Online Appendix

Appendix A Deriving the price schedule

As in Bernardo and Welch (2004), we assume that there is a risk-averse, competitive market maker who absorbs shares upon demand. Now we assume that the asset pays a random cash flow, z with mean v. Note that the investors are assumed to be risk-neutral, so they care only about v.

The market maker is immune to liquidity shocks and does not discount future consumption. In setting a price for buying 1 unit of the asset, the market maker behaves myopically, i.e. does not account for future trading opportunities. Let w_0 be the initial wealth of the market maker and w_k be the wealth after buying k units of the asset:

$$w_k = w_0 - \sum_{h=0}^{k-1} p_h + kz \tag{10}$$

The price is set in such a way that:

$$E[u(w_k)] = E[u(w_{k+1})]$$
(11)

where u is the utility function of the market maker. With the following assumptions:

$$u(w) = -e^{-\gamma w} \tag{12}$$

$$z \sim N(v, \sigma^2) \tag{13}$$

it is easy to show that the price is given by:

$$p_k = v - \frac{1}{2}\gamma\sigma^2 - \gamma\sigma^2 k \tag{14}$$

This is the same function used in the CARA-Normal example of Bernardo and Welch (2004) and it motivates the use of a linear price schedule in our experiment.

Appendix B Risk Aversion

In the baseline model, as in Bernardo and Welch (2004), we assume risk neutral traders. However, this of course is unlikely to be the case with subjects in our lab experiments. As such, it is informative to understand how the model predictions change with risk averse traders. To implement this, we assume that investors have a CRRA utility function: u(x) = $\frac{x^{1-\alpha}}{1-\alpha}$. In our numerical computation of equilibrium below we assume that $\alpha = 0.5$: while this is a relatively moderate degree of risk aversion, its effects on predicted behavior are significant, as shown below. Larger values of α will yield larger effects in the same direction. To give readers a general sense of how risk aversion impacts the model, we again plot the option value of holding on to the asset if no other trader has sold $(V^{RA}(\pi))$ and if every other trader has sold $(U^{RA}(\pi))$ in Figure B.1. As is clear from this figure, risk aversion lowers the liquidation thresholds. Specifying the number of traders and the information process as above, we solve for the equilibrium liquidation strategies numerically, which are presented in Appendix D. The average stopping points under risk aversion are reported in Table 2. Focusing for now on the NoCB case, we note that even a moderate degree of risk aversion $(\alpha = 0.5)$ has a significant effect on liquidation decisions. Specifically, we find that the average market belief at the time of the first sale is equal to 0.676 in the HIGH information environment and 0.534 in the LOW information environment. Thus, the average probability at the first sale declines with risk averse investors across environments, as is highlighted in Figure B.1.

Appendix C Solving for Equilibrium with CB

To model the circuit breaker rule implemented in the lab, we assume that a circuit breaker is triggered in the current period if s > 1 or s = 1 and player *i* chooses to liquidate. In this section, *s* denotes the number of players attempting to sell, excluding player *i*. The actual number of effective sales in a period before a circuit breaker is triggered is at most one. We

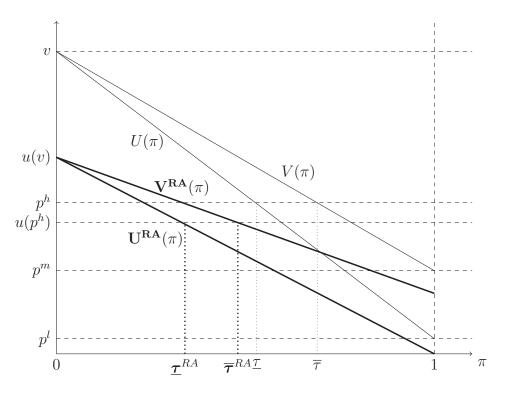


Figure B.1: Liquidation thresholds with Risk Aversion

also assume that once a circuit breaker is triggered, the market is frozen for two periods.

Before the circuit breaker is triggered, the *ex-ante* value function for player *i* is given by:

$$V^A(n,\pi) = \max\{X;Y\}\tag{15}$$

where X represents the value of attempting to sell a share and Y represents the value of holding on to the share. In turn, the expected value from attempting to sell a share is given by:

$$X \equiv E_s[\gamma(s)p_n + (1 - \gamma(s))W^{I1}(n - 1, \pi))]$$
(16)

In this equation, $\gamma(s) \equiv \frac{1}{s+1}$ denotes the probability that player *i*'s selling order goes through when *s* other players are attempting to sell. If player *i* chooses to attempt to sell, with probability $\gamma(s)$ he is successful and earns the highest available price p_n . If however he is not successful, he obtains the *interim* continuation value $W^{I1}(n-1,\pi)$, which represents the value of owning a share at the beginning of the first period of a market freeze. The value of choosing to wait is given by:

$$Y \equiv \Pr[s=0]W^{A}(n,\pi) + \Pr[s=1]W^{A}(n-1,\pi) + \Pr[s>1]W^{I1}(n-1,\pi)$$
(17)

If player *i* waits and no other player attempts to sell, then player *i* obtains the ex-ante continuation value $W^A(n, \pi)$. Similarly, if only a player attempts to sell, s = 1, then player *i* obtains the ex-ante continuation value $W^A(n-1,\pi)$. When more than one player attempt to sell, the circuit breaker is triggered and player *i* gets the interim continuation value $W^{I1}(n-1,\pi)$.

The ex-ante continuation value is defined as usual as:

$$W^{A}(n',\pi) = \lambda[\pi\rho(n',n'-1) + (1-\pi)v] + (1-\lambda)E_{\pi'}[V^{A}(n',\pi')|\pi]$$
(18)

The interim continuation value is instead defined as:

$$W^{I1}(n',\pi) = \lambda[\pi\rho(n',n'-1) + (1-\pi)v] + (1-\lambda)E_{\pi'}[W^{I2}(n',\pi')|\pi]$$
(19)

where $W^{I2}(n', \pi)$ represents the value of owning a share at the beginning of the second period of a market freeze, given by:

$$W^{I2}(n',\pi) = \lambda[\pi\rho(n',n'-1) + (1-\pi)v] + (1-\lambda)E_{\pi'}[W(n',\pi')|\pi]$$
(20)

In this equation, W() is the continuation value after the market unfreezes, given by equation (4).

As before, we solve for a symmetric equilibrium numerically. The procedure are identical to those described above, except that now an equilibrium is defined by the set of functions $\{V, W, V^A, W^A, W^{I1}, W^{I2}\}$ and liquidation strategies.

Appendix D Equilibrium Strategies

D.1 Risk Neutral Investors

D.1.1 Numerical solutions: HIGH

HIGH NoCB

$$\sigma(1,\pi) = 0 \quad \forall \quad \pi$$

$$\sigma(2,\pi) = \begin{cases} 1 & \text{if } \pi \ge 0.95 \\ 0 & \text{if } \pi < 0.95 \end{cases}$$

$$\sigma(3,\pi) = \begin{cases} 1 & \text{for } \pi > 0.8 \\ 0.0155 & \text{if } \pi = 0.8 \\ 0 & \text{if } \pi < 0.8 \end{cases}$$

$$\sigma(4,\pi) = \begin{cases} 1 & \text{for } \pi > 0.8 \\ 0.775 & \text{if } \pi = 0.8 \\ 0 & \text{if } \pi < 0.8 \end{cases}$$

D.1.2 Numerical solutions: LOW

LOW NoCB

$$\begin{split} \sigma(1,\pi) &= 0 \quad \forall \quad \pi \\ \sigma(2,\pi) &= \begin{cases} 1 & \text{if } \pi > 0.897 \\ 0.195 & \text{if } \pi = 0.897 \\ 0 & \text{if } \pi < 0.897 \end{cases} \\ \sigma(3,\pi) &= \begin{cases} 1 & \text{if } \pi > 0.885 \\ 0.95 & \text{if } \pi = 0.885 \\ 0.73 & \text{if } \pi = 0.872 \\ 0.46 & \text{if } \pi = 0.858 \\ 0.16 & \text{if } \pi = 0.843 \\ 0 & \text{if } \pi < 0.843 \end{cases} \\ \sigma(4,\pi) &= \begin{cases} 1 & \text{if } \pi > 0.827 \\ 0.86 & \text{if } \pi = 0.827 \\ 0.59 & \text{if } \pi = 0.809 \\ 0.35 & \text{if } \pi = 0.789 \\ 0.11 & \text{if } \pi = 0.769 \\ 0 & \text{if } \pi < 0.769 \end{cases} \end{split}$$

HIGH CB

$$\begin{aligned}
\sigma(1,\pi) &= 0 \quad \forall \quad \pi \\
\sigma(2,\pi) &= \begin{cases} 1 & \text{if } \pi \ge 0.95 \\ 0 & \text{if } \pi < 0.95 \end{cases} \\
\sigma(3,\pi) &= \begin{cases} 1 & \text{for } \pi \ge 0.9 \\ 0 & \text{if } \pi < 0.9 \end{cases} \\
\sigma(4,\pi) &= \begin{cases} 1 & \text{for } \pi \ge 0.8 \\ 0 & \text{if } \pi < 0.8 \end{cases}
\end{aligned}$$

LOW CB

$$\sigma(1,\pi) = 0 \quad \forall \quad \pi$$

$$\sigma(2,\pi) = \begin{cases} 1 & \text{if } \pi > 0.907 \\ 0 & \text{if } \pi < 0.907 \end{cases}$$

$$\sigma(3,\pi) = \begin{cases} 1 & \text{if } \pi > 0.843 \\ 0 & \text{if } \pi < 0.843 \end{cases}$$

$$\sigma(4,\pi) = \begin{cases} 1 & \text{if } \pi \ge 0.769 \\ 0 & \text{if } \pi < 0.769 \end{cases}$$

D.2 Equilibrium Strategies with Risk Averse Investors

D.2.1 Numerical solutions with Risk Aversion: HIGH

HIGH NoCB

HIGH CB

LOW CB

$$\begin{aligned} \sigma(1,\pi) &= 0 \quad \forall \quad \pi \\ \sigma(2,\pi) &= \begin{cases} 1 & \text{for } \pi > 0.9 \\ 0.86 & \text{if } \pi = 0.9 \\ 0 & \text{if } \pi < 0.9 \end{cases} & \sigma(2,\pi) &= \begin{cases} 1 & \text{for } \pi \ge 0.9 \\ 0 & \text{if } \pi < 0.9 \\ 0 & \text{if } \pi < 0.9 \end{cases} \\ \sigma(3,\pi) &= \begin{cases} 1 & \text{for } \pi \ge 0.8 \\ 0.8868 & \text{if } \pi = 0.8 \\ 0 & \text{if } \pi < 0.8 \end{cases} & \sigma(4,\pi) &= \begin{cases} 1 & \text{for } \pi \ge 0.675 \\ 0 & \text{if } \pi < 0.675 \\ 0 & \text{if } \pi < 0.675 \\ 0 & \text{if } \pi < 0.675 \end{cases} \\ \sigma(4,\pi) &= \begin{cases} 1 & \text{for } \pi \ge 0.675 \\ 0 & \text{if } \pi < 0.675 \\ 0 & \text{if } \pi < 0.675 \end{cases} \end{aligned}$$

D.2.2 Numerical solutions with Risk Aversion: LOW

LOW NoCB

$\sigma(1,\pi) = 0 \quad \forall \quad \pi$ $\sigma(2,\pi) = \begin{cases} 1 & \text{for } \pi > 0.897 \\ 0.910 & \text{if } \pi = 0.897 \\ 0.763 & \text{if } \pi = 0.885 \\ 0.559 & \text{if } \pi = 0.872 \\ 0.240 & \text{if } \pi = 0.858 \\ 0 & \text{if } \pi < 0.858 \end{cases}$ $\sigma(3,\pi) = \begin{cases} 1 & \text{for } \pi > 0.809 \\ 0.760 & \text{if } \pi = 0.809 \\ 0.505 & \text{if } \pi = 0.789 \\ 0.233 & \text{if } \pi = 0.769 \\ 0 & \text{if } \pi < 0.769 \end{cases}$ $\sigma(4,\pi) = \begin{cases} 1 & \text{for } \pi > 0.747 \\ 0.893 & \text{if } \pi = 0.747 \\ 0.598 & \text{if } \pi = 0.723 \\ 0.349 & \text{if } \pi = 0.699 \\ 0.103 & \text{if } \pi = 0.646 \end{cases}$

$$\sigma(1,\pi) = 0 \quad \forall \quad \pi$$

$$\sigma(2,\pi) = \begin{cases} 1 & \text{for } \pi \ge 0.843 \\ 0 & \text{if } \pi < 0.843 \end{cases}$$

$$\sigma(3,\pi) = \begin{cases} 1 & \text{for } \pi \ge 0.747 \\ 0 & \text{if } \pi < 0.747 \end{cases}$$

$$\sigma(4,\pi) = \begin{cases} 1 & \text{for } \pi \ge 0.672 \\ 0 & \text{if } \pi < 0.672 \end{cases}$$

Appendix E Additional Empirical Results

E.1 Non-parametric analyses

Tests	Rounds	NoCB	CB
$Belief_{HIGH} > Belief_{LOW}$	All	p=0.0361	
$\operatorname{Belief}_{HIGH} > \operatorname{Belief}_{LOW}$	Bad	p=0.0004	
$\operatorname{Belief}_{HIGH} > \operatorname{Belief}_{LOW}$	All		p=0.0001
$\operatorname{Belief}_{HIGH} > \operatorname{Belief}_{LOW}$	Bad		p=0.0095

Table E.1: Reports non-parametric statistical tests for the probability of a forced sale at the time of the first sale in each round. p-values are reported from paired Wilcoxon sign-rank tests.

Tests	Rounds	HIGH info	LOW info
$\operatorname{Belief}_{CB} > \operatorname{Belief}_{NoCB}$	All	p=0.3453	
$\operatorname{Belief}_{CB} > \operatorname{Belief}_{NoCB}$	Bad	p=0.9363	
$\operatorname{Belief}_{CB} < \operatorname{Belief}_{NoCB}$	All		p=0.1948
$\operatorname{Belief}_{CB} < \operatorname{Belief}_{NoCB}$	Bad		p=0.7692

Table E.2: Reports non-parametric statistical tests for the probability of a forced sale at the time of the first sale in each round. p-values are reported from paired Wilcoxon sign-rank tests.

Tests	Rounds	HIGH info	LOW info
$Time_{CB} < Time_{NoCB}$	All	p=0.0337	
$\operatorname{Time}_{CB} < \operatorname{Time}_{NoCB}$	Bad	p=0.1782	
$\operatorname{Time}_{CB} < \operatorname{Time}_{NoCB}$	All		p=0.0003
$\operatorname{Time}_{CB} < \operatorname{Time}_{NoCB}$	Bad		p=0.0002

Table E.3: Reports non-parametric statistical tests for the time of first sale. p-values are reported from paired Wilcoxon sign-rank tests.

Tests	HIGH info	LOW info
$\mathrm{Eff}_{CB} > \mathrm{Eff}_{NoCB}$	p=0.0002	
$\mathrm{Eff}_{CB} < \mathrm{Eff}_{NoCB}$		p=0.0003

Table E.4: Reports non-parametric statistical tests for the efficiency in each round. p-values are reported from paired Wilcoxon sign-rank tests.

E.2 Regression analyses using "bad" and 2nd half round data

Belief at First Sale	Coeff.	Std. Err.	P-Value
CB	0.000	0.020	0.989
LOW	-0.125	0.015	0.000
CBxLOW	-0.022	0.021	0.915
Cons.	0.643	0.015	0.000

Table E.5: Reports regression results from specification (6) using "bad" rounds only. The regression includes round fixed effects and is estimated via pooled OLS. There are 433 observations and the regression has an $R^2 = 0.1973$. Robust standard errors are reported.

Probability at First Sale	Coeff.	Std. Err.	P-Value
СВ	0.010	0.025	0.701
LOW	-0.078	0.019	0.000
CBxLOW	-0.024	0.026	0.352
Cons.	0.611	0.018	0.000

Table E.6: Reports regression results from specification (6) using 2nd half rounds only. The regression includes round fixed effects and is estimated via pooled OLS. There are 329 observations and the regression has an $R^2 = 0.0803$. Robust standard errors are reported.

Time (Seconds)	Coeff.	Std. Err.	P-Value
CB	-0.559	1.082	0.606
LOW	21.430	6.011	0.000
CBxLOW	-2.917	1.398	0.107
Cons.	7.280	1.054	0.001

Table E.7: Reports regression results from specification (7) using "bad" rounds only. The regression includes round fixed effects and is estimated via pooled OLS. There are 376 observations and the regression has an $R^2 = 0.319$. Robust standard errors are reported.

Time (Seconds)	Coeff.	Std. Err.	P-Value
CB	-1.048	1.119	0.350
LOW	1.790	2.159	0.408
CBxLOW	-1.430	1.963	0.467
Cons.	5.688	1.436	0.000

Table E.8: Reports regression results from specification (7) using 2nd half rounds only. The regression includes round fixed effects and is estimated via pooled OLS. There are 329 observations and the regression has an $R^2 = 0.291$. Robust standard errors are reported.

Efficiency	Coeff.	Std. Err.	P-Value
CB	0.069	0.022	0.002
LOW	0.272	0.038	0.000
CBxLOW	-0.094	0.026	0.000
Cons.	0.725	0.034	0.000

Table E.9: Reports regression results from specification (9) using only the 2nd half rounds. The regression includes round fixed effects and is estimated via pooled OLS. There are 280 observations and the regression has an $R^2 = 0.479$ Robust standard errors are reported.

E.3 Clustering of sales after market halts

This figure depicts the evolution of the probability of a forced liquidation (given by the blue line) in a bad-state round. The vertical lines show the time at which trades are entered to the market. After the third bad signal the first two sale attempts occur in rapid succession. The first sale is executed and the second triggers the circuit breaker, and is not executed. During the circuit breaker, more bad signals arrive and the Bayesian updated probability of

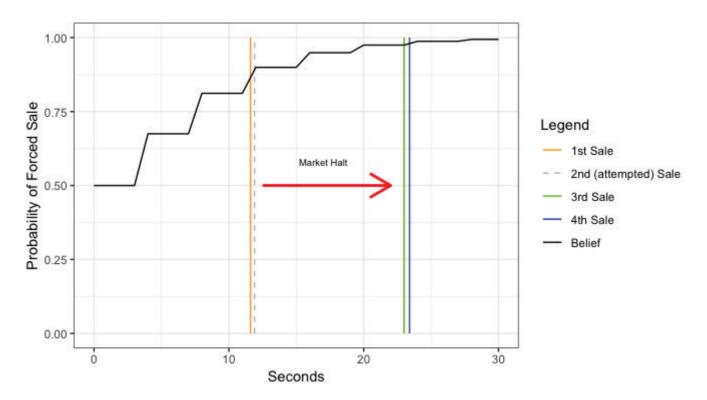


Figure E.1: Plots an example of the clustering of sales that follows a halt in trading.

a forced liquidation stands at over 95% by the end of the trading halt. When the market re-opens, two of the remaining traders rush to liquidate their assets as there is now a very high probability that the round will end poorly. In these sorts of cases a circuit breaker may induce a strong clustering of sales, when without a circuit breaker it is likely those sales would have taken place over a more dispersed time interval.

Appendix F Experiment Instructions

This section reproduces instructions given to experiment subjects for the baseline CB sessions.

Instructions

You are about to participate in an experiment in the economics of decision-making. The National Science Foundation and other agencies have provided the funding for this project. If you follow these instructions carefully and make good decisions, you can earn a CONSID-ERABLE AMOUNT OF MONEY, which will be PAID TO YOU IN CASH at the end of the experiment.

Your computer screen will display useful information. Remember that the information on your computer screen is PRIVATE. To insure best results for yourself and accurate data for the experimenters, please DO NOT COMMUNICATE with the other participants at any point during the experiment. If you have any questions, or need assistance of any kind, raise your hand and one of the experimenters will come.

Rounds

The experiment will be divided into 55 rounds. The length of a round will be random – you will never know how long a round will last or when it is about to end (details below). When a round ends, your experiment will show a round summary page in red for a few seconds and then a new round will begin. Decisions and points made in one round do not affect other rounds.

The Basic Idea

You and three other players are traders market where an asset is traded. Each round you start the game with one unit of a asset. Your only decision is when, if ever, to sell your asset. First, we will describe what happens if you decide to sell the asset before the end of the round and then we will describe what happens if you decide to keep the asset until the end of the round.

Selling

At any moment you can decide to sell the asset. If you sell the asset, the asset is bought by the computer and you are paid a price. The amount you will be paid depends only on how many other participants have already sold their asset: each sale of a asset lowers its price. The exact price schedule the computer will use is reproduced in Table F.1. For example: if you decide to sell and you are the first to sell you will be paid a price of \$8 ; if 1 unit has already been sold (by the another participant) and you decide to sell now, you will be paid a price of \$6, etc.

Price schedule		
Number of assets already sold	Price you are paid if you sell	
0	8	
1	6	
2	4	
3	2	

Table F.1: Price Schedule

Holding on to the asset

What if you have decided not to sell your asset and the round randomly ends? One of the following will occur:

- 1. Forced Sale: You are forced to sell your asset, together with all the other players who are still in possession of their assets. Your points in this round are given by the price at which your asset is sold (see more below). or
- 2. Payout: You and all the other player(s) who decided not to sell receive the asset payout, equal to 20 points.

The computer will randomly decide whether the round ends in a Forced Sale or Fixed Payout. Each round has a 50% probability of ending with a Forced Sale and 50% probability of ending with the Fixed Payout.

Figure 1 illustrates what can happen at the end of a round and how this affects your score if you have not sold your asset by then.

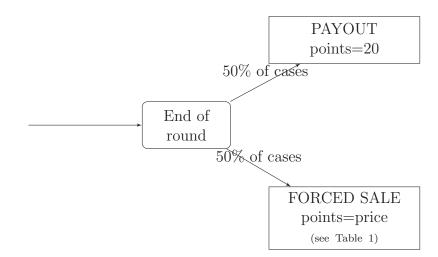


Figure F.1: Points if you have not sold before the random end

Forced sales

When the round ends in a forced sale the computer will randomly decide the selling order for those players who have not sold earlier and pay each player in that order according to the schedule in Table F.1. Examples:

- If none of the participants have decided to sell in the round and the round ends in a forced sale, the computer will randomly decide the selling order of the four participants. The first player will receive 8 points, the second 6 points, the third 4 points and the fourth 2 point.
- If two players decided to sell earlier in the round and the round ends in a forced sale the computer will randomly order the remaining 2 participants. The first participant will receive 4 points and the second 2 point.

The likelihood that the asset pays out

Whether a forced sale will occur in a particular round will not be known to you until it happens. However, you will receive real-time signals about whether a Forced Sale will occur.

During the round you will receive either a **Good** or **Bad** signal every 4 seconds. On your computer screen you will be shown whether the current message is Good or Bad and a tally of the Good and Bad signals received so far in that round. For example, if a good signal arrives you may see +Good (+2/-3). This message indicates that the current signal is Good and that there have been 2 Good signals and 3 Bad signals so far in the round.

This tally of signals will be updated every 4 seconds, until the round ends. In each round the signal tally will begin at (+0/-0). Over time the Bad tally will become larger than the Good tally if a Forced Sale will occur. Conversely, over time the Good tally will become larger than the Bad tally if a Payout will occur.

Here are some details on the probability that a Good signal or a Bad signal arrives at each update. If in this round a Forced Sale will occur, then the probability that a Bad signal arrives is 67.5% and the probability that a Good signal arrives is 32.5%. If in this round the assets will Payout, then the probability that a Bad signal arrives is 32.5% and the probability that a Good signal arrives is 67.5%. Therefore at each update, a Bad signal is more likely to arrive if a Forced Sale will occur at the end of the round and a Good signal is more likely to arrive if a Payout will occur at the end of the round.

Market Freeze

During each round the market may freeze. During a market freeze your sell button will be disabled and you will be unable to sell your asset. The market will freeze when too many players attempt to sell their assets at once. Specifically, if one player sells their asset and another player attempts to sell their asset within 3 seconds of that sale the market will freeze.

In this case the first sale will go through but the second will not. The market will unfreeze after 10 seconds at which point any participant who still owns an asset is again able to sell it if they choose to. The market can only freeze once per round. You will be notified when the market is frozen in the Market Status part of your screen.

Screen Information

The screenshot reproduced in Figure F.2 shows an example of the screen you will see during each round.

The table at the top of the screen shows you the current signal and the tally of Good and Bad signals. You will see the signals and tallies updating during the experiment.

The plot shows you the current price that you can obtain if you sell your asset now, as a yellow line (remember this is entirely determined by how many people have already sold). The rightmost tip (the leading edge) of the line shows what is happening right now. Whenever some player sells his or her asset you will see a discrete jump in this line.

At any moment you can sell your asset by clicking the button at the bottom of the screen that says Sell. However remember that your sale goes through, the button will be disabled for the rest of the round.

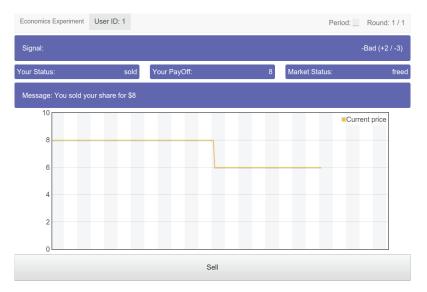


Figure F.2: Example Screen View

Feedback

After the round is over, you will be shown a summary message in your page repeating your score and whether a forced sale occurred. The break between rounds will last around 10 seconds. During this break you will see: 1) your score in this round, 2) whether you sold

your asset by clicking on the button during the round, 3) how the round ended: Forced Sale or Payout.

Earnings

At the end of the last round, you will be paid \$7.00, plus earnings based on your total points throughout the experiment.

At the end of the experiment you will be presented with a summary table with your earnings in each round and your total earnings in the experiment. The points you earn in the experiment will be converted to U.S. Dollars at an exchange rate of 55 to 1. **THAT IS, FOR EACH 55 POINTS YOU EARN IN THE EXPERIMENT YOU WILL BE PAID 1 Dollar.**

Details

Here are a few more details on the experiment, in case you want to know.

How long will a round last?

- The minimum round length is eight seconds.
- The actual round length is random. The round ends with some constant probability every four seconds.
- The average length of a round is 32 second. Many rounds will last less than the average, and a few will last much longer.
- Rounds longer than a couple of minutes are so unlikely that you probably will never see one.

Frequently Asked Questions

Q1. Is this some kind of psychology experiment with an agenda you haven't told us?

Answer: No. It is an economics experiment. If we do anything deceptive, or don't pay you cash as described, then you can complain to the campus Human Subjects Committee and we will be in serious trouble. These instructions are meant to clarify how you earn money, and our interest is in seeing how people make market decisions.

Experiment Quiz

2. In a certain period, you did not sell your asset. How much do you earn in a Payout?

If, instead, you decided to sell and you're first to sell before the round ends, what would you have earned in this round? _____

3. If a round will end in a Forced Sale, what is the probability that a Bad signal arrives at each update? _____

If a round will end in a Payout, what is the probability that a Good signal arrives at each update? _____