdf/109hr3997ai.pdf>.

<sup>13</sup> “Lesson from savings and loans rescue”, *Financial Times*, September 24, 2008.

<sup>14</sup> See e.g. Varian (2008), Brusco (2008), or Ausubel and Cramton (2008).

<sup>15</sup> Decisions about the selection of the auction design were made entirely by the Treasury. Employees from the Federal Reserve only acted in an advisory capacity. Jacob Goeree, Charles Holt and Charlie Plott were put under contract by the Bank of New York Mellon (the auction custodian hired by the Treasury) to provide advice regarding the design and the implementation of the Reference Price auction.

<sup>16</sup> Observe that, because of the marked-to-market accounting practices in the U.S., underpayments by the Treasury would have hurt not only the banks that sold a given security, but also the banks that still owned shares of that security, as they most likely would have had to mark down the value of the security in their books. Given the fragility of the entire financial system at the time, such write-downs could have had severe consequences (see Swagel 2009). Thus, underpayment could involve a type of “externality” with an industry wide, negative impact.

time, and the “hold to maturity price” which reflects the stream of mortgage revenues a patient investor would receive at maturity.<sup>17</sup> Additional objectives were also considered, e.g., price discovery and provision of bank liquidity. Although recognized as important and considered when designing the auction, these additional objectives were not deemed to be first-order priorities.<sup>18</sup>

## 1.2 The Design of the TARP Auction

The design of an auction to purchase MBS as part of the Troubled Asset Relief Program (or TARP) presented a number of challenges, including:

1. **Dimensionality:** The universe of possible MBS eligible for purchase by the Treasury was extremely large. In particular, within the realm of residential MBS alone, there were more than 23,000 distinct securities. Likewise, the auction had to be designed to accommodate a large number of bidders (possibly in the hundreds).
2. **Heterogeneity:** MBS are highly heterogeneous as they can differ along several observed and unobserved dimensions, including their ratings, the vintages of the underlying mortgages, the locations and/or the amounts of the mortgages, the characteristics of the borrowers (e.g. credit ratings), the mortgage delinquency rates, and the originators of the loans. The ratings assigned by credit agencies to MBS were supposed to capture these differences, but many observers at that point in time believed that the ratings had ceased to reflect the securities’ actual risks and values.<sup>19</sup>
3. **Valuation:** At the time the auction was designed, there was virtually no market for most MBS that the Treasury was considering for purchase, and hence no price information. Moreover, the unprecedented rate of commercial and residential foreclosures over the preceding year made it hazardous to rely on standard simulation models to value these securities.<sup>20</sup>
4. **Informational Asymmetry:** Security owners could be assumed to have access to better information about the underlying MBS values than outside analysts and prospective buyers (e.g., by observing repayment streams and borrower default rates).

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<sup>17</sup> See B. Bernanke Sept 23, 2008 testimony to the Senate Banking Committee ([http://banking.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing\\_ID=7a41ae9e-30b2-4d7f-8f1b-4ef2e8ae28f7](http://banking.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=7a41ae9e-30b2-4d7f-8f1b-4ef2e8ae28f7)).

<sup>18</sup> There was considerable doubt about the ability of an auction to reveal meaningful price information. In particular, with the \$700 billion purchase budget being contemplated at that time, the Treasury was likely to substantially shift the demand function for these assets.

<sup>19</sup> See e.g. “Triple A Failure,” *New York Times*, April 27, 2008, (<http://www.nytimes.com/2008/04/27/magazine/27Credit-t.html>).

<sup>20</sup> See e.g. “Paulson Seeks Mortgage Value That Eluded Bear, Lehman,” *Bloomberg*, Sept 24, 2008 ([http://www.bloomberg.com/apps/news?pid=newsarchive&refer=home&sid=aGT\\_xTYzbbQE](http://www.bloomberg.com/apps/news?pid=newsarchive&refer=home&sid=aGT_xTYzbbQE)).

5. **Concentration of Ownership:** A single financial institution could own most shares of a specific security, thereby creating a thin market problem. Although the extent of the problem was unknown, it was believed to apply to many of the securities under consideration (Swagel 2009).
6. **Time Constraints:** The time constraints were threefold. First, as the Treasury initially considered conducting the first auction within a matter of weeks, the auction had to be designed, tested, and explained to bidders under considerable time pressure. In addition, a platform to submit bids and to effectively settle the winning tenders had to be developed immediately. Second, for any given auction, the bidding process needed to be completed in a short time frame so as to avoid outside influence and possible sellers' regret.<sup>21</sup> Third, once initiated, the program needed to have a significant and immediate impact to restore market confidence.

The Treasury realized that it might not be able to fully address all of these challenges. In particular, it understood that in the presence of asymmetric information, it is often difficult to avoid inefficiencies (Swagel 2009). The goal then became to rapidly design a simple yet robust auction that would effectively mitigate possible adverse consequences.<sup>22</sup>

Two simple auction formats were quickly abandoned. The first was a "Grand Auction," whereby different securities would be pooled together in a single procurement (reverse) auction and purchased at a single price, irrespective of the type of security accepted. A perceived advantage of this approach was that it could promote competition by letting owners of different securities compete against each other in a single auction. However, as illustrated in Section II of the paper, theory suggests that adverse selection could be severe in such a simple, simultaneous, multi-object auction.

The second format to be ruled out was a security-by-security auction. This approach would effectively deal with the unobserved value heterogeneity, as a separate auction would be conducted for each of the thousands of securities. Because of the problems of dimensionality, ownership concentration, and time constraints, however, this approach was considered not only impractical but also undesirable.

Multi-round auctions were also discussed in the press at the time the TARP auction was conceived (Ausubel and Cramton 2008). For example, a reverse "clock auction" was suggested whereby bidders indicate quantities they wish to sell at current clock prices, which would be reduced sequentially until requested

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<sup>21</sup> Given the high market volatility at the time, it was feared that bidding could be influenced by sudden market developments if the bidding process was to last for more than a few minutes. Conversely, concerns were expressed about the possibility that financial markets could be affected or manipulated during the auction process.

<sup>22</sup> The economic environment that led to the TARP auction and the process of designing and implementing the auction are described in detail in the Supplemental Materials.

sales no longer exceeded a government purchase budget. A potential problem with clock auctions was the time required to complete a single auction, given the need to run many auctions per day with up to 100 securities in each auction. It was also feared that, given the high market volatility at the time, bidding could be influenced by sudden market developments if the bidding process was to last for more than a few minutes. Conversely, concerns were expressed about the possibility that financial markets could be affected during the auction process.

The Treasury decided to implement a uniform price format for the TARP auction, whereby owners of the same security would all receive the same price for each unit they sell to the Treasury. Three arguments were mentioned in support of this design choice: i) it may provide some protection against the winner's curse (the bidders with the lowest bids are less likely to be penalized since they should receive a price exceeding their bids), ii) it may encourage participation from smaller or less informed bidders (who know that making a mistake may not be too costly since they are unlikely to set the market clearing price), and iii) it would generate a single market clearing price for each security, which might help with price discovery. The main argument in favor of the uniform price auction, however, was familiarity, as most financial institutions were experienced bidders under this format through Treasury auctions or the recently implemented "Term Auction Facility."

We now describe the basic features of the auction design the Treasury selected, and how it might have been implemented.<sup>23</sup> A series of 20 to 30 different auctions was expected to be conducted, each at a different date. A few days before a given auction, Treasury officials would ask eligible bidders to indicate how many shares of each of a pre-announced set of (say 1,000) securities they would be willing to sell.<sup>24</sup> For each security, a bidder would not be allowed to submit a bid to sell a quantity that exceeded what was listed in this "nomination" phase. In addition, the Treasury was considering asking participating bidders not to buy or sell any of the securities they listed during the interval between the nomination phase and the completion of the auction. The Treasury would select a subset of securities (e.g., 500) to be included in this particular auction, and it would decide on a total purchase budget. These decisions would be based in part on information obtained from the nomination process. For instance, the Treasury could decide not to purchase more than 50% of the face value of the assets nominated.

For the securities to be included in an auction the Treasury would have set reference prices combining the latest transactions data, other market information (e.g. Markit ABX index, the subprime residential MBS credit derivative),

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<sup>23</sup> This section borrows heavily from Armantier, Asker and Vickery (2008).

<sup>24</sup> Eligibility restrictions (i.e. which institutions would be allowed to bid) were not handled by the team in charge of designing the auction. Likewise, the legislation required that firms selling assets through TARP should provide warrants to the government. The Treasury team was not asked to design an auction that would include warrants. The auction eligibility and the warrant issues are therefore not discussed here.

valuation models, expert opinions, and prices from previous TARP auctions. The Treasury team was aware that estimating relative values of MBS could not be done with perfect accuracy. This task, however, was arguably easier than estimating absolute values of MBS. In particular, some argued that MBS had been hit by a common unobserved macroeconomic shock. As a result, although the absolute values of MBS became highly uncertain, their relative values were believed to have remained relatively unchanged.

This basic reference price design, however, had not been tested, and it was not clear how it would perform. In such situations, it is becoming increasingly common to use laboratory experiments to test and refine the design of specific auction procedures.<sup>25</sup> We began the process of setting up experiments in mid-October of 2008, just weeks before the design consultants were told to “take a vacation” (which presumably meant that the auction was on hold, although an official announcement was not ready at that time). On November 12, the Treasury officially announced that it had abandoned its plan for the TARP auction. Instead, it decided to use the funds allocated by Congress to take an equity position in several banks. Secretary Paulson explained that the situation had changed and that capital injections were now a more effective approach to address the situation faced by the financial system.<sup>26</sup>

## References

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<sup>25</sup> The experimental study that is the most relevant for the Treasury’s TARP program is that of Cason, Gangadharan, and Duke (2003), who score bids for land conservation on the basis of a measure of environmental benefit. One major difference from the Treasury situation, however, was that the environmental benefit primarily mattered to the government purchaser, whereas security values matter to both sellers and the government purchaser of MBS.

<sup>26</sup> See “Remarks by Secretary H. Paulson, Jr. on Financial Rescue Package and Economic Update,” November 12, 2008 (<http://www.ustreas.gov/press/releases/hp1265.htm>).

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## 2. Robustness Checks

We conducted two additional sets of experiments to assess the robustness of our results. The general objective is to verify that the ranking of the four auction formats in terms of purchase efficiency ratios does not change when we modify some features of the design.

The first robustness check experiment is concerned with the fact that, in the baseline design presented in Section III, subjects earn nothing when their bids are not accepted. Although, this feature is common to a number of auction experiments (see e.g. Kagel and Levin 2008) and may be rationalized in the context of the TARP auctions (the banks owned the toxic assets prior to the auctions and would not modify their books unless they sell to the government), it may also affect behavior. In particular, paying nothing on shares not sold may provide subjects with an incentive to bid aggressively in order to improve their chances of selling their shares to the government and thereby earn money. On the other hand, because of loss aversion, it may lead subjects to bid conservatively in order to avoid losses. In other words, paying nothing for the shares not sold at the auction could affect behavior, although the direction of the effect is difficult to predict.

To evaluate the possible effect of the earnings frame we modify the payment function in the baseline design. For each bid accepted, the bidder now receives the price produced by the auction. Otherwise, the bidder earns the true value of the asset. Whether or not a bid is accepted, earnings are normalized by subtracting  $(Signal_{i,s} - 10)$ , where  $Signal_{i,s}$  is the signal received by subject  $i$  about the true value of security  $s$ . To summarize, for each share of security  $s$  sold to the government bidder  $i$  earns  $P_s - (Signal_{i,s} - 10)$  where  $P_s$  is the price of security  $s$  at the auction, and for each share of security  $s$  not sold at the auction bidder  $i$  earns  $V_s - (Signal_{i,s} - 10)$  where  $V_s$  is the true value of security  $s$  revealed after the auction. Observe that the normalizing factor  $(Signal_{i,s} - 10)$  is the lower bound of the support of the true value conditional on the subject's signal. As a result, a bidder is guaranteed to earn between \$0 and \$20 per rejected bid, and losses are not possible unless the bid is below the lower bound  $(Signal_{i,s} - 10)$ . Note also that the normalization process is such that a bidder's expected revenue is *ex ante* the same for a high value asset and for a low value asset. Finally, note that the other features of the design, including the random draws for the signals and the security values, are identical to the baseline experiment. Therefore, the results can be compared directly across the two sets of experiments.

The outcomes of the first robustness check experiment for the four treatments (with 6 sessions each) are summarized in Figure 3 and Table 6. Although not statistically significant at the 5% level, two differences with the baseline experiment seem to emerge. First, the average purchase efficiency (value to

expenditure ratio) is slightly higher in each treatment of the robustness check experiment (compare the 3<sup>rd</sup> column in Tables 4 and 6). This therefore suggests that providing subjects with a positive payoff when they do not sell a share leads them to bid more aggressively (lower). Second, as indicated in Figure 3, there appears to be some learning as the purchase efficiency ratios decline over the first three auctions.

Despite these slight differences, the robustness check experiment confirms the general conclusions reported in section IV: i) with an average efficiency ratio of 0.975, the Reference Price auction is almost perfectly efficient when the government possesses accurate information, ii) the two noisy reference price treatments produce lower efficiencies and cannot be distinguished statistically, and iii) the Grand Auction is systematically less efficient than the Reference Price auctions, even when the government has very noisy information about the value of the securities.

The second robustness check experiment we conducted is concerned with the asymmetry in the baseline design between the information available to bidders through their signals and the information provided by the government through the reference prices. Indeed, a subject receives a signal about the absolute value of a security, while, when announced before the auction, the reference price provides information about the relative value of the security. This asymmetry in information may be difficult to process, which could explain why in the baseline experiment subjects are not able to better exploit the errors made by the government when it announces noisy reference prices.

To test this hypothesis we modify the way reference prices are calculated by having the government estimate the absolute (rather than relative) value of the corresponding security. In other words, the government sets the reference price of a security equal to the signal it receives about the true value of this security. Recall that in the two noisy reference price treatments, the government's signals can take any integer value in a range from \$20.00 below the true value to \$20.00 above the true value, and is therefore twice as noisy as the bidders' signals. Although the reference prices are different than in the baseline experiment, the allocation and payment mechanisms remain identical in the second robustness check experiment. In particular, submitted bids are still divided by the corresponding reference price, and the lowest normalized bids are still accepted first. Finally, observe that compared to the baseline experiment, the reference prices are not only easier to process for the subjects, but also, they can be much more informative. In some cases for instance, they can even reveal the true value of a security to a bidder (e.g. a bidder receiving a signal of \$30 and observing a reference price of \$60 should infer that the true value of the security is \$40).

We only conducted the two noisy reference price treatments (6 sessions each) for the second robustness check experiment. Indeed, the Grand Auction is not affected by the change in reference prices, and running the accurate reference

price treatment would mean revealing the true value of the assets to the bidders. The results reported in Table 7 and Figure 4 confirm once again that the Reference Price auction performs better than the Grand auction even when the government has imprecise estimates of the reference prices. In addition, as indicated in Figure 4, the noisy reference price treatment produces slightly higher average efficiency ratio (0.894 versus 0.847) when the reference prices are announced instead of kept secret. As indicated in the last column of Table 7, however, the difference between the two treatments is not significant at the 10% significance level. In other words, consistent with the results reported in Section V, subjects are not able to exploit the government mistakes, even when the announced reference prices are expressed in terms of absolute rather than relative values.

## **References**

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**Table 6. Alternative Earnings Robustness Check: Purchase Efficiency**  
 Value purchased to expenditure ratios averaged over all 8 auctions per session

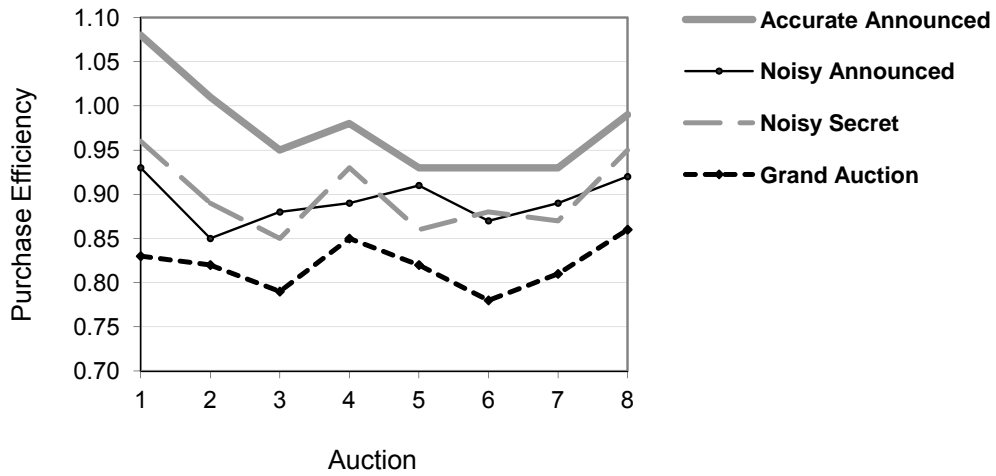
Treatment: Reference Prices	Session Purchase Efficiency Averages for Seeds 1 to 6	Treatment Average	Wilcoxon Signed-Rank Test <sup>*</sup>
None (unitary)	.79, .76, .82, .80, .83, .91	.819	
Announced, Accurate	.88, 1.00, 1.03, .95, 1.02, .96	.975	Z = -1.794 P value = 0.047
Announced, Noisy	.82, .88, .90, .94, .97, .83	.890	Z = -2.201 P value = 0.028
Secret, Noisy	.99, .85, .87, .83, .90, .85	.899	Z = 0.000 P value = 1.000

<sup>\*</sup> Each test compares the distribution of the 6 ratios in the corresponding row with the distribution in the row above.

**Table 7. Absolute Reference Price Robustness Check: Purchase Efficiency**  
 Value purchased to expenditure ratios averaged over all 8 auctions per session

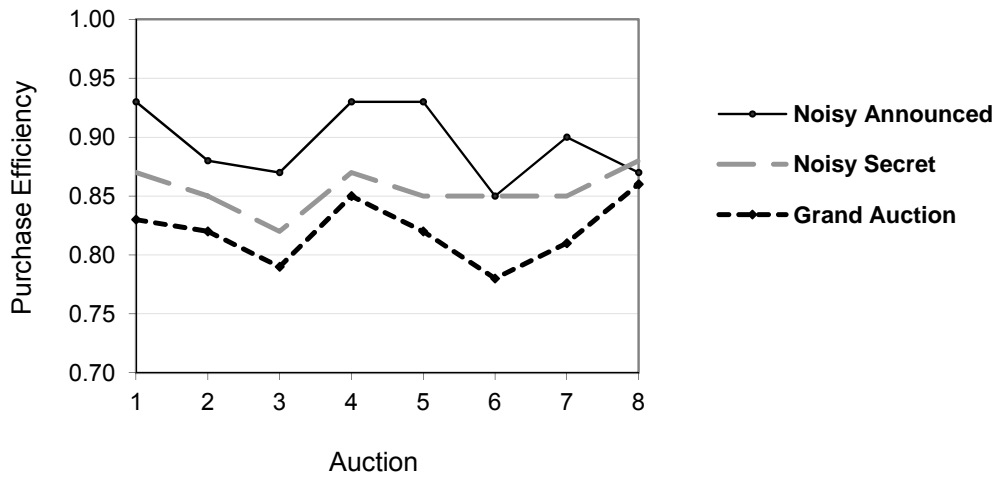
Treatment: Reference Prices	Session Purchase Efficiency Averages for Seeds 1 to 6	Treatment Average	Wilcoxon Signed-Rank Test <sup>*</sup>
None (unitary)	.79, .81, .79, .77, .72, .74	.766	
Announced, Noisy	.89, .93, .87, .88, .99, .82	.894	Z = -2.201 P value = 0.028
Secret, Noisy	.81, .82, .91, .82, .89, .84	.847	Z = -1.572 P value = 0.116

<sup>\*</sup> Each test compares the distribution of the 6 ratios in the corresponding row with the distribution in the row above.



**Figure 3. Alternative Earnings Robustness Check: Purchase Efficiency by Auction**

Purchase value to expenditure ratio averaged over the 6 sessions



**Figure 4. Absolute Reference Price Robustness Check: Purchase Efficiency by Auction**

Purchase value to expenditure ratio averaged over the 6 sessions

# 3 Experimental Instructions

## Instructions, Page 1 of 6

- **Securities:** This is an auction in which you have the role of a bank with a portfolio of mortgage-backed assets, referred to as "securities." Owning different securities is like owning different stocks. Just as shares of stock in a given company are identical, units of a specific security are identical. These units will be referred to as "contracts."
- **Security Values:** There are 6 different securities, labeled A ... F. Each security has an underlying value that is the same for all bidders, but no bidder knows prior to the auction what this common value will turn out to be. You have the opportunity to sell some of your contracts to the government, but you will incur a loss if you sell contracts at prices that are below their values, which will be revealed after the auction.
- **Value Estimates:** For each security you own, you will receive a signal that is an imperfect estimate of the value of that security. Different bidders receive different signals about the value of the same security. Some bidders' signals may be above that security's true value, and some may be below. The average of all possible signal draws is equal to the underlying common value of the security (details to follow).
- **Purchase Budget for Combined Auction:** The government has budgeted a fixed amount, **\$2000**, to purchase contracts for the 6 securities to be included in the auction. This budget will typically limit the number of contracts that can be purchased.
- **Reverse Auction:** This a "reverse auction" in which the government prefers to purchase from low bidders. You will be given the chance to submit an offer to sell your contracts for each of the different securities that you own. You will be bidding against **5 other bidders** in each auction.

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- **Reference Prices:** Since securities are different assets, some are intrinsically more valuable than others. Many of these securities are not actively traded, and the government has hired financial experts to estimate their values. Prior to the auction, each security has been assigned an official "reference price" that will be used to compare bids for different securities. The reference price is an estimate of the value of the security relative to the first security (A). For instance, if the reference price for

security B is 2, then it means that the government believes that security B is twice as valuable as security A. And securities with reference prices below 1 are deemed to be less valuable than A. By construction, the reference price for security A is 1.

- **Comparisons:** The government is not necessarily interested in purchasing the securities with the lowest bid prices. Instead, the government is willing to pay more for securities that it believes to be more valuable. To compare bids across different securities, each bid submitted will be transformed into a **normalized bid** by dividing it by the reference price for that security.
- **Example:** For example, suppose that the reference price for a security is 2. Then a bid of \$24 on this valuable security is the same as a bid of \$12 on security A (which always has a reference price of 1), since both bids result in the same normalized price:  $\$24/2 = \$12/1 = \$12$ .
- **Purchase Decision:** The government will accept bids with low normalized bid prices, moving to bids with higher and higher normalized bid prices until the fixed budget is exhausted or until all bids are accepted, whichever comes first.
- **Reserve Prices:** The government also reserves the right to reject offers that it deems to be unacceptably high, i.e. the maximum payment is capped at **\$100** for each security.

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- **Cutoff Normalized Price:** As just explained, offers with lower normalized bid prices will be accepted, and offers with high normalized bid prices will be rejected. The cutoff normalized price is the lowest normalized bid price among the rejected bids. This cutoff is like a market-clearing price, and it determines the price paid for all of the bids that have been accepted. To summarize, bids with normalized bid prices below the cutoff are accepted, and those at or above the cutoff are rejected.
- **Uniform Sale Price:** For a given security, the government will purchase all accepted contracts at the same price: **Uniform Price = (cutoff normalized price)\*(reference price)** for each contract of that security. Note that the price paid for two different securities will differ, since the reference prices of the two securities will generally be different.
- **Example 1:** Suppose that there is a bid price of 50 for a security with reference price of 2, and a bid price of 80 for a security with a reference price of 4. These bids have normalized prices of  $50/2 = 25$  and  $80/4 = 20$

respectively, so the 80 bid (with the lower normalized price) is more likely to be accepted. If this is the only accepted bid, the normalized price of 25 for the rejected bid of 50 is the cutoff normalized price. Thus contracts associated with the accepted bid of 80 would be sold for 25 times the reference price of 4 or for 100 per contract.

- **Earnings:** The amount you receive for a sale is at least as high as your bid, since all accepted bids have normalized prices that are at or below the cutoff normalized price. If a bid is not accepted, you earn nothing for those contracts. If a bid is accepted, the difference between the sale price and the value of the security will be added to you earnings. Thus you will be penalized if you sell below value, and you will earn more to the extent that your sale is above value (revealed after the auction).

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- **Example 2:** Suppose there are bids on 4 different securities, some with high prices and some low, but the normalized bids are ranked at 8, 9, 11, and 14. If the auction budget is such that only the bids with the two lowest normalized bid prices are accepted, then the cutoff normalized price for the first rejected bid is **11**, and each of the two bids with low ratios result in sales for amounts that equal 11 times the relevant reference prices. If the accepted bids were 16 with reference price 2 and 9 with reference price 1, then the bid of 16 will result in a sale at  $22 = (11) \cdot (2)$ , and the bid of 9 will result in a sale at  $11 = (11) \cdot (1)$ .

Bid Price	Reference Price	Normalized Bid	Sale Price
16	2	$8 = 16/2$	$22 = (11) \cdot (2)$
9	1	$9 = 9/1$	$11 = (11) \cdot (1)$
11	1	<b>11</b> = $11/1$	(no sale at cutoff)
7	0.5	$14 = 7/(.5)$	(no sale)

- **Note:** What you receive for an accepted bid is not affected by the bid price. But bidding too high can be risky since a high bid is less likely to be accepted. Conversely, if a low bid is accepted, you will receive an amount at least this high, but bidding too low can be risky since the amount received could be as low as what you bid. You **incur a loss** if you sell contracts below their values (revealed after the auction).
- **Earnings Example:** If the true security values for the bids in the top two rows of the table turned out to be 20 and 10, then earnings would be \$22 (sale price) - \$20 (value) = \$2 for the bid in the top row and \$11 (sale



price) - \$10 (value) = \$1 for the bid in the second row. Earnings are 0 for bids that are not accepted (bottom two rows). But if the values for the securities in the top two rows were 24 and 12, then earnings for these bids would have been negative:  $\$22 - \$24 = -\$2$  and  $\$11 - \$12 = -\$1$ .

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- **Values:** The table below provides an example of your signal values and contract holdings for each of the 6 securities. The signal values are estimates and may turn out to differ from the actual values that are realized after the auction.
- **Value Range:** All security values are between \$0 and \$100, so you can think of bidding in terms of "dollars per hundred of par value" and the contracts as being par value amounts.
- **Value Distributions:** The value of any given security will be drawn randomly from a range between lower and upper bounds, with all values in that range being equally likely. For example, if the range is from 20 to 80, then the value of the security may be 20, 21, ... 80, as if the value were determined by a hard spin of a roulette wheel with stops labeled for each possible value in this range. The upper and lower bounds for the security value ranges will be shown in a table that you can look at while selecting your bids.
- **Signal Values:** Your signal for a given security is drawn randomly from a range between **\$10.00** below the true value to **\$10.00** above the true value. All signals in the interval are equally likely. The signals received by others about the value of a given security will be drawn randomly in the same manner. The range of possible signal draws for a more valuable security will be higher than the range for a less valuable security.
- **High or Low Signals:** If you have a high signal value for a given security, it could be because your signal draw was high in the interval of possible signals, or it could be because the signal draws for all bidders are high relative to those of other less valuable securities. Conversely, all bidders' signal draws will tend to be low for a less valuable security.
- **Reference prices:** For each security, the government receives a signal drawn from between **\$20** below the true value and **\$20** above the true value. The government then calculates the reference price by dividing its signal for each security by its signal for security A. For instance, if the government signals are 60 and 30 for securities A and B, then the reference prices are 1 ( $=60/60$ ) for A and 0.5 ( $=30/60$ ) for B. Note that a higher reference price will generally

correspond to a more valuable security, but reference prices are subject to error since the government receives imperfect signals about security values.

Security Code	Reference Price (per contract)	Contracts Owned	Value Signal
A	\$*.**	**	\$*.**
B	\$*.**	**	\$*.**
C	\$*.**	**	\$*.**
D	\$*.**	**	\$*.**
E	\$*.**	**	\$*.**
F	\$*.**	**	\$*.**

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### Summary Page

- **Bids** specify the price at which you are offering to sell contracts of a specific security.
- **Different bids** (offers to sell) may be submitted for different contracts of a given security. Each bid specifies the security and the bid price for a single contract.
- In order to compare bids for different securities in a combined auction, all bids are divided by pre-announced **reference prices** and the resulting normalized bids for all securities are ranked together; those with low normalized bids are more likely to be accepted.
- A **fixed budget** of **\$2,000.00** is used to purchase the securities to be accepted, beginning with the lowest normalized bids and working up sequentially until the budget is exhausted (with ties at the cutoff decided at random).
- The **cutoff normalized bid** for the first rejected bid is used to determine the sale price for all bids with normalized bids below the cutoff. This cutoff normalized bid is the *same for all securities*.
- **Sale Price = (Cutoff Normalized Bid) \* (Reference Price)**, so all successful bidders will receive the same amounts per contract of a given security, regardless of their actual bid amounts.
- The **sale price** for an accepted bid is at least as high as the bid, since the normalized bid for an accepted bid will be at or below the cutoff normalized bid.

- **Earnings** equal the difference between the revenues from contracts that are sold and their values (revealed after the auction). You earn nothing on contracts not sold.
- **Values** for each security will be drawn randomly from a range that is between \$20 and \$80.
- **Signals** for each security will be taken from a range that is within plus or minus \$10.00 of its actual value.
- For each security, the government receives a signal that is within plus or minus \$20.00 of its true value. Dividing this signal by the government's signal for security A gives the **reference price** of the security.
- There is only a **single round** of bidding in the auction. Bids may not be revised once submitted.
- There will be **8 auctions**, and your security values and signal value estimates will be randomly regenerated for each new auction. The program will keep track of your total earnings for all auctions.

**Special Earnings Announcement:** Your cash earnings will be **5%** of your total earnings at the end of the experiment.

**Table 8. Econometric Analysis**  
Model with Significant Parameters Only

		Panel 1: Price Bids <sup>1</sup>				Panel 2: Bid Acceptance <sup>2</sup>				Panel 3: Governments Losses <sup>3</sup>			
		Treat 1*	Treat 2*	Treat 3*	Treat 4*	Treat 1*	Treat 2*	Treat 3*	Treat 4*	Treat 1*	Treat 2*	Treat 3*	Treat 4*
1	Signal	0.921*** (0.012)	0.817*** (0.022)	0.739*** (0.021)	0.858*** (0.023)	—	—	—	—	—	—	—	—
2	Security Value	—	—	—	—	-0.090*** (0.010)	—	—	-0.011** (0.004)	0.906*** (0.024)	0.156*** (0.019)	0.214*** (0.042)	0.159*** (0.036)
3	Signal Bias (i.e. Signal – Value)	—	—	—	—	-0.080*** (0.015)	-0.111*** (0.011)	-0.063*** (0.008)	-0.069*** (0.009)	-0.077** (0.034)	-0.128*** (0.033)	-0.216*** (0.066)	-0.230*** (0.054)
4	Auction #	0.326*** (0.074)	0.430*** (0.097)	0.179 (0.145)	-0.288*** (0.071)	—	—	—	—	-0.279** (0.123)	—	—	—
5	# of Contracts Owned	-0.451* (0.273)	—	—	—	0.239*** (0.057)	0.144*** (0.042)	0.142*** (0.039)	0.162*** (0.027)	—	0.144** (0.073)	—	—
6	Bid #	3.467*** (0.554)	5.456*** (1.030)	5.548*** (1.305)	6.064*** (0.588)	-0.303*** (0.034)	-0.251*** (0.044)	-0.186*** (0.024)	-0.304*** (0.030)	-0.116** (0.034)	—	-0.191** (0.079)	-0.233* (0.119)
7	Bid # * # of Contracts Owned	-0.310** (0.125)	-0.561** (0.214)	-0.569** (0.216)	-0.663*** (0.121)	—	—	—	—	—	—	—	—
8	Reference Price	—	5.818*** (0.529)	2.345*** (0.534)	—	—	—	—	—	—	-6.829*** (0.429)	-4.232*** (0.762)	—
9	“Overpriced” Reference Price <sup>†</sup>	—	—	1.688* (0.889)	—	—	—	0.430* (0.208)	1.233*** (0.218)	—	—	-4.684*** (1.233)	-2.792*** (1.523)
10	“Underpriced” Reference Price <sup>†</sup>	—	—	-6.290*** (1.796)	—	—	—	-2.052*** (0.266)	-3.013*** (0.264)	—	—	32.479*** (3.300)	31.806*** (3.448)
11	Constant	-2.191 (1.573)	-7.341** (2.331)	3.967 (2.920)	1.280 (1.297)	0.541*** (0.070)	0.697** (0.271)	0.515 (0.178)	0.600* (0.205)	-39.276*** (1.442)	-0.490 (0.911)	-9.883*** (1.869)	-12.175*** (1.378)
12	$\sigma_U$	5.215*** (0.426)	6.237*** (0.689)	7.341*** (1.112)	6.645*** (0.713)	0.588*** (0.079)	0.575*** (0.075)	0.516*** (0.081)	0.434*** (0.052)	2.147*** (0.080)	1.197*** (0.157)	2.823*** (0.208)	1.856*** (0.324)
13	$\sigma_t$	5.312*** (0.122)	6.367*** (0.226)	8.750*** (0.265)	6.028*** (0.135)	0.423*** (0.053)	0.516*** (0.047)	0.478*** (0.065)	0.455*** (0.037)	2.031*** (0.165)	1.825*** (0.236)	6.787*** (0.331)	5.828*** (0.369)
14	$\sigma_t$	4.053*** (0.139)	3.848*** (0.188)	4.731*** (0.200)	3.864*** (0.128)	0.238*** (0.051)	0.188*** (0.036)	0.214*** (0.048)	0.282*** (0.050)	1.578*** (0.209)	1.320*** (0.176)	1.837*** (0.240)	1.917*** (0.236)
15	$\sigma_{i,t}$	1.337*** (0.428)	1.851*** (0.320)	3.824*** (0.650)	2.700*** (0.867)	—	—	—	—	0.892*** (0.279)	0.828*** (0.273)	1.159*** (0.283)	0.960*** (0.339)
16	Log Likelihood	-8830.1	-11066.7	-11398.7	-9515.9	-881.9	-1493.0	-1562.8	-1401.7	-4590.2	-4492.9	-5571.7	-5419.1

<sup>1</sup> Panel Data Model where the Endogenous Variable is the Price Bid

<sup>2</sup> Panel Probit Model where the Endogenous Variable Equals 1 if Bid Is Accepted

<sup>3</sup> Panel Data Model where the Endogenous Variable is the Government Losses for each Security Purchased (i.e. Value - Price)

\* Treat 1=Grand Auction (No Reference Prices); Treat 2=Accurate Announced Reference Prices; Treat 3=Noisy Announced Reference Prices; Treat 4=Noisy Secret Reference Prices

<sup>†</sup> For security S, Overpriced (Underpriced) is set equal to  $|A|*I_{A>0}$  ( $|A|*I_{A<0}$ ), where  $A=Reference\ Price_S - Value_S / Value_A$ .

The models are estimated by maximum simulated likelihood. Standard errors are evaluated by bootstrap. \*\*\*, \*\*, and \* indicate significance at respectively the 1%, 5% and 10% levels.