ASSET MARKET REACTIONS TO NEWS:

AN EXPERIMENTAL STUDY

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Abstract

An experimental asset market is used to test the effect of news concerning the underlying value of an asset on its trading price. Participants were divided into two groups and received different expected earnings values. Statistical support is found for the hypothesis that investors underreact to news on asset valuation. The results are consistent with the viewpoint that price and valuation history have a significant effect on trader behavior. Two sets of experiments involve a single asset with the same final earnings at the end of the experiment. Expected earnings are updated at the midpoint of the market trading. The two sets of experiments have different expectations of earnings during the first half of the experiment, which became identical after the midpoint. Despite this, the trading prices for the two sets of experiments differ significantly even after their expected earnings coincide. This provides support for underreaction and indicates that decision makers tend to "anchor" their price expectations to preexisting prices and/or valuations.

1. Introduction

In classical finance, there is the assumption of informed investors who possess a huge amount of capital and public information and can exploit any market inefficiency, thereby restoring the asset price to its true value. Furthermore, although not everyone will agree on the correct value of a security, the market acts as though there were unanimity among market participants on this assessment. Thus the classical theory would stipulate that the perturbations in asset prices have two sources: one is due to the randomness of the news entering the market, the other to a small amount of randomness due to mistakes made by some investors that are quickly exploited by the better informed.

Although this viewpoint is espoused by many academic theorists and practitioners offering index funds, it is sharply challenged by market practitioners, particularly those who are involved in managed funds. These practitioners—who typically charge 1 or 2 percent of the fund's value per year for selecting assets to hold in their portfolio and timing their purchases and sales—believe that there are a number of factors that distort prices, enabling a skilled manager the opportunity to buy at bargain prices and sell at full value or higher. In fact, hedge fund managers typically charge these fees plus about 30 percent of the yearly profits. Hence the debate over market efficiency is more than academic.

This assertion that asset markets are efficient because they instantaneously incorporate all public information into a unique assessment of value via asset prices has been questioned from a number of perspectives. Studies of market data have often concluded that market volatility is excessive when measured against classical concepts of valuation (see, e.g., Shiller 1981; Pontiff 1997). There are also a number of empirical market studies suggesting systematic underreaction,

including Lys and Sohn (1990), Abarbanell and Bernard (1992), Ali, Klein, and Rosenfeld (1992), and Elliot, Philbrick, and Wiedman (1995).

The empirical market evidence for both overreaction and underreaction leads to the important questions of determining whether there are fundamental biases that underlie these observations. This suggests that experimental asset markets can be very useful because experiments can be repeated and modified.

The question of whether prices underreact to new information has been explored in an experimental setting without disparate information by Gillette et al. (1999), who examined forecasts and trading on the final in response to releases of public information. They showed that both forecasts and trading prices underreact to the public signals.

Stevens and Williams (2004) showed that the forecast data reveal systematic underreaction to both positive and negative information and that the underreaction is generally greater for positive information than for negative information.

Welfens and Weber (2004) showed that following a positive shock in fundamental value, prices underreact strongly; following negative shocks, they find evidence of a much less pronounced underreaction. After the shock, prices in both situations slowly drift toward the new fundamental value.

In a set of experiments, Nosic and Weber (2009) found overreaction to new information both in stock price forecasts and transaction prices. They also found that subjects are not able to learn from their previous failures and thus do not correct their erroneous beliefs.

The possibility that large investors may have systematic biases, such as overreaction or underreaction, has led to the growing area known as *behavioral finance*. Among these biases is the concept of *anchoring*, whereby a decision maker focuses on a particular value or set of

values for the asset and neglects the possibility that the true value is very different from these (Shefrin 2005). Another is the concept of *affect*, whereby an attractive and appealing idea mesmerizes the investor so that a realistic assessment of value is short-circuited (Slovic et al. 2002). Analogously, a company that is involved in a business that is unpleasant or unexciting will often be out of favor. Oil companies are often considered to be within this ugly-duckling group until energy prices soar. Often a stock or industry that is out of favor tends to remain at suppressed prices (i.e., a trading price that is low by measures of price/earnings, price/book ratios, etc.), reinforcing the undesirability. There is also the possibility that a stock with a suppressed price is also a victim of anchoring; that is, investors have become accustomed to observing the low stock price and are skeptical of any improvement in price, and thereby fail to react optimally when there is evidence that the situation has turned around. Hence this could be a fundamental origin of underreaction and could be tested experimentally. Alternatively, if the market price were to increase disproportionately to news of improving prospects, it would suffer from an overreaction to news. Both under- and overreaction have been noted in the literature.

One of the underlying causes for overreaction may be explained through the *representativeness heuristic*. Grether (1980) examined the evidence on representativeness heuristics from an experimental perspective. In his experiment, subjects were first given two different prior probabilities presented by two bingo cages. Six balls were then drawn sequentially with replacement from one of the bingo cages, based on which subjects estimated which bingo cage the balls were drawn from. Grether found that subjects gave too much weight to the new evidence and too little weight to the objective prior probabilities (though the priors are not ignored, especially with experienced subjects). He also found that financial incentives did little

to improve on estimate accuracy among inexperienced subjects. His results confirmed previous evidence on overreaction due to representativeness heuristics.

There may be many other reasons for overreaction in the markets. For example, in a competitive situation (e.g., a money manager who must keep up with the index average performance), one might recognize that some news is not terribly significant in the long run but may fear that others will not share this calculation. Hence there is an incentive to increase one's positions in an asset based on the uncertainty involving others' reactions. As noted by Smith, Suchanek, and Williams (1998), even when there is no uncertainty about the ultimate earnings, there is the uncertainty involving others' actions. In the fundamental experiments of Beard and Beil (1994), it was noted that while agents seek to self-optimize, they tend not to rely on the self-optimization of others. Thus, in any situation in which there are two different calculations, one of them biased, a trader who recognizes the flaws in the biased reasoning must nevertheless worry that many others could be subject to it and that there could be a movement toward the prices reflecting the biased reasoning.

The fundamental causes of underreaction are also complex. Practitioners have long noted that investors tend to use reference points to make their decisions. In particular, they are aware of the price at which they purchased the asset and would like to avoid a loss. In this way, they "frame" their decisions and "anchor" potential trades about values such as the purchase price. Kahneman and Tversky (1979) popularized this concept through a series of small experiments in which they asked participants questions about their preferences. The two sets of questions were identical in terms of the expected value but differed in that one set framed the choice as a loss, while the other framed it as a gain. Extrapolating from this theory (see also Shefrin 2005) suggests that someone who purchased a stock at $50 and observed it fluctuating between $40 and $50 might

have an incentive to sell when the price reaches $50 once again. Consequently, as the stock moves from $40 toward $50, a person receiving a signal that the probability of the stock reaching $60 is significantly higher would hold if he were evaluating the situation objectively but sell if he were strongly influenced by the anchoring bias. As the price reaches $50, the trader has the opportunity to avoid a loss, which prospect theory advocates suggest is a strong motivation to trade at $50. Hence one might postulate from prospect theory that anchoring is a fundamental cause of underreaction.

In a particular situation, the various behavioral effects can suggest biases that are in different directions. For example, a slightly positive signal on the value of an asset might suggest overreaction through representativeness theory but underreaction due to prospect theory and anchoring. Distinguishing between the two in market situations is the focus of our research.

In a typical market situation, an asset (e.g., common stock) trades each day, and relevant information (such as an earnings report) is released at the end of the trading day. As in Grether's (1980) study, overreaction to new information about the final dividend due to representativeness heuristics is possible in such environments. However, a significant difference between this environment and that of Grether (1980) is that continuous trading may have the tendency to establish a price through repetition and reinforcement, which provides an example of anchoring whereby a decision maker focuses on the price history and neglects the possibility that the true value is very different (Shefrin 2005). Therefore persistent trading at a low price for an extended period might lead to an underreaction to the announcement due to anchoring at the lower price that has been established during the trading period. Thus a dynamical setting rather than a static or two-step process has some additional richness.

While efficient market theorists view the trading price as a harmonious unanimity on the value of the security, many practitioners view it as a tug-of-war between different camps. The small fluctuations about a single value may appear superficially as an equilibrium but in fact comprise a tense stalemate that is ultimately resolved, sometimes with a small amount of additional buying or selling arising from new information. It is very common for different large investment houses to offer completely incompatible assessments on everything from stocks to commodities to currencies. However, even as they espouse very different views, they optimize their trading by placing their trades as close to the other camp as they are able. In other words, if one investment company values a stock at $50 and another at $100 while the stock is trading at $75, the company trying to buy will not do so at $100. They will try to buy as low as possible, namely, near $75. Hence a casual observer of the market price will see the price fluctuating close to $75 and may conclude, falsely, that there is general agreement among market participants that this is the true value. Thus an experiment designed to understand market behavior can be made more realistic by giving disparate information to different groups. This can also be used to understand the interaction between the assets of the groups and their assessment of value.

To meet this objective, we design a set of experiments in which there are two ten-minute rounds separated by a short break. Participants trade an asset with a single payment occurring at the end of the second round. The traders are classified into two distinct groups receiving different information but trade without the knowledge of the other group's information. In the baseline experiments, there is no change in the earnings probabilities during the break. In the second set of experiments, however, one or both groups have updated information that improves the expected earnings, thereby matching the earnings in the baseline treatments. Hence the anticipated earnings are identical for both groups during the entire second half of the two sets of

experiments. In the absence of either underreaction or overreaction, there should be no statistical difference between the two treatments. If the second set of experiments has higher (or lower) trading prices than the baseline treatment, it would suggest overreaction (or underreaction).

Understanding the assimilation of new information is critical to the development of models of market dynamics such as the *asset-flow approach* (Caginalp and Balenovich 1999), which incorporates the concepts of the finiteness of capital and the fundamental tendency to buy due to the trend as well as the valuation. This approach has been useful in discovering the underlying causes of bubbles in asset market experiments (Caginalp, Porter, and Smith 2001).

The rest of this article is organized as follows. Section 2 is a detailed description of the design of the experiment, section 3 gives the hypotheses of the study, section 4 analyzes the results, and section 5 concludes the article with some discussion of the results.

2. Experimental Design

Undergraduate students of various majors at George Mason University were recruited, and the experiments were conducted between October 2005 and April 2006. Sessions were run one at a time. A single asset was traded using an open-book (traders can observe all bids and asks being offered at any moment) double auction on a computer network. In each experiment, 8–12 participants were given instructions and a 5-minute practice session to ensure that they had understood the mechanics of the auction.[1] Participants in the experiment were evenly and randomly assigned to trader types in the experiment, which we label group A and group B. Participants were not aware that there were groups and only knew their own earnings information and the history of market prices and transaction volume. In one set of treatments, the

[1] The experimental instructions can be found in Appendix A.

groups were differentiated based on the news they received during the experiment. In particular, both groups were informed that the asset traded would have a dividend of either 100 or 10 e-dollars (i.e., experimental dollars that we also denote by E$) at the end of the experiment. The e-dollars were converted to U.S. dollars at the end of the experiment at a rate that was announced before the experiments started. Each trader was given information (called a "hint") at the beginning of the experiment on the probability of the two earnings. For example, our "hint75" listed on a participant's screen "the earnings of the share at the end of the experiment is 100 e-dollars with a chance of 75% and 10 e-dollars with a chance of 25%." Thus the expected earnings for hint75 is 100 (75%) + 10 (25%) = 77.5 e-dollars.

Subjects were told that the shares last exactly one period, which consists of two rounds[2] of ten minutes each, with a one-minute break between the rounds. During the break, news concerning a change in the probability of the dividend earnings was provided privately to each participant. To ensure that subjects were aware of the news, the experimenter announced before the second round started that "you may have received updated information on the final payment. Please read it very carefully." In the *Baseline* treatment, there was no updated information so that the initial probability assessments remained the same. The participants in group A were provided information in the form of hint75, while the group B participants were given the more pessimistic estimates of hint25—"the earnings of the share at the end of the experiment is 100 e-dollars with a chance of 25% and 10 e-dollars with a chance of 75%"—with an expected earnings of 32.5. Besides the baseline with no news, we had two types of information treatments where news was released at the break between rounds to the different groups, which involved increasing the probability of the 100-dividend earnings. In the *Disparate Information* treatment,

[2] The dividend was realized after round 2.

group A started with hint60,[3] which moved to hint75, and group B started with hint10,[4] which moved to hint25. In the *Merge Information* treatment, we had both groups merge to the same probability estimate. In one case, group A started with hint75, which remained unchanged at the break, while group B started with hint25, which merged to hint75 at the break. In a second merge treatment, group A started with hint60 and moved to hint75 at the break, while group B started at hint10 and merged to hint75 at the break. These information treatments allow us to examine price movements in a variety of information updates.

Previous experiments have demonstrated the strong role of the ratio of cash and number of shares in trading prices (Caginalp, Porter, and Smith 1998), which we call *liquidity*. To ensure robustness of the experimental conclusions, we created variations in the share and cash endowments of the two groups. In both *Baseline* and *Disparate Information* treatments, each participant in both groups was given the same initial portfolio of "E$500 and ten shares" in type 1 sessions and "E$1000 and ten shares" in type 4 sessions. In type 2 and 3 sessions, we varied the cash-to-shares ratio of the two groups. One group had more cash (E$750 and five shares), while the other group had the base amount of E$500 and ten shares. Table 1 summarizes our experimental design.

3. Hypotheses

The null hypothesis is that after the midpoint of the experiment, there will be no significant difference between the trading prices in the two sets of experiments because both consist of the

[3] The message for hint60 was "the earnings of the share at the end of the experiment is 100 e-dollars with a chance of 60% and 10 e-dollars with a chance of 40%."

[4] The message for hint10 was "the earnings of the share at the end of the experiment is 100 e-dollars with a chance of 10% and 10 e-dollars with a chance of 90%."

Table 1: Experimental Design

Treatment	Information* (before break → after break)	Endowment variations: Type	Group	Cash amount	No. shares	No. sessions
Baseline	Group A: hint75 → hint75	1	A	500	10	3
			B	500	10	
		2	A	750	5	3
			B	500	10	
	Group B: hint25 → hint25	3	A	500	10	3
			B	750	5	
		4	A	1000	10	2
			B	1000	10	
Disparate Information	Group A: hint60 → hint75	1	A	500	10	3
			B	500	10	
		2	A	750	5	3
			B	500	10	
	Group B: hint10 → hint25	3	A	500	10	3
			B	750	5	
		4	A	1000	10	1
			B	1000	10	
Merge Information	Group A: hint75 → hint75	1	A	500	10	3
	Group B: hint25 → hint75		B	500	10	
	Group A: hint60 → hint75	2	A	500	10	3
	Group B: hint10 → hint75		B	500	10	

Note. Baseline treatment does not inject news during the midpoint break, so group A had hint75 and group B had hint25 throughout the experiment. There are four types of endowment variations; for example, in type 1 of *Baseline*, each member of both groups was endowed with E$500 and ten shares, whereas in type 2, each member in group A was given E$750 and five shares, and each in group B was given E$500 and ten shares. All four variations in the *Disparate Information* treatment have the same endowments with their corresponding *Baseline* treatment types. In the *Disparate Information* treatment, group A started with hint60 and group B started with hint10 and were updated with higher expected earnings of hint75 and hint25, respectively, during the break. Comparing type 1 in *Disparate Information* and *Baseline*, we note that each has exactly the same endowments, but *Disparate Information* initially gives group A hint60, with expected earnings 100 (0.6) + 10 (0.4) = 64, and group B hint10, with expected earnings 100 (0.1) + 10 (0.9) = 19. During the midpoint break, group A was updated with hint75, and group B was updated with hint25, that is, the same level of expected earnings as in the *Baseline Information* treatment.

same information after that point. In other words, prices should depend on the available information of expected earnings and not on the price history. However, the key question we will examine is whether there is underreaction or overreaction to the updated information that is injected during the midpoint break. Recall that the *Disparate Information* sessions have lower expected earnings in the first half of the experiment but are then updated to the same expected earnings after the midpoint as the *Baseline* sessions. If investors underreact to positive

information after a prolonged state of lower expectations, then the prices in the information experiments should be lower than the prices in the baseline experiments, namely, those in which the information is the same throughout the experiment. Such a result would provide support for the role of anchoring in financial markets and to the concept that price history has a strong effect on future prices, even in the face of updated information on fundamental value.

Alternatively, if investors overreact to new information, then the treatments with news would have higher prices in the second half than the baseline, even though the expectations of earnings are exactly the same during this latter part of the experiment. This would be consistent with representativeness or affect, whereby participants exaggerate the impact of the new and positive information.

In addition to the fundamental hypotheses, we will also examine the effect of changes in the underlying environment in terms of liquidity.

4. Results

Appendix B contains the time series of prices of trades for each experimental session. The graphs strongly suggest that there is anchoring in the decision making of the market participants. There seems to be no evidence of overreaction to updated market information. To formalize these ocular results, we begin with the following notation:

$W1_A$ = expected earnings by group A in the first round, prior to information update
$W1_B$ = expected earnings by group B in the first round, prior to information update
$W2_A$ = expected earnings by group A in the second round, after information update
$W2_B$ = expected earnings by group B in the second round, after information update.

These are calculated in the usual way by multiplying the probability with the outcome. For example, if group A is given hint75 that there is a 75 percent chance of $100 earnings and a 25 percent chance of $10 earnings, group A has expected earnings of (0.75) (100) + (0.25) (10) = E$77.50.

The cash endowments of the two groups are denoted by M_A or M_B, and the total number of shares in each group is given by N_A or N_B. The asset flow differential equations approach and various experiments have shown the importance of the liquidity price per share, computed as the total cash in the system divided by the total number of shares, that is,

$$L = \frac{M_A + M_B}{N_A + N_B}. \tag{1}$$

We first examine the relative impact of these variables on the trading prices in the absence of news. This can be accomplished by considering prices just before the end of the first round, denoted $P1$. The initial impact of the news, combined with these variables, can be studied by examining prices just at the beginning of the second round, denoted $P2$. Finally, one can study the final prices just before the end of the experiment, denoted Pf, to understand how this information is assimilated in time. Because the news is presented prior to the start of the second round, a perfectly efficient market would accurately reflect the current outlook. Even if there is some delay in assimilating the new information, however, the effect of the information should be reflected in the prices at the end of the experiment. These questions will be examined through a series of regressions. Because many prices are generated by the same group, we cannot regard them as independent. Consequently, an ordinary linear regression would overstate the statistical confidence. This problem can be overcome by using a fixed effects model that compensates for

the dependence of the data on different groups, in this case, the experimental sessions (Pinheiro and Bates 2000). Recapitulating the definitions, we have the following:

$P1$: The last nine trading prices in the first round.
$P1_{t-1}$: The tenth to last trading price to the second to last trading price in the first round.
$P2$: The second to the tenth trading prices in the second round.
$P2_{t-1}$: The first nine trading prices in the second round.
Pf: The final nine trading prices at the very end of the experiment (the second round).
Pf_{t-1}: The tenth to last trading price to the second to last trading price at the very end of the experiment (the second round).

First we calculate the logarithm of all prices, and then we control for the session as a random effect and perform the regression using the SPlus fixed effects model on the following three regressions.

4.1. Trading Prior to News

Using the data from all treatments and the first round only, which does not involve any new information, we write

$$\text{Log}\,(P1) = \alpha_0 + \alpha_1 \text{Log}\,(P1_{t-1}) + \alpha_2 L + \alpha_3 W1_{\text{B}}. \qquad (2)$$

Table 2 provides the estimates of our model.

The term $P1_{t-1}$ is the one-trade-lag of $P1$, which we utilize to determine if there is a trend effect at the end of the first round. We find no support for any trend as prices have essentially settled nearly ten minutes after the start of trading.

Table 2: Regression Estimates

	Value	*SE*	*df*	*t*-value	*p*-value
(Intercept)	2.1194	0.2949	215	7.1870	<.0001
Log ($P2_{t-1}$)	0.0379	0.0661	215	0.5729	.5673
L	0.0094	0.0026	24	3.5761	.0015
$W1_B$	0.0230	0.0073	24	3.1389	.0045

Note. Number of observations = 243; number of groups = 27.

Previous experimental studies suggest the trading price moves up as the cash per share ratio increases. We investigate this by including the term liquidity L, which varies across treatments. We confirm previous evidence as α_2 (the coefficient of L) is positive and significant (p = .0015).

The expected earnings of group A in the first round, $W1_A$, either remains unchanged or increases in the same direction with $W1_B$, so we only include $W1_B$ in the regression. We find that the coefficient of $W1_B$ is positive and significant, as expected, which indicates that the trading price rises as the expected earnings rise.

4.2. Trading after News

We now investigate the impact on trading prices right after the news was released in the midpoint break between the two rounds. The binary variable INFO equals 1 when the session has an upgrade of the expected earnings during the break (such as the *Disparate Information* treatments), and 0 otherwise (such as the *Baseline* treatment). A fixed-effects linear regression analysis is then performed for the trading price just after the second session starts. The fixed-effects model we estimate is

$$\text{Log}\,(P2) = \alpha_0 + \alpha_1\,\text{Log}\,(P2_{t-1}) + \alpha_2 L + \alpha_3\text{INFO} + \alpha_4 W2_B.$$

Table 3 contains the estimates of this model.

Table 3: Regression Estimates with Information Dummy

	Value	*SE*	*df*	*t*-value	*p*-value
(Intercept)	1.8241	0.2527	215	7.2188	<.0001
Log ($P2_{t-1}$)	0.4246	0.0529	215	8.0245	<.0001
L	0.0041	0.0019	23	2.1699	.0406
INFO	–0.2112	0.0674	23	–3.1338	.0047
$W2_B$	0.0032	0.0020	23	1.6041	.1223

Note. Number of observations = 243; number of groups = 27.

Unlike the results of the regression on trading prices right before news, the coefficient on the lagged trading price Log ($P2_{t-1}$) is now significant (and positive), indicating that the market price is adjusting to the new expected earnings, which are now higher than before. Liquidity L's coefficient α_3 is again positive and significant as it is a fixed feature within a treatment and thus invariant to whether it is regressed on trading prices before or after news.

Note that subject traders who did not receive news had higher expected earnings throughout the entire experiment; traders who received news started low but then were upgraded in the second session to the same level. The term INFO has a significantly negative coefficient (p = .0047), indicating that the markets that received news did not fully incorporate the information into the trading prices. This result strongly suggests market underreaction to news. In the next section, we will further test and report on the impact of the news on trading prices near the end of the experiment, when prices are stabilized.

In addition, the coefficient $W2_B$ is not significant owing to the fact that the news is not incorporated by the market and thus the expected earnings are not yet reflected in the trading prices.

4.3. Trading in the End

In addition to this initial reaction to the new information, one can examine the final trades of the experiment to determine whether the underreaction that is evident immediately after the announcement is remedied. This yields the regression model and results in

$$\text{Log}\,(Pf) = \alpha_0 + \alpha_1\,\text{Log}\,(Pf_{t-1}) + \alpha_2 L + \alpha_3 \text{INFO} + \alpha_4 W2_{\text{B}}.$$

Table 4 summarizes the results of the preceding regression.

As expected, the trend effect disappeared in the end of the trading (p = .9191) as the market stabilized nearly ten minutes after the news was released. Liquidity remains significant and thus reconfirms its positive effect on trading prices.

The coefficient of INFO remains negative and significant (p = .0765), indicating that markets starting with lower expected earnings trade at lower prices near the end of the experiment, even though the expectations were identical in the second half. This confirms again that market underreaction to news persists even after trading prices stabilize. In addition, the coefficient of $W2_{\text{B}}$ is significant (p = .0252), suggesting that the trading prices now again reflect the expected earnings across treatments, as they did in the end of the first round, prior to the news. Combining these two results, we conclude that the markets do incorporate the new expectations after a long

Table 4: Regression Estimates

	Value	*SE*	*df*	*t*-value	*p*-value
(Intercept)	2.5308	0.5400	215	4.6862	<.0001
Log (Pf_{t-1})	–0.0067	0.0653	215	–0.1016	.9191
L	0.0112	0.0050	23	2.2197	.0366
INFO	–0.3260	0.1758	23	–1.8547	.0765
$W2_{\text{B}}$	0.0129	0.0054	23	2.3936	.0252

Note. Number of observations = 243; number of groups = 27.

period of trading, but the trading prices are not as high as the markets, which had higher expectations throughout.

5. Conclusions

We have conducted a series of experiments in which participants trade an asset that has single earnings at the end of two rounds of ten minutes each. In some of the experiments, the information given to some or all traders was updated at the end of the first ten-minute round, while it was left unchanged in other experiments. The experiments also differed in terms of the cash-to-asset level of participants (liquidity levels). Previous work has shown that liquidity is an important factor in determining trading prices, so a range of liquidity levels were used for robustness.

The data have been analyzed using a series of mixed-effects regressions that compensate for heteroskedasticity or the fact that many data points are generated by the same group. The first regression concerns only the first round, entailing no new information during the time round analyzed. Each of the nine prices at the end of this first round is regressed against the expected earnings, the liquidity, and the previous trading price. As expected, the trading prices increase with increasing expected earnings and liquidity. These are highly significant statistically, with p values of .0045 and .0015, respectively. The dependence on the previous trading price is not significant. Although it was expected from our previous results, the role of liquidity remains strong even after much trading has occurred, suggesting that it is not due to initial confusion or lack of familiarity with the trading system.

The next regression explores the impact of new information by examining the dependence of the first nine trades of the second round on the earnings, liquidity, and previous price, plus the

dummy variable (INFO) that is defined as 1 if there is new information and 0 if there is none. The INFO variable is highly significant, with a *p* value of .0047. The negative value indicates that those experiments in which the information was updated exhibited lower trading prices during the second half compared to the experiments in which the information remained the same. The two sets of experiments featuring identical expected earnings during the second half nevertheless differed in terms of trading price, depending on the conditions that prevailed in the first half. Hence the lower trading price observed in the experiments featuring a more subdued past demonstrated a strong deviation from any concept of optimization (e.g., Bayesian) that utilizes only current information.

The issue of whether these lower trading prices are transient is examined in the subsequent regression, which differs from the previous one in that we utilize the last nine trades of the second round. Using identical independent variables, we find results that are quite similar, indicating that the lower prices resulting from the lower expectations of the *first* round are persistent in time. In fact, the INFO variable is still negative and even larger in magnitude. The main difference between the two sets of regressions (first vs. last nine trades of the second round) is that the role of liquidity and the expected earnings are both larger at the end of the experiment. It is not entirely surprising that some time is required for traders to assimilate the expected earnings. However, one may have predicted that the role of liquidity would diminish as traders have more time to consider the expected earnings. The result that the impact of liquidity increases with time suggests a deeper role for liquidity. In particular, as the trading evolves, more dollars chasing the same number of shares tends to influence how people place their bids and asks. A higher liquidity level means that there are more dollars with which one can bid, thereby raising the price, which in turn influences others to raise their bids and asks. That there is a

significant trend term during the initial trades of the second round suggests that rising prices influence trading decisions. The trend term is not significant during the last nine trades, by which time the price has settled. The asset flow used by Caginalp and collaborators since 1989 has indicated a complex relationship between the trend, the past history of prices and valuations, and current valuations. The positive trend term in the initial trades of the second round is consistent with the expectations of this theory. In particular, consider the experiments in which one of the groups receives updated information while the other does not. The group receiving no new information has the same expected earnings but notices rising prices that indicate that perhaps others have information upgrading the earnings, and they react by bidding higher for the asset.

A number of questions that arise from these results have the potential to be addressed by additional asset market experiments. With a larger number of experiments that differ only in the distribution of assets among groups (defined as receiving or not receiving updated information), one can hope to obtain enough data to understand the motivations underlying the higher prices. A pilot experimental study on these questions was performed by Caginalp (2002), where the asymmetric information was given to three groups of participants with varying levels of cash. Though trading prices reflected the additional information given to just one of the three groups, a large amount of additional cash led to prices that were much higher than could be expected even with all the information. This leads to a number of questions. If information is received by only some of the participants, what is the mechanism whereby the market assimilates that information? Does the price reach the level it would had all participants received the information? What is the timescale on which the new equilibrium (or steady state) price is reached, and how does it depend on the fraction of assets owned by the group receiving the new information?

In summary, our statistical analysis provides support for the assertion that market prices underreact to information that upgrades expected earnings following a prolonged round of less positive information and prices. This means that the price (when adjusted for the other variables such as liquidity) is lower in the experiments featuring an upgrade of the earnings than it is for the experiments having the higher expected earnings from the start. Furthermore, this underreaction persists throughout the remainder of the experiment, providing support for the concept of anchoring in asset price dynamics. If fundamentals and trading prices are low for a prolonged time, then improvement of fundamentals does not lead to the same price that would be attained if the fundamentals were always high. In other words, the market price in our experiments is not simply a function of the current expectations, as efficient market theory and classical economics would predict; rather, the trading price depends strongly on the past price history of the asset. Even in this experimental setting, where the fundamentals are clearer than they are in field markets, participants appear to be influenced either by the lower price or by the lower fundamentals of the past. On a practical level, this study provides some support to value managers who claim that bargains among out-of-favor stocks persist for some time.

The findings of underreaction—possibly as a consequence of anchoring—appear at first glance to be in contrast to the Grether experiments in which an update providing a small increase in earnings leads to an overreaction. One factor that distinguishes the two types of experiment is time. In Grether's experiment, the new information is only the second piece of information, and there has been no opportunity to observe others' reactions in the intervening time. In our experiments, there is a significant amount of time and trading that occur prior to the release of the new information. It is possible that there is some tendency for overreaction to the new information that is much smaller than a competing tendency for underreaction caused by the

nature of trading. In other words, when the updated information (suggesting higher earnings) is released at the start of the second half of our experiments, some traders may react in accordance with representativeness rather than Bayesian strategy and be prone to overreacting. However, others may be focusing on the trading that has occurred and remain skeptical of the new information. If the latter dominate during the initial trades of the second round, then traders who initially were prone to overreacting may be readjusting their strategy in light of the information on others' strategies obtained through observing the trading prices. Undoubtedly, the effect of overreaction to new information (due to representativeness) observed by Grether is present in our experiments; however, other factors leading to underreaction appear to be stronger under the conditions of our experiments. Thus one might regard underreaction and overreaction as competing effects, just like stability and instability, with the winner of the competition depending on many factors that are yet to be discovered.

One of these factors may be closely related to prospect theory. Behavioral finance has shown that decision makers treat potential losses differently from gains. When the news upgrades the earnings at the midpoint of the experiment, there is the possibility of greater profit for those who wish to purchase more of the asset. However, failure to do so will not lead to loss. At this point in the experiment, the participants have come to regard the current value of the stock plus cash as their own. By not rushing to buy more shares, they are not losing any money that they have become accustomed to regarding as their own. It is possible that with short selling or selling of futures contracts, there would be some traders scrambling to cover their shorts and bidding up prices aggressively. This could be a source of overreaction.

Ultimately, the issues of underreaction and overreaction are at the heart of behavioral finance. If these effects did not exist in a statistically verifiable sense, then there would be no change in

the trading price due to behavioral effects, and the classical paradigm would be realized. Moreover, if the effects of underreaction and overreaction cannot be distinguished *a priori*, even with the comprehensive information that we have in asset experiments, then it would be difficult to build behavioral finance into a quantitative and predictive science. Thus developing an understanding of the conditions that lead to underreaction and overreaction, respectively, is an essential step in understanding the motivations that underlie nonclassical behavior in finance.

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Appendix A: Experimental Instructions

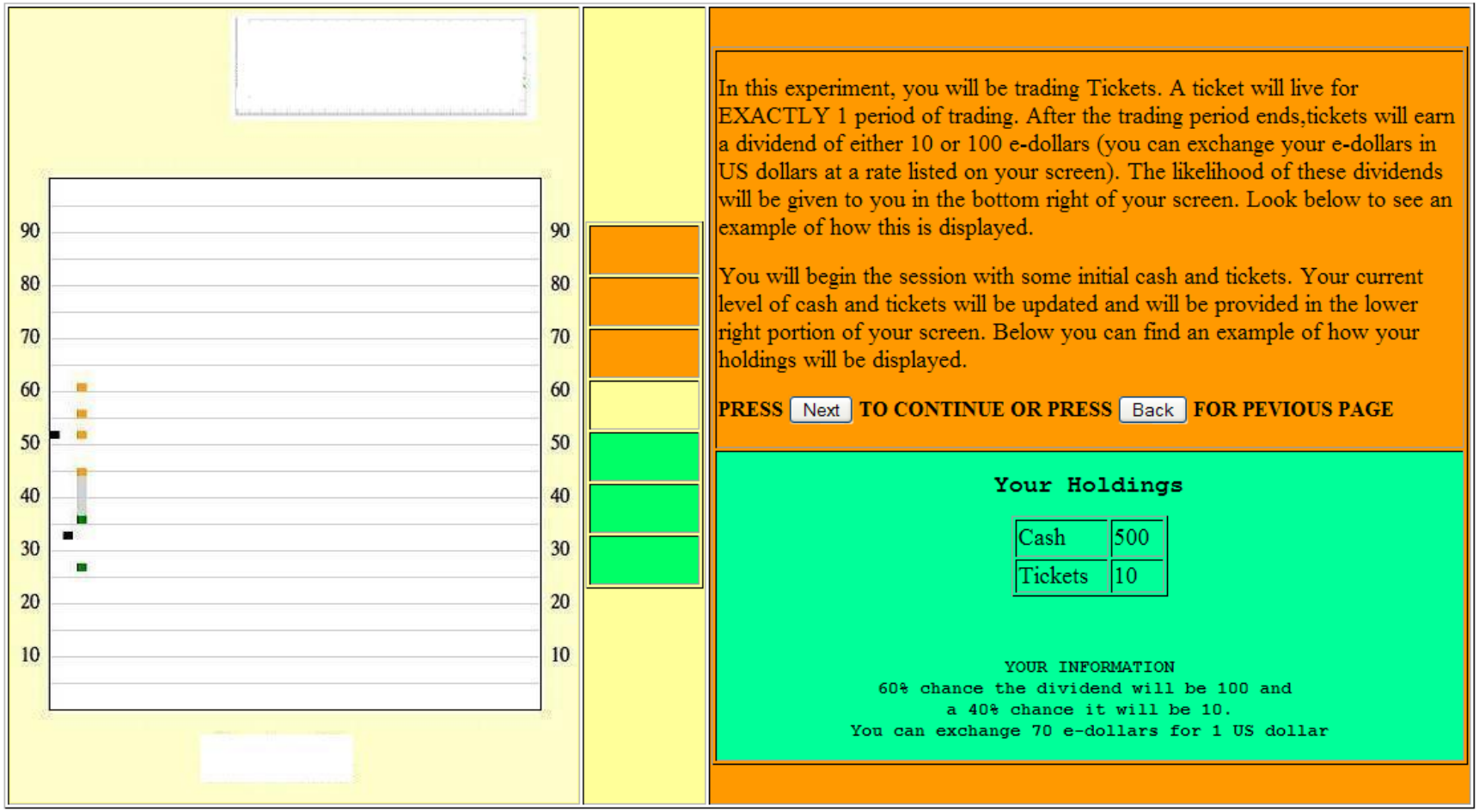
INSTRUCTIONS

This is an experiment in market decision making, and you will be paid for you participation in cash, at the end of the experiment. Different participants may earn different amounts. What you earn depends on your decisions and the decisions of others.

The experiment will take place through computer terminals at which you are seated. We will start with a detailed instruction period. During the instruction period, you will be given a complete description of the experiment and will be shown how to interact with the computers.

If you have any questions during the instruction period, raise your hand and your question will be answered so everyone can hear. If any difficulties arise after the experiment has begun, raise your hand, and a monitor will come and assist you.

Next **PRESS NEXT TO CONTINUE**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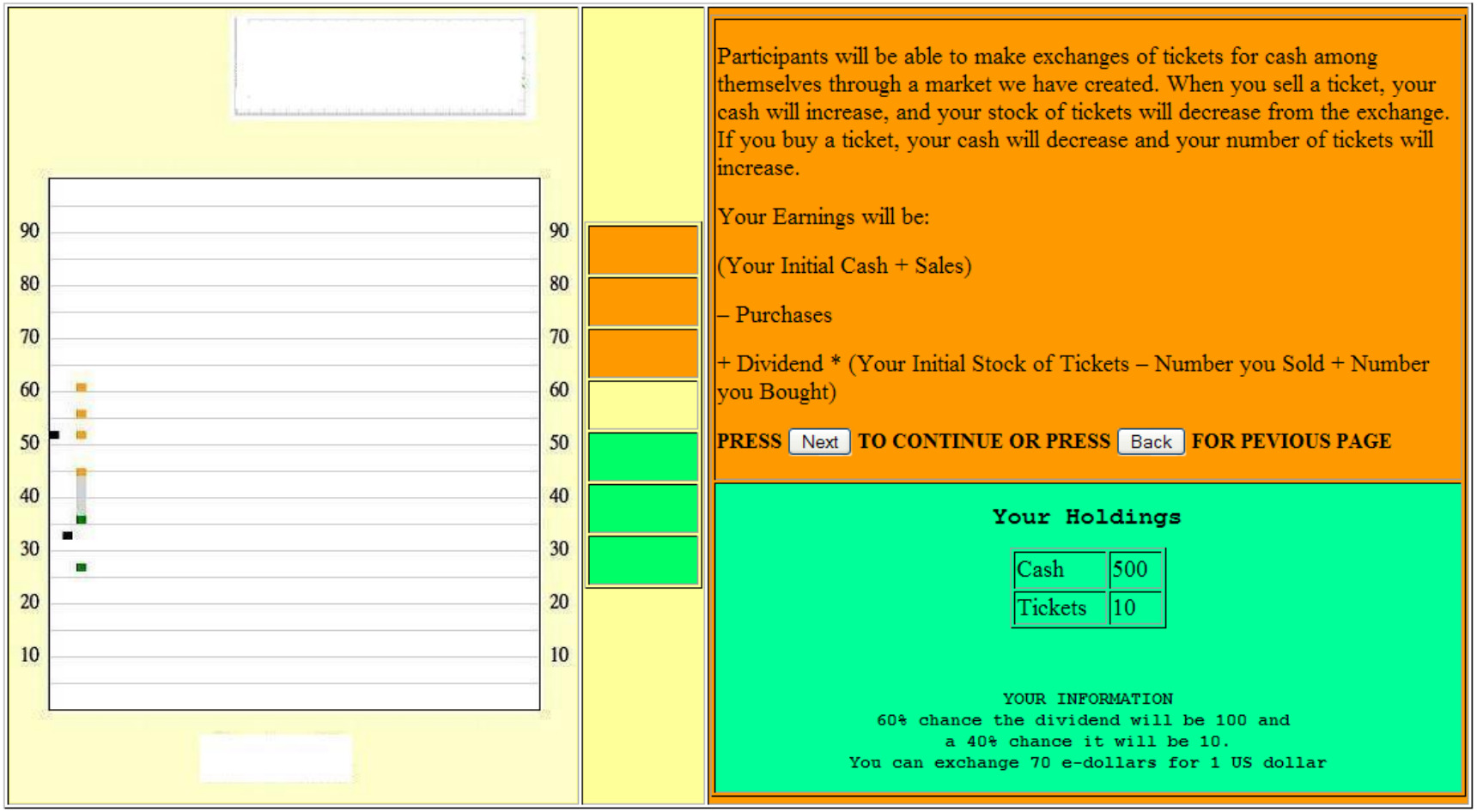
In this experiment, you will be trading Tickets. A ticket will live for EXACTLY 1 period of trading. After the trading period ends,tickets will earn a dividend of either 10 or 100 e-dollars (you can exchange your e-dollars in US dollars at a rate listed on your screen). The likelihood of these dividends will be given to you in the bottom right of your screen. Look below to see an example of how this is displayed.
You will begin the session with some initial cash and tickets. Your current level of cash and tickets will be updated and will be provided in the lower right portion of your screen. Below you can find an example of how your holdings will be displayed.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE
Your Holdings
Cash 500
Tickets 10
YOUR INFORMATION
60% chance the dividend will be 100 and
a 40% chance it will be 10.
You can exchange 70 e-dollars for 1 US dollar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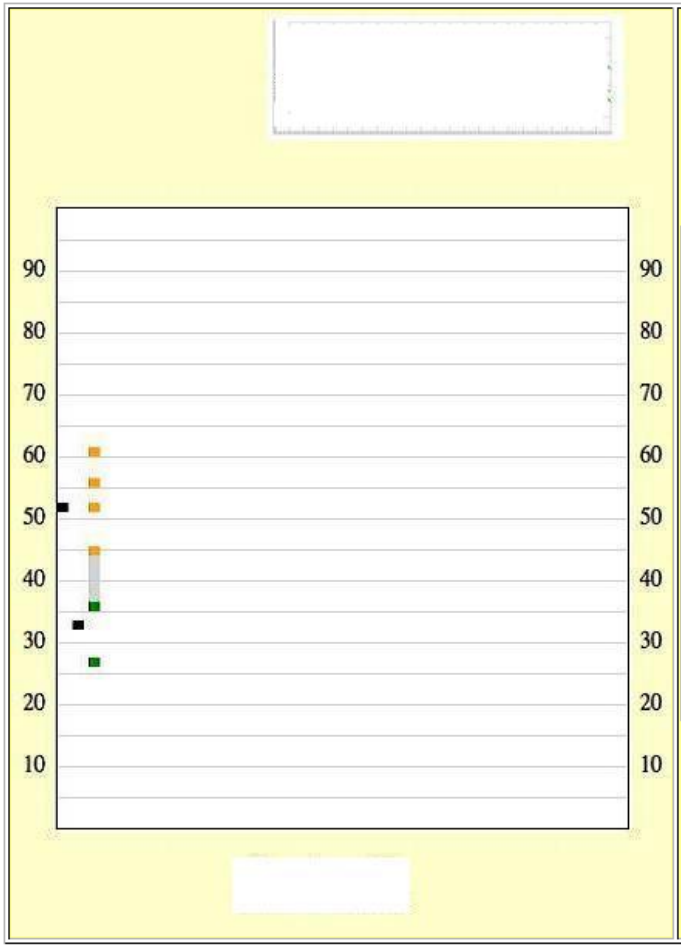
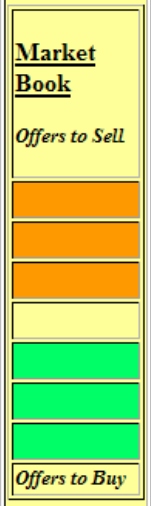
Participants will be able to make exchanges of tickets for cash among themselves through a market we have created. When you sell a ticket, your cash will increase, and your stock of tickets will decrease from the exchange. If you buy a ticket, your cash will decrease and your number of tickets will increase.
Your Earnings will be:
(Your Initial Cash + Sales)
– Purchases
+ Dividend * (Your Initial Stock of Tickets – Number you Sold + Number you Bought)
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE
Your Holdings
Cash 500
Tickets 10
YOUR INFORMATION
60% chance the dividend will be 100 and
a 40% chance it will be 10.
You can exchange 70 e-dollars for 1 US dollar





In the center of the screen is the market book. The market book contains all offers to buy or sell tickets.

Later you will learn how to place offers to buy and sell.

OFFERS TO SELL:

Top half of the market book contains the offers to sell 1 ticket. Every trader can submit his/her offers to sell a ticket. They will be displayed in the market book with the order of the lowest price is on the bottom and the highest price is on the top.

PRESS Next **TO CONTINUE OR PRESS** Back **FOR PEVIOUS PAGE**

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YOUR INFORMATION
60% chance the dividend will be 100 and
a 40% chance it will be 10.
You can exchange 70 e-dollars for 1 US dollar
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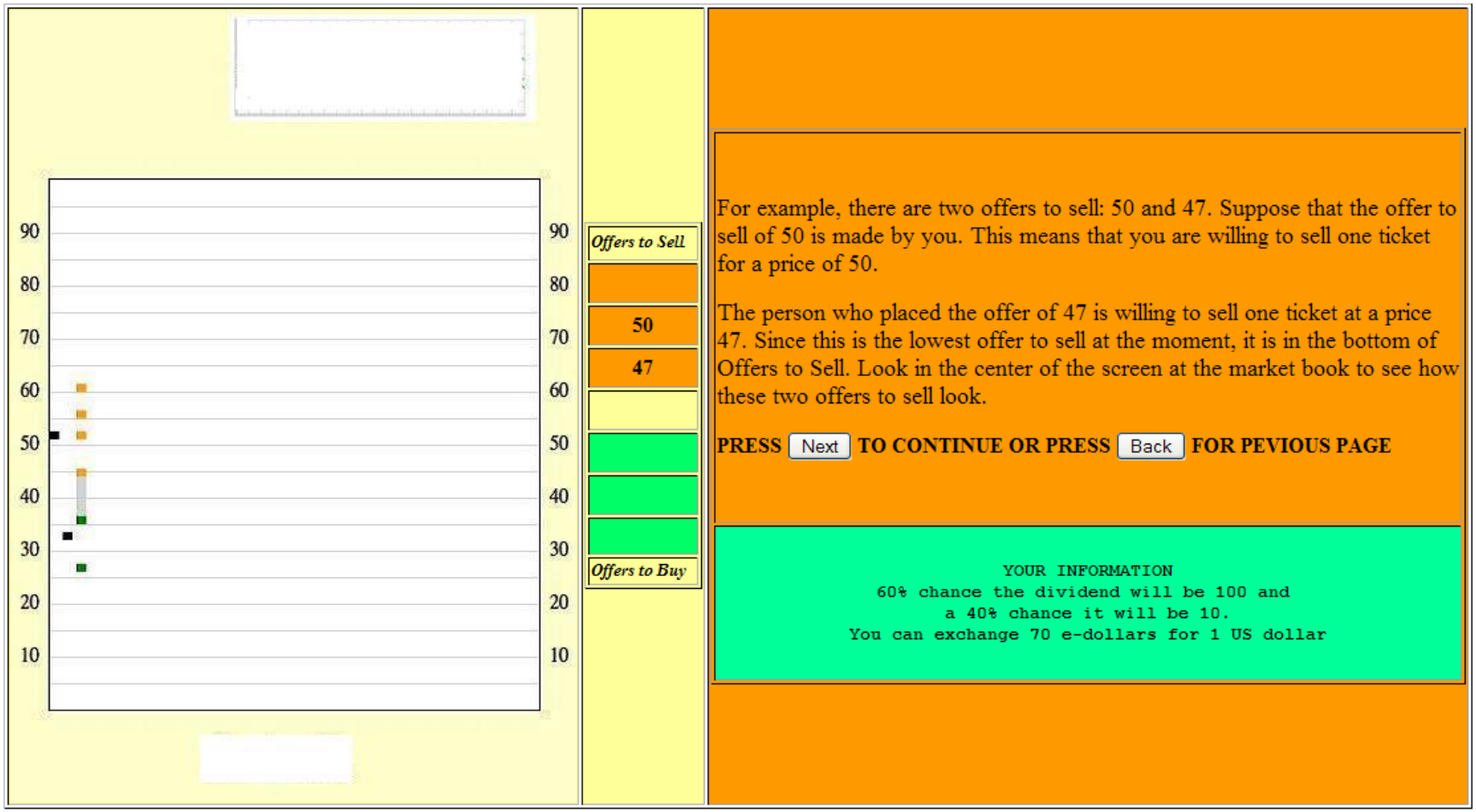
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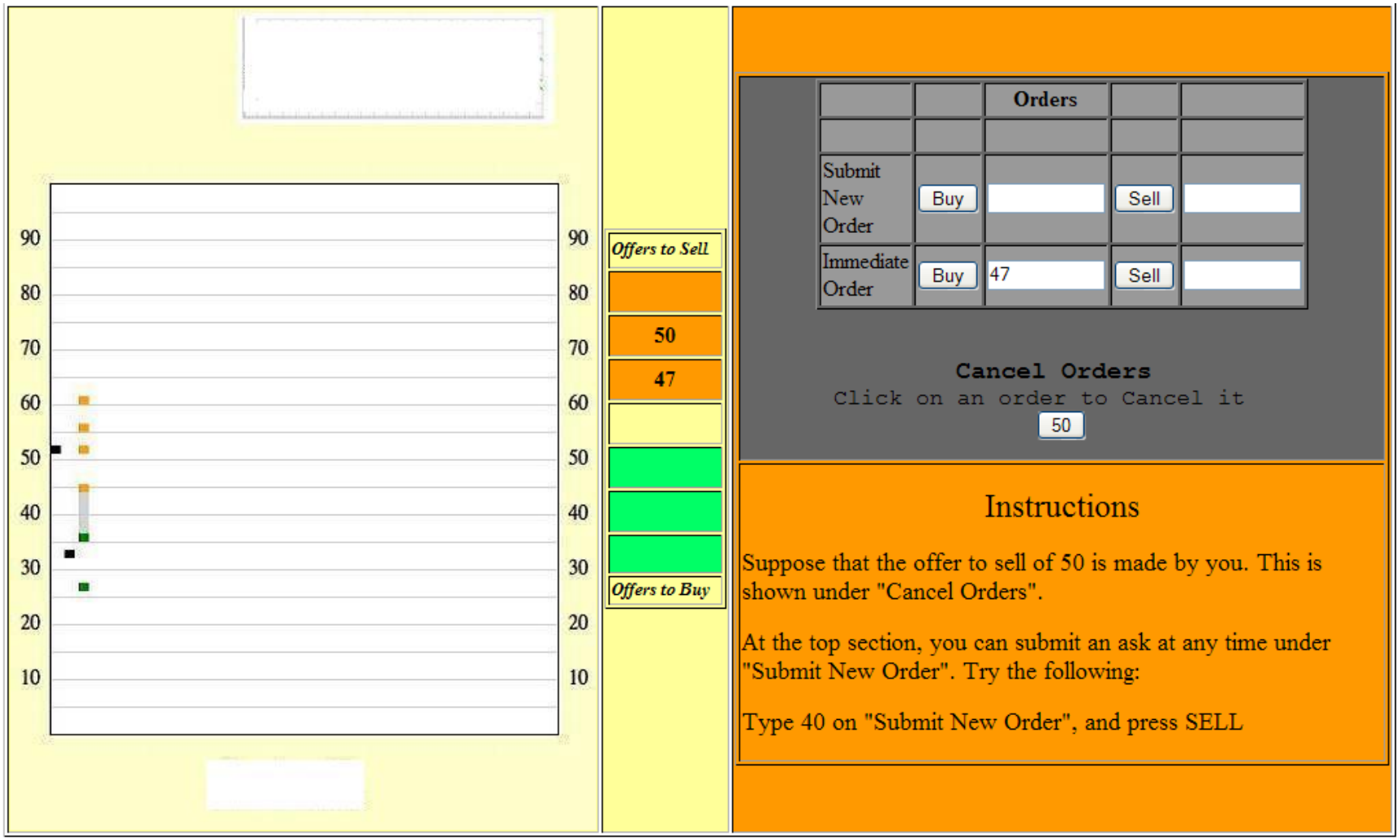
Offers to Sell
50
47
Offers to Buy
For example, there are two offers to sell: 50 and 47. Suppose that the offer to sell of 50 is made by you. This means that you are willing to sell one ticket for a price of 50.
The person who placed the offer of 47 is willing to sell one ticket at a price 47. Since this is the lowest offer to sell at the moment, it is in the bottom of Offers to Sell. Look in the center of the screen at the market book to see how these two offers to sell look.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE
YOUR INFORMATION
60% chance the dividend will be 100 and
a 40% chance it will be 10.
You can exchange 70 e-dollars for 1 US dollar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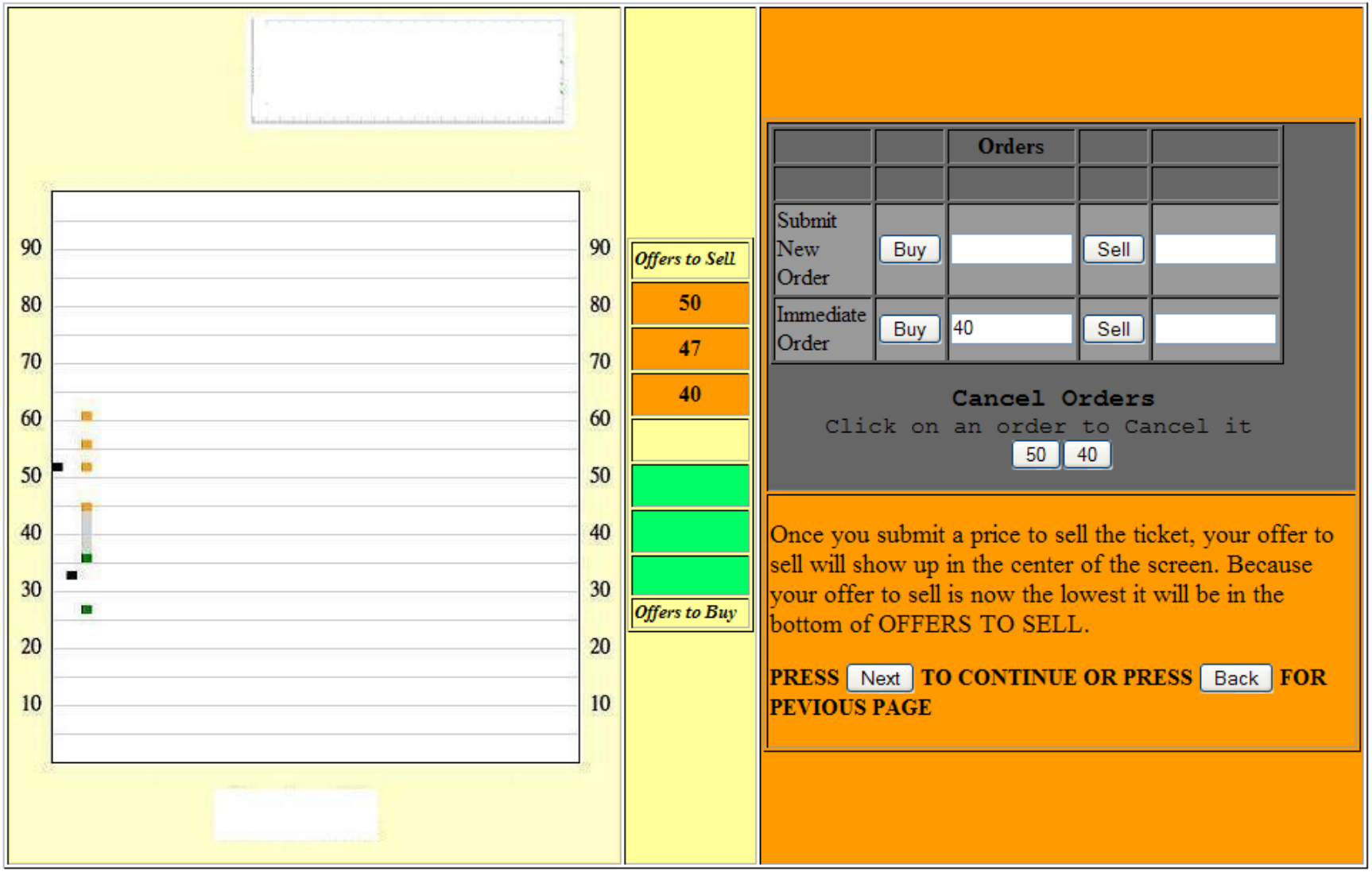
10
Offers to Sell
50
47
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
47
Sell
Cancel Orders
Click on an order to Cancel it
50
Instructions
Suppose that the offer to sell of 50 is made by you. This is shown under "Cancel Orders".
At the top section, you can submit an ask at any time under "Submit New Order". Try the following:
Type 40 on "Submit New Order", and press SELL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Offers to Sell
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47
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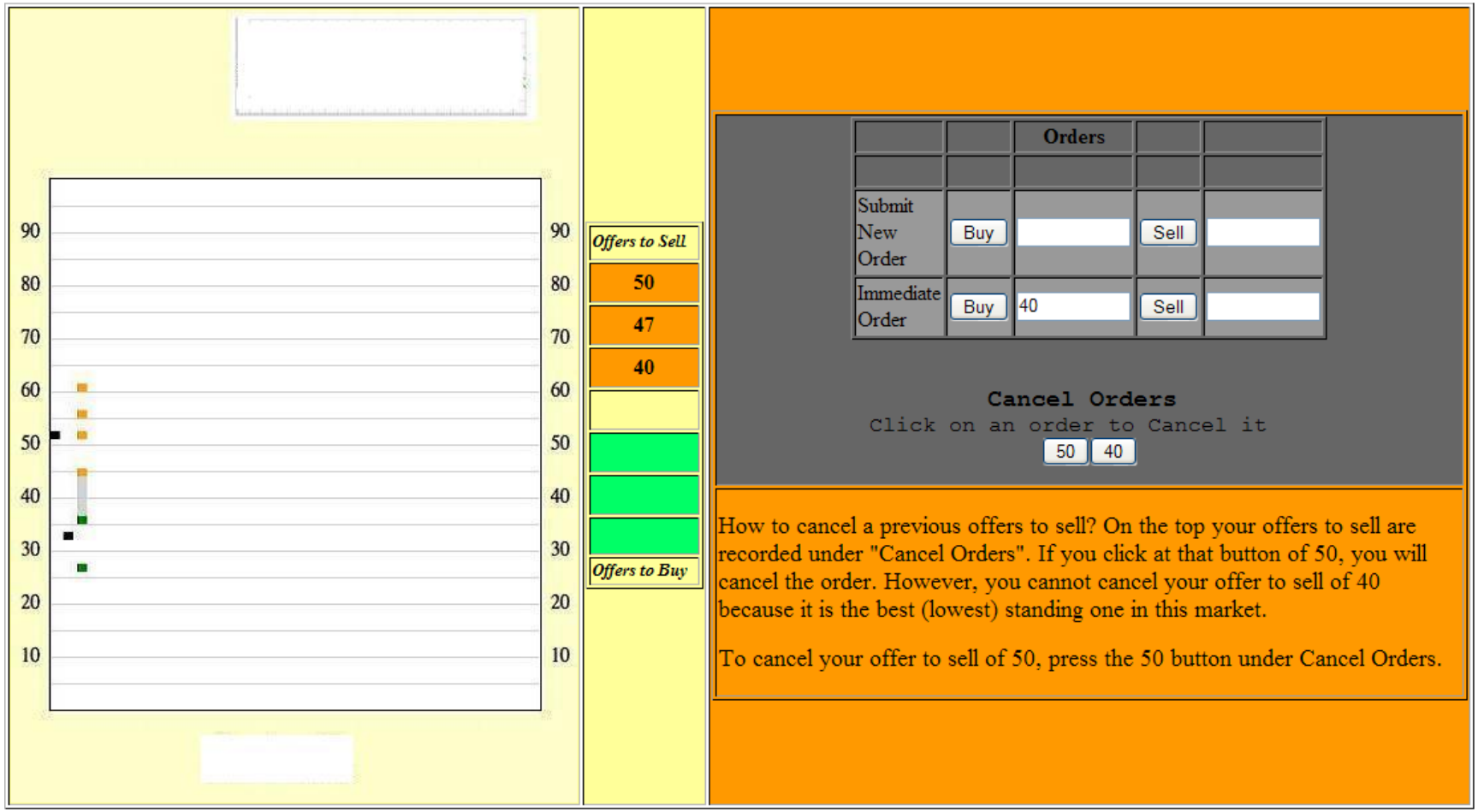
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
Cancel Orders
Click on an order to Cancel it
50
40
Once you submit a price to sell the ticket, your offer to sell will show up in the center of the screen. Because your offer to sell is now the lowest it will be in the bottom of OFFERS TO SELL.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE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Offers to Sell
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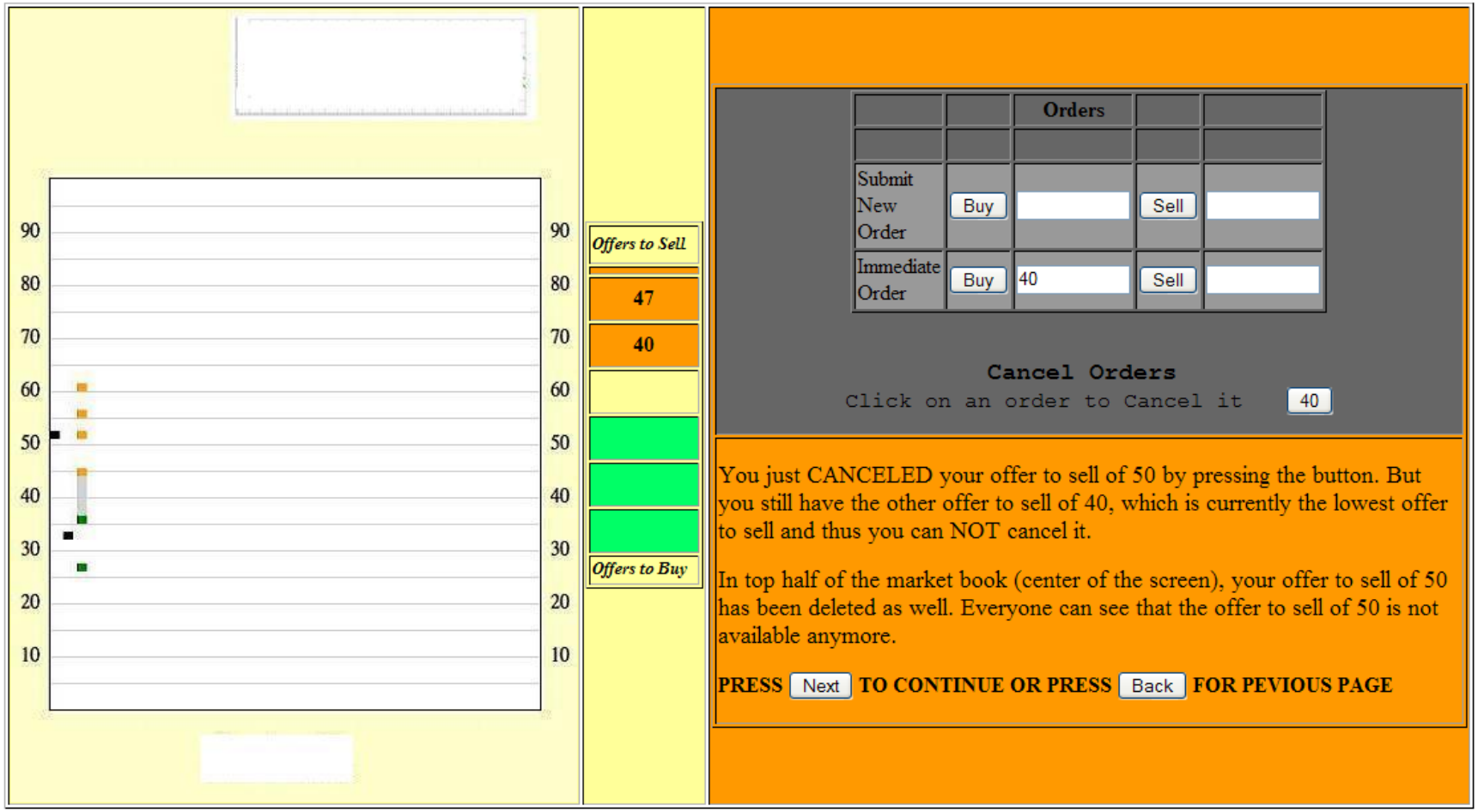
47
40
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
Cancel Orders
Click on an order to Cancel it
50
40
How to cancel a previous offers to sell? On the top your offers to sell are recorded under "Cancel Orders". If you click at that button of 50, you will cancel the order. However, you cannot cancel your offer to sell of 40 because it is the best (lowest) standing one in this market.
To cancel your offer to sell of 50, press the 50 button under Cancel Orders.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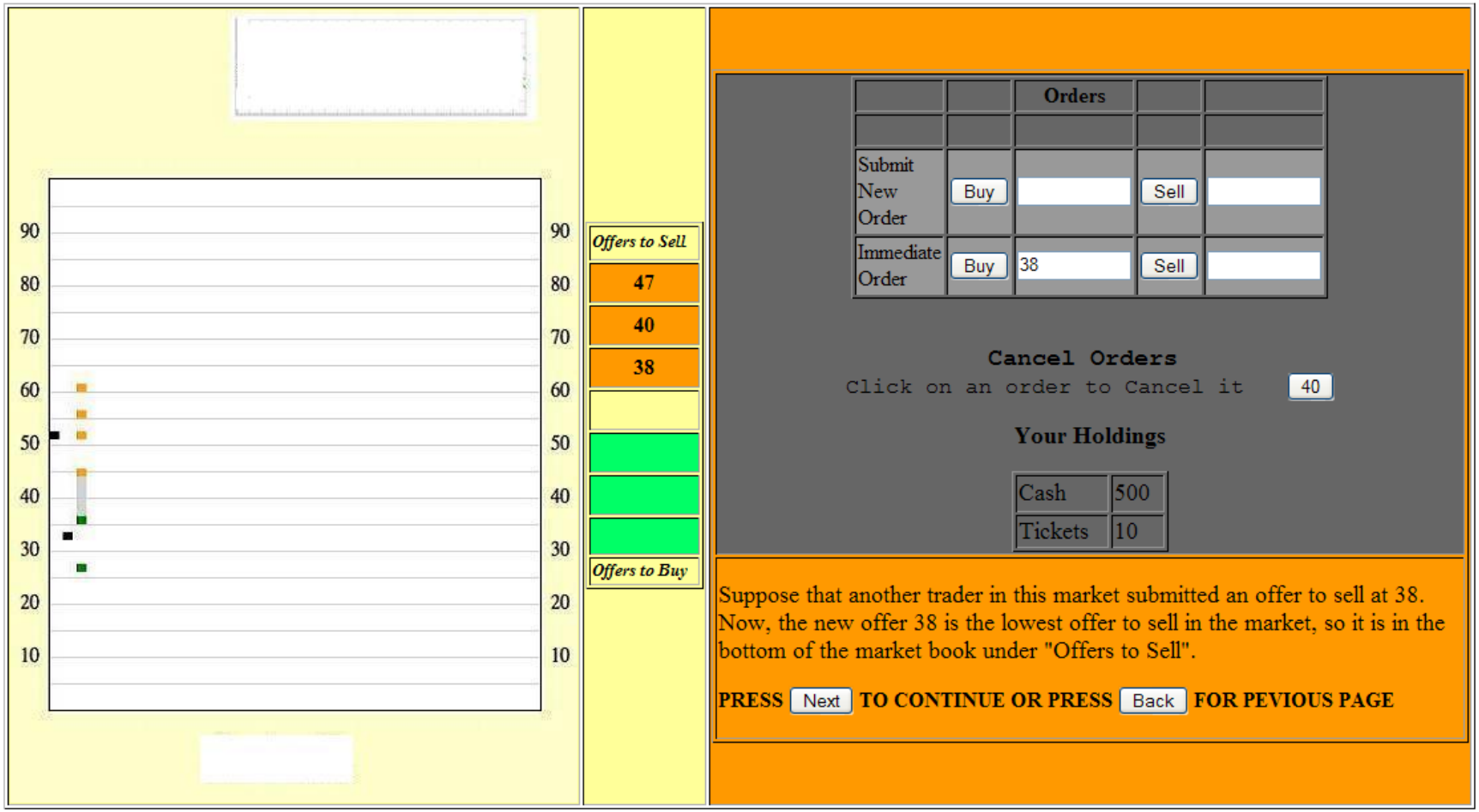
Offers to Sell
47
40
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
Cancel Orders
Click on an order to Cancel it
40
You just CANCELED your offer to sell of 50 by pressing the button. But you still have the other offer to sell of 40, which is currently the lowest offer to sell and thus you can NOT cancel it.
In top half of the market book (center of the screen), your offer to sell of 50 has been deleted as well. Everyone can see that the offer to sell of 50 is not available anymore.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE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Offers to Sell
47
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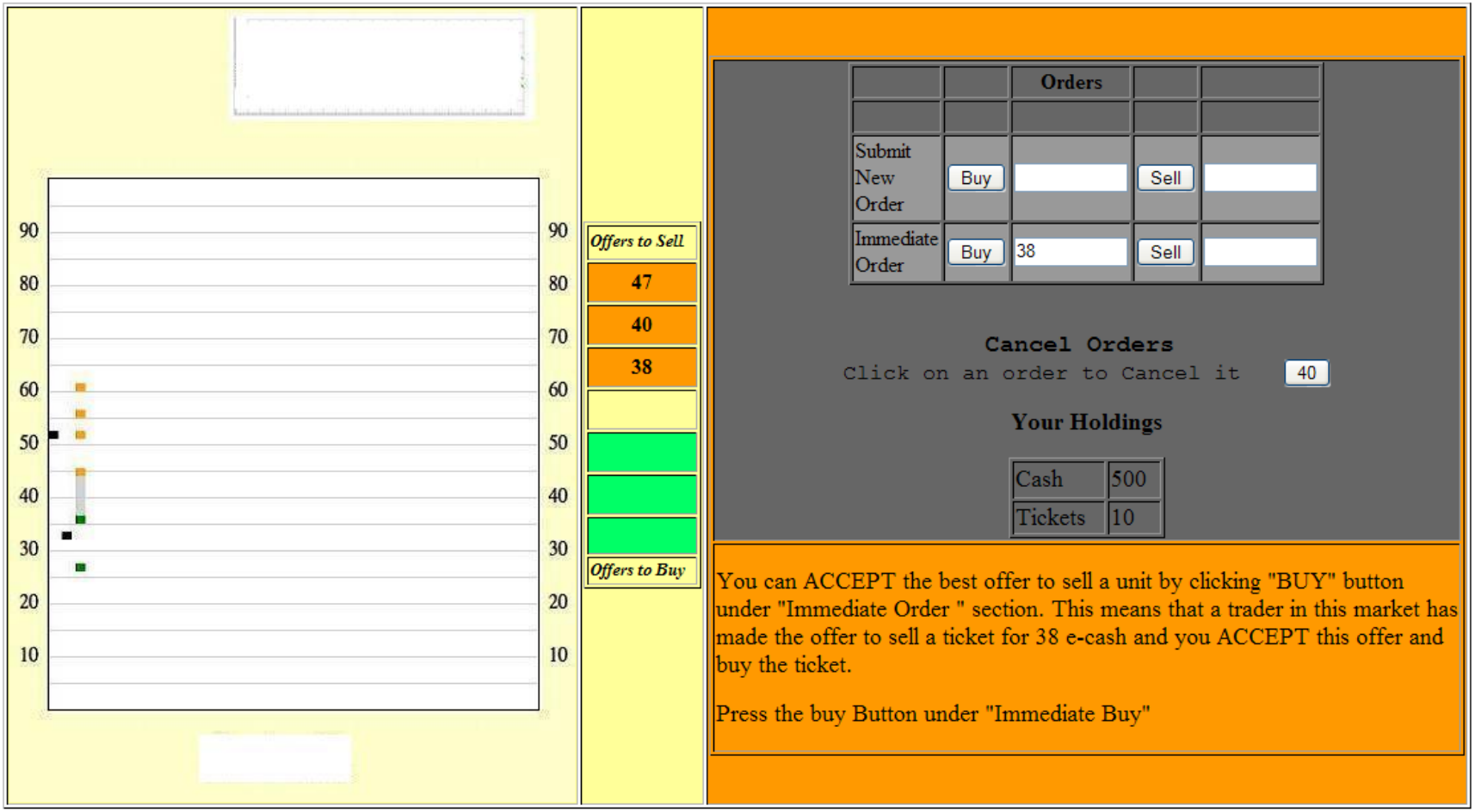
38
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
38
Sell
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
500
Tickets
10
Suppose that another trader in this market submitted an offer to sell at 38. Now, the new offer 38 is the lowest offer to sell in the market, so it is in the bottom of the market book under "Offers to Sell".
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE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Offers to Sell
47
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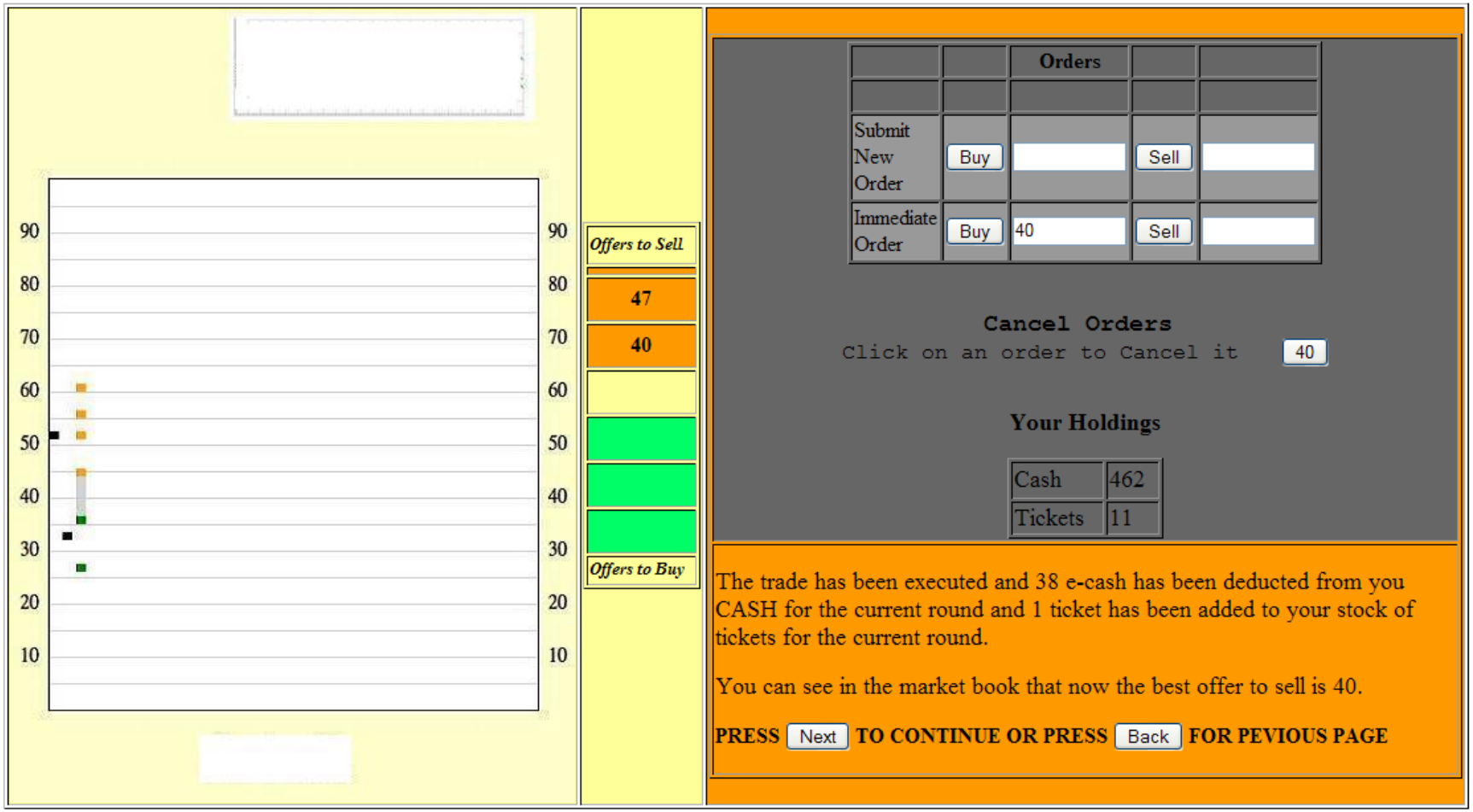
38
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
38
Sell
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
500
Tickets
10
You can ACCEPT the best offer to sell a unit by clicking "BUY" button under "Immediate Order " section. This means that a trader in this market has made the offer to sell a ticket for 38 e-cash and you ACCEPT this offer and buy the ticket.
Press the buy Button under "Immediate Buy"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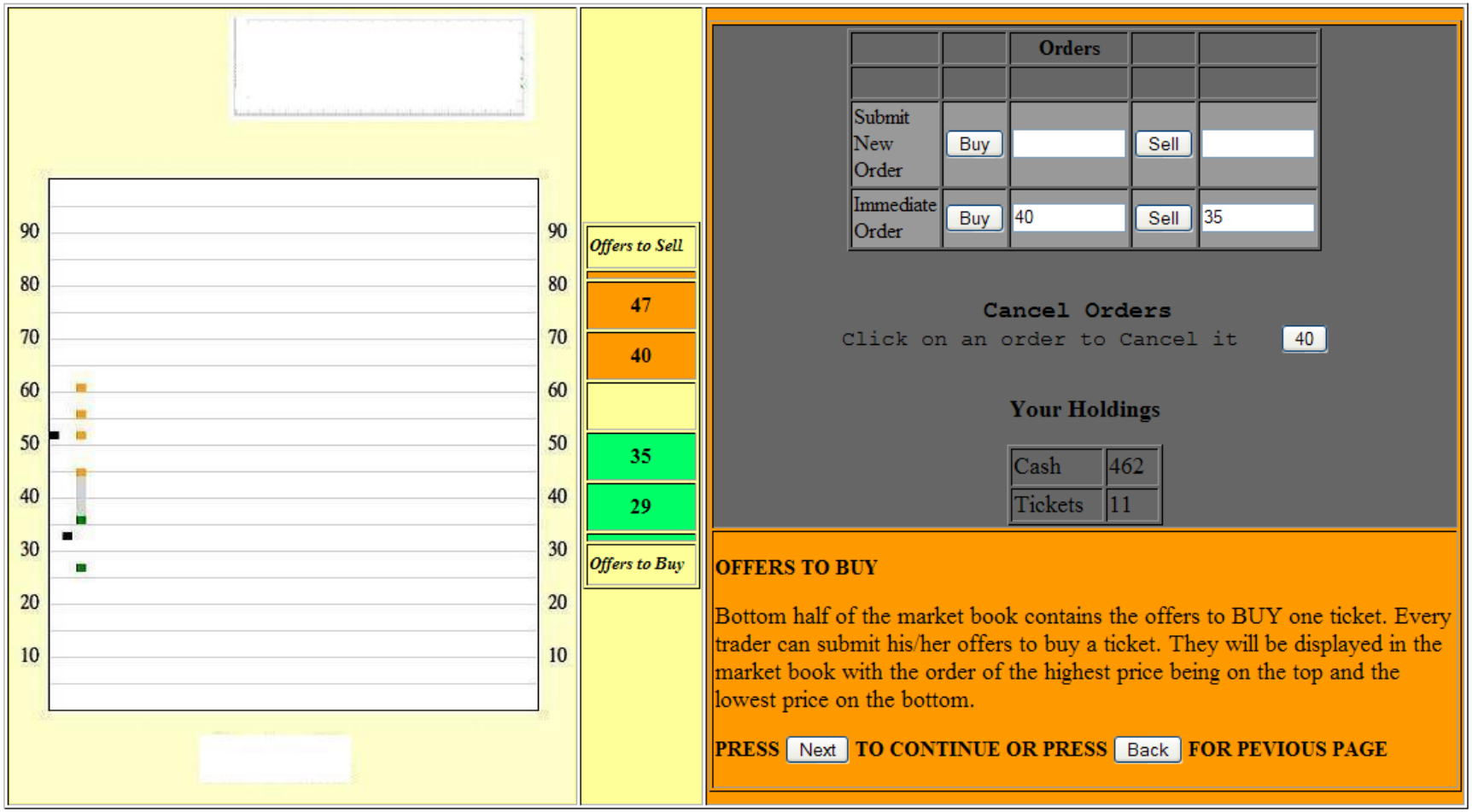
Offers to Sell
47
40
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
462
Tickets
11
The trade has been executed and 38 e-cash has been deducted from you CASH for the current round and 1 ticket has been added to your stock of tickets for the current round.
You can see in the market book that now the best offer to sell is 40.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE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Offers to Sell
47
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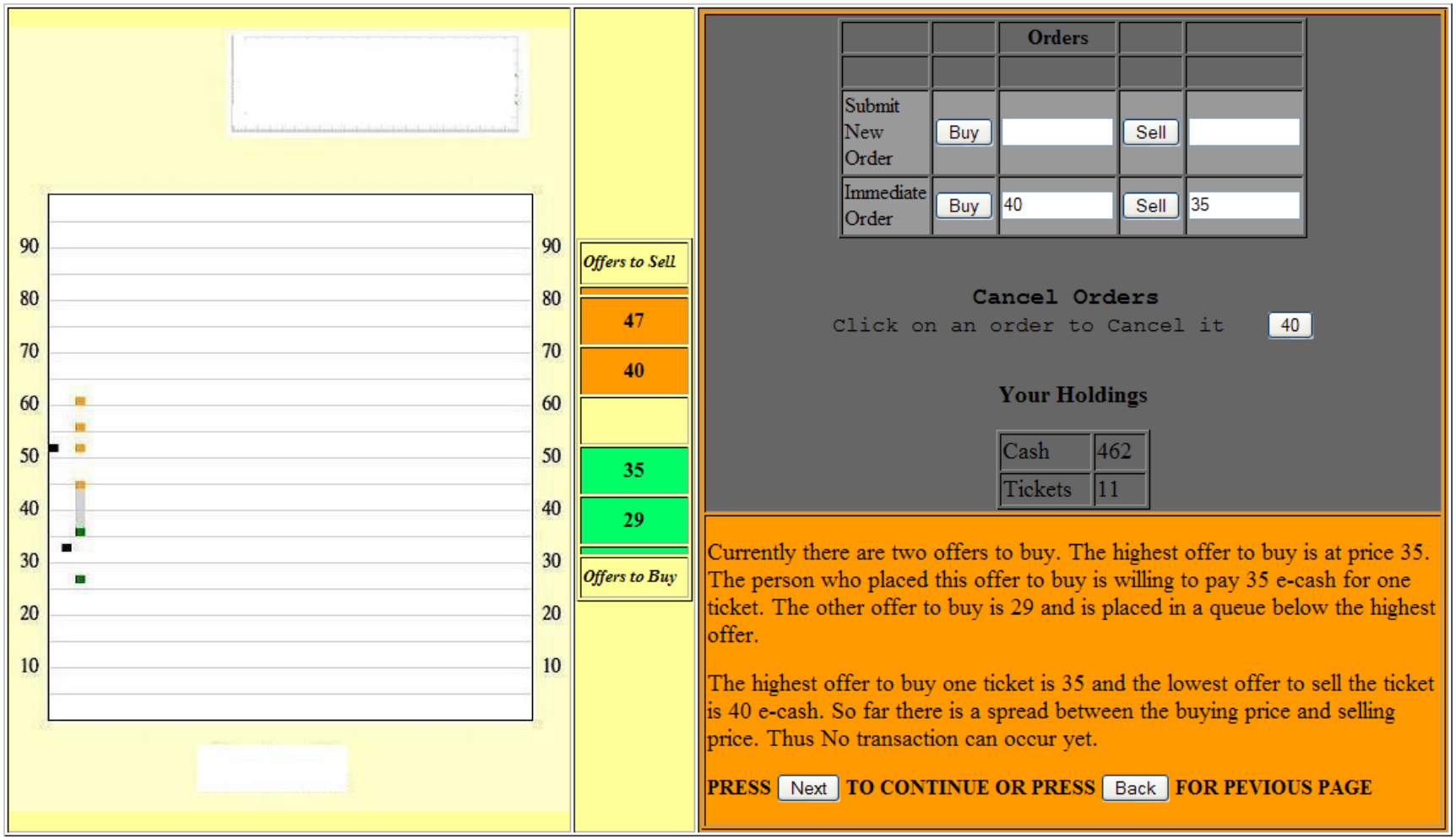
35
29
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
35
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
462
Tickets
11
OFFERS TO BUY
Bottom half of the market book contains the offers to BUY one ticket. Every trader can submit his/her offers to buy a ticket. They will be displayed in the market book with the order of the highest price being on the top and the lowest price on the bottom.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE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Offers to Sell
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35
29
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
35
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
462
Tickets
11
Currently there are two offers to buy. The highest offer to buy is at price 35. The person who placed this offer to buy is willing to pay 35 e-cash for one ticket. The other offer to buy is 29 and is placed in a queue below the highest offer.
The highest offer to buy one ticket is 35 and the lowest offer to sell the ticket is 40 e-cash. So far there is a spread between the buying price and selling price. Thus No transaction can occur yet.
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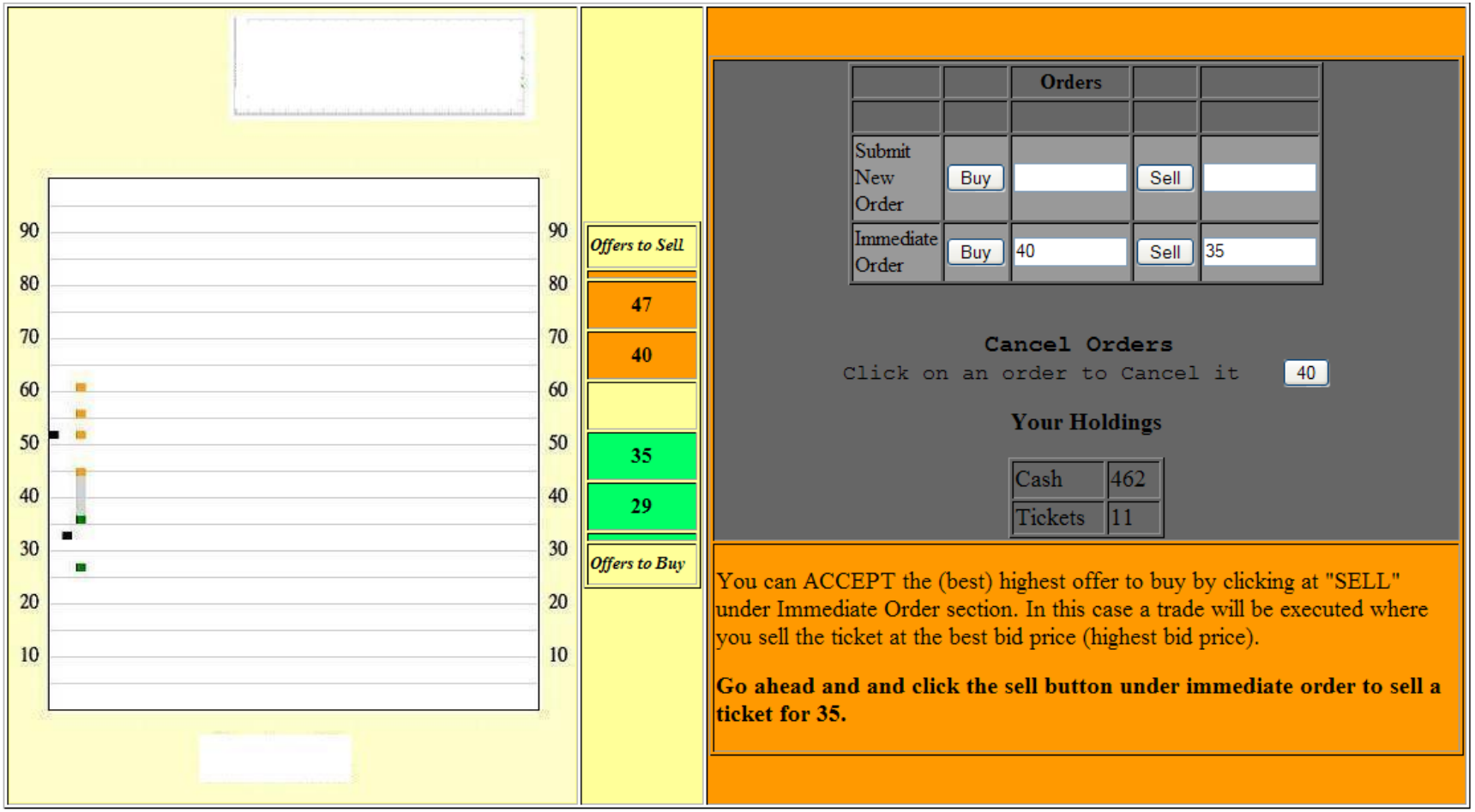
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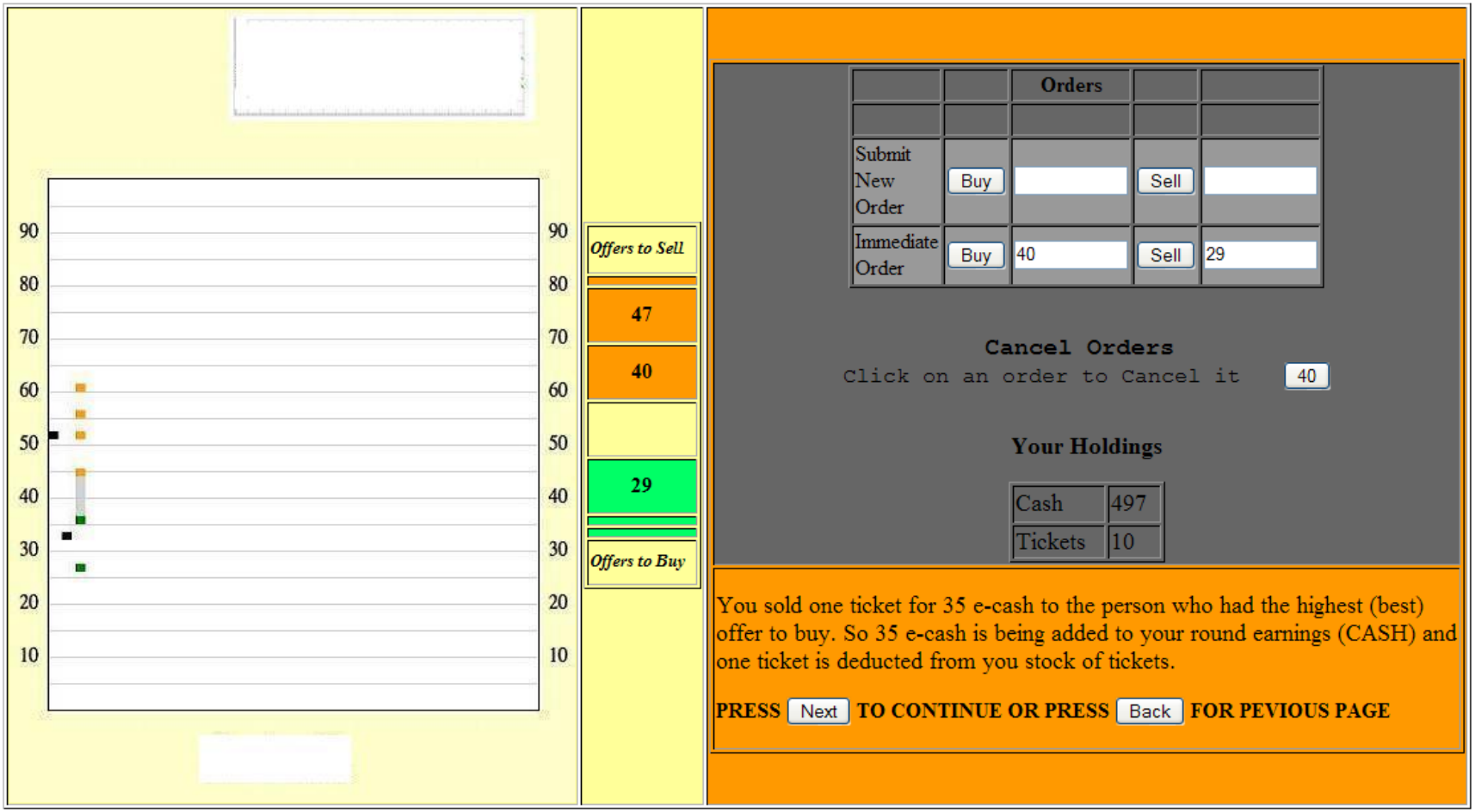
Offers to Sell
47
40
35
29
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
35
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
462
Tickets
11
You can ACCEPT the (best) highest offer to buy by clicking at "SELL" under Immediate Order section. In this case a trade will be executed where you sell the ticket at the best bid price (highest bid price).
Go ahead and and click the sell button under immediate order to sell a ticket for 35.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Offers to Sell
47
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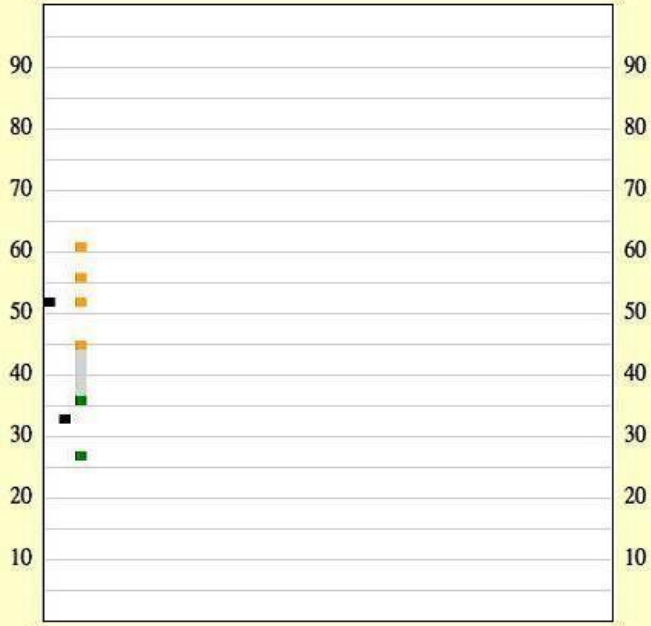
29
Offers to Buy
Orders
Submit New Order
Buy
Sell
Immediate Order
Buy
40
Sell
29
Cancel Orders
Click on an order to Cancel it
40
Your Holdings
Cash
497
Tickets
10
You sold one ticket for 35 e-cash to the person who had the highest (best) offer to buy. So 35 e-cash is being added to your round earnings (CASH) and one ticket is deducted from you stock of tickets.
PRESS Next TO CONTINUE OR PRESS Back FOR PEVIOUS PAGE



Offers to Sell

47

40

29

Offers to Buy

The Graph to the left shows visually all the offers to sell and offerst to buy and the contracts made.

The Graph shows:

a. All offers to sell (orange dots) and all offers to buy (green dots) for the current round

b. the spread between the lowest offer to sell and highest offer to buy. When there is a spread, that means that traders selling and buying the ticket do not agree on a common price, and no transaction occurs until:

c. transaction points (black dots). For example, before you sold the ticket for 35. This is a transaction and it will show as black dot on the graph, while the trade continues for the rest of the offers.

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Summary

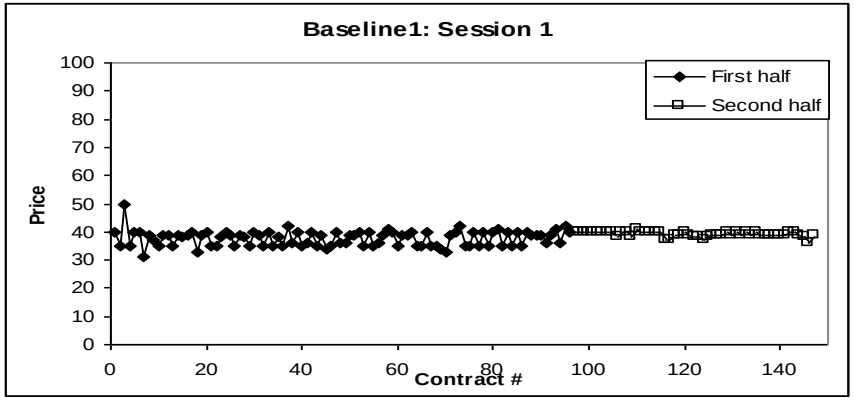
1. You will begin the experiment with some cash and some units of tickets.

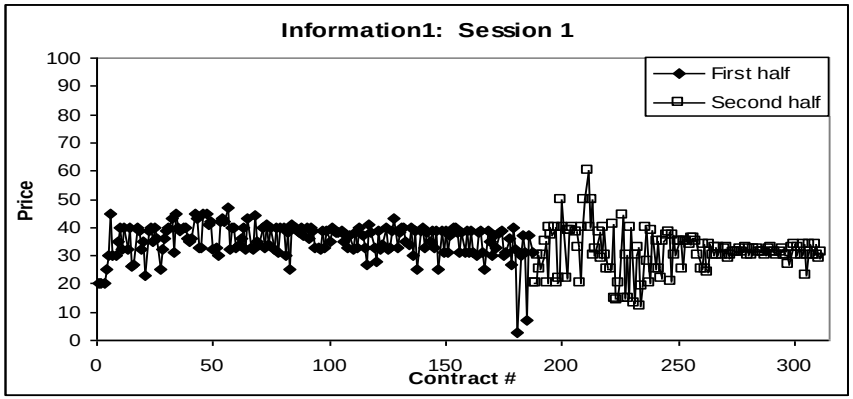
2. Each ticket generates a dividend of either 10 or 100 at the end of the trading period. The likelihood of each outcome will be given to you.

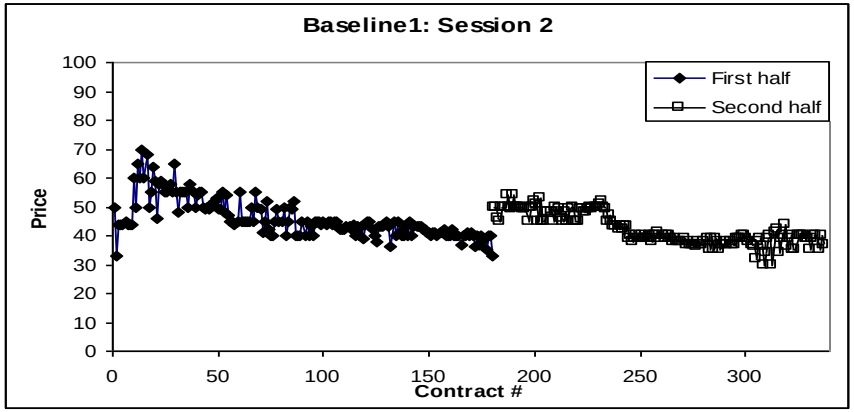
3. You can submit Bids to Buy a ticket and Offers to Sell a ticket.

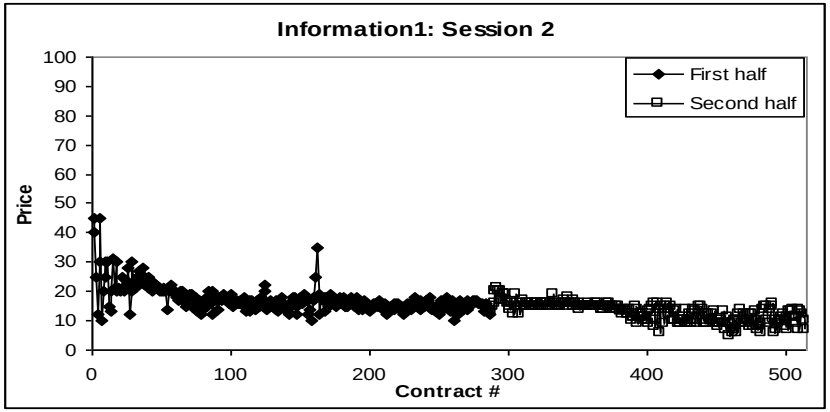
4. The experiment will last for 1 period. At the end of the period, there will be a dividend. Tickets expire after the final period and have no other value to you.

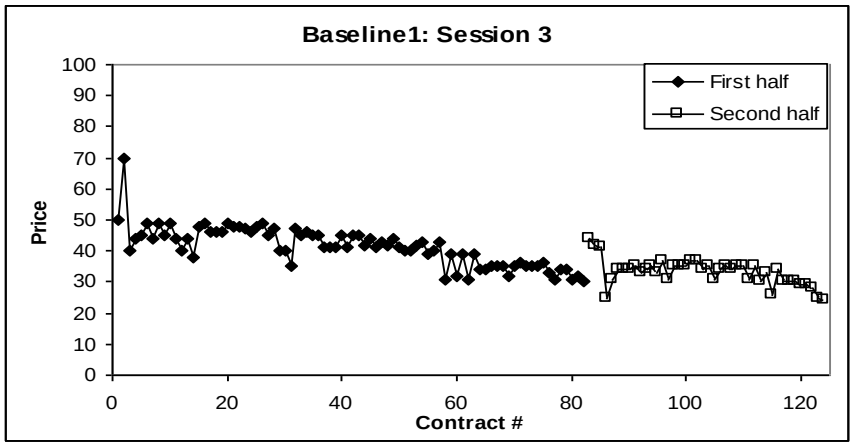
Appendix B: Time Series of Contract Prices per Session

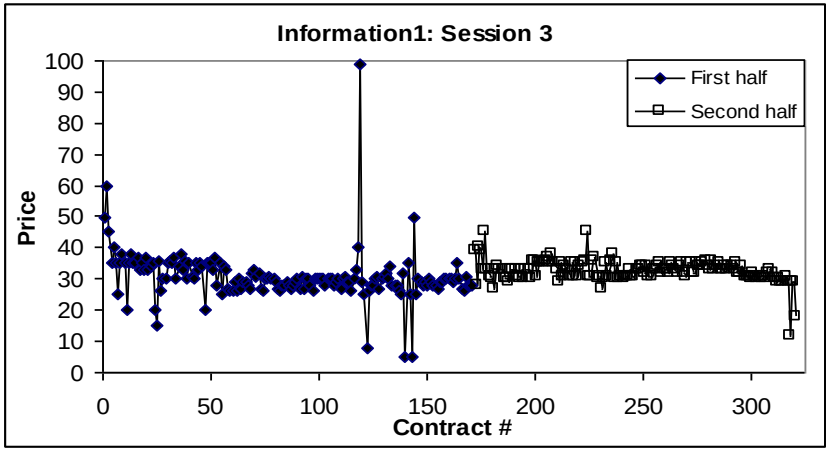


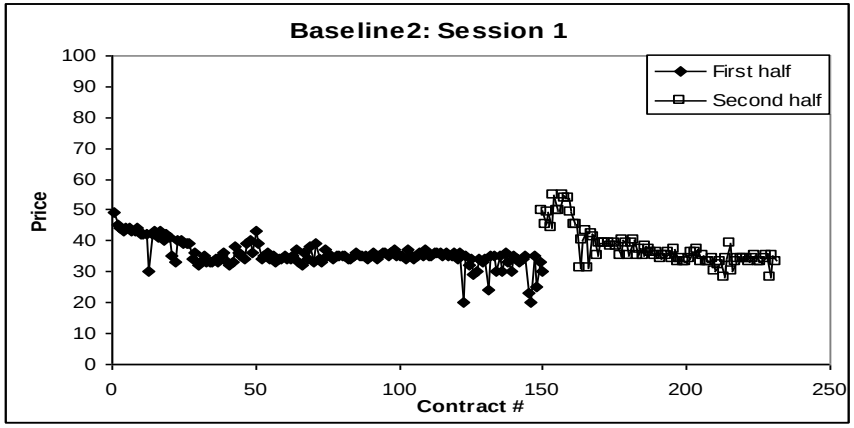


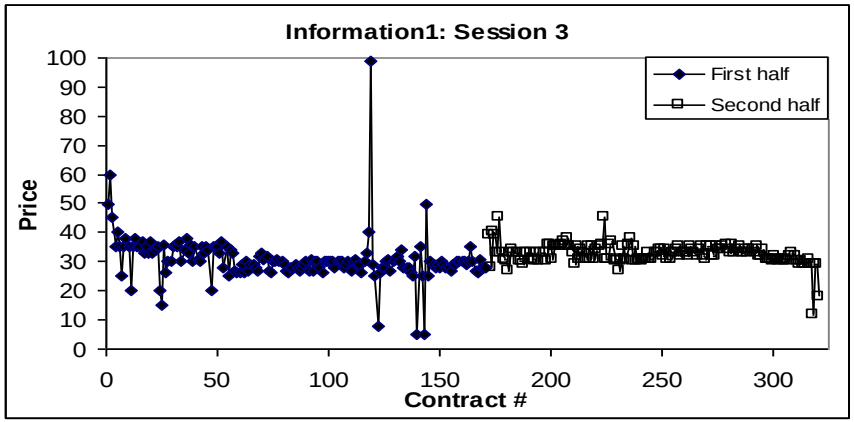


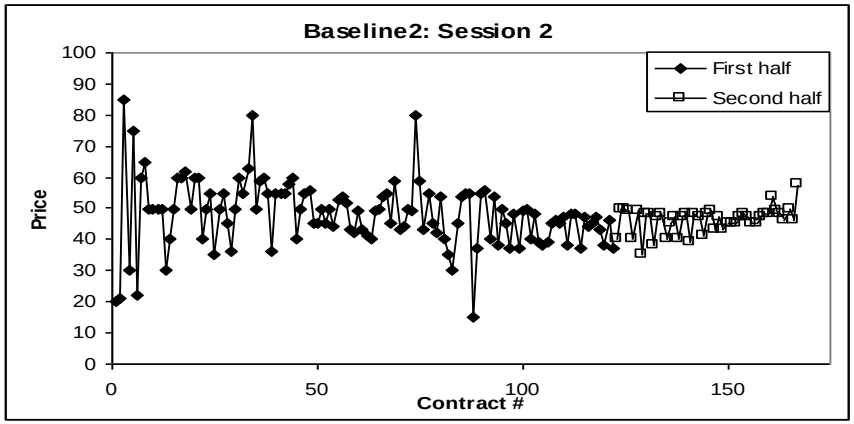


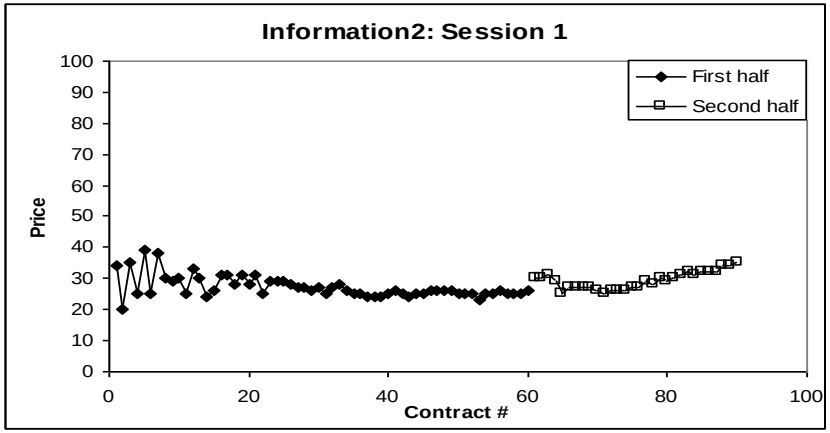





Baseline2: Session 1
First half
Second half
Price
Contract #


Information1: Session 3
First half
Second half
Price
Contract #


Baseline2: Session 2
First half
Second half
Price
Contract #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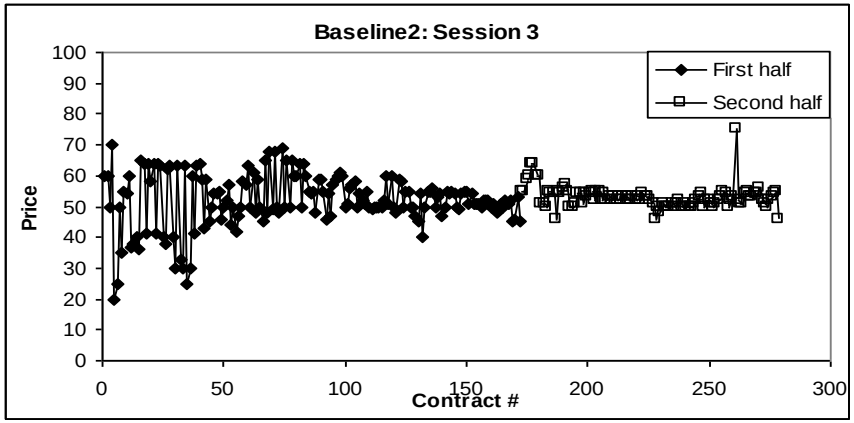
First half
Second half
Price
Contract #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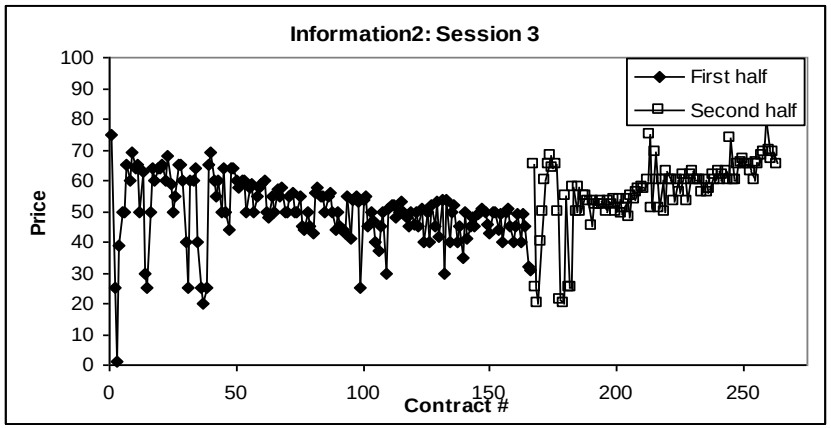
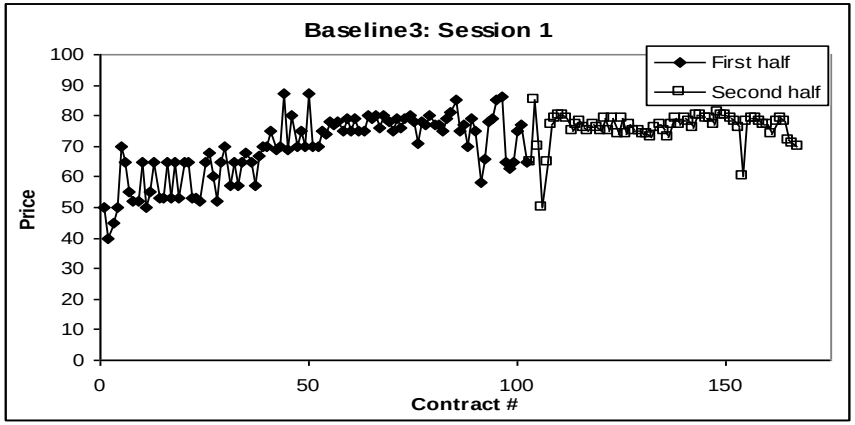
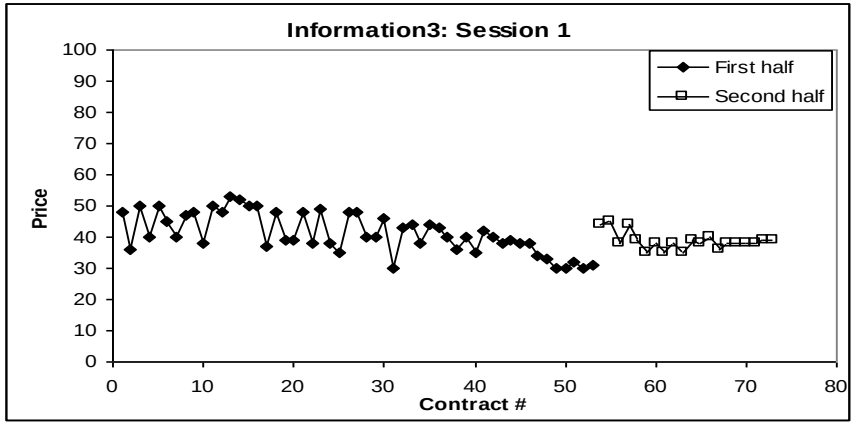
First half
Second half
Price
Contract #


Information2: Session 3
First half
Second half
Price
Contract #


Baseline3: Session 1
First half
Second half
Price
Contract #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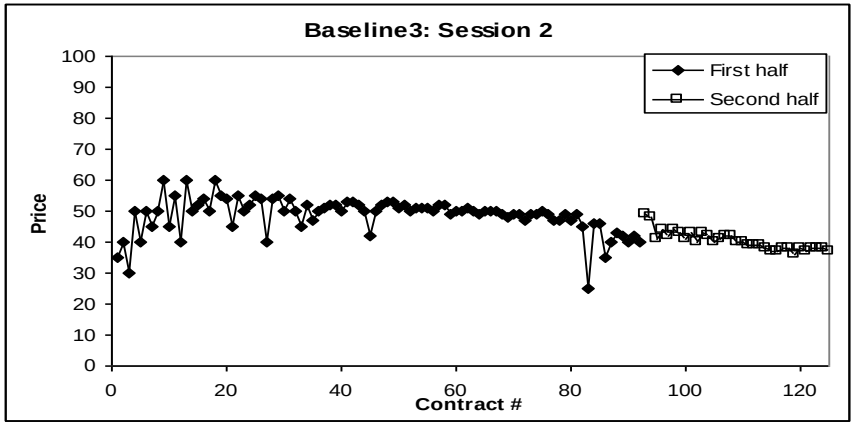
Second half
Price
Contract #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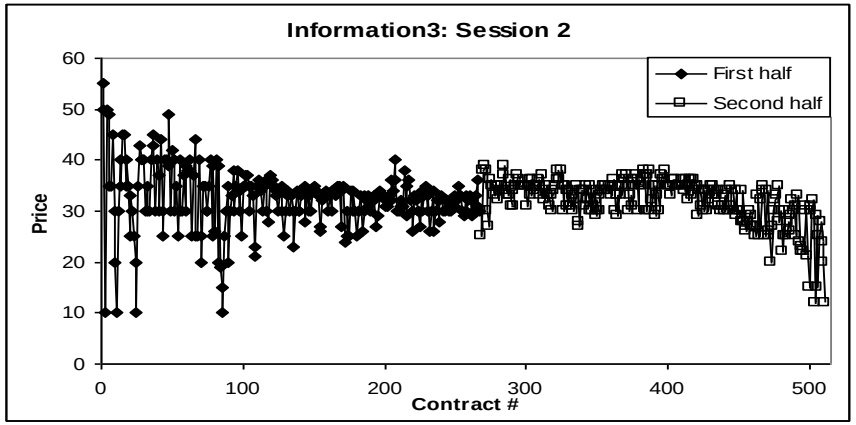
Price
Contract #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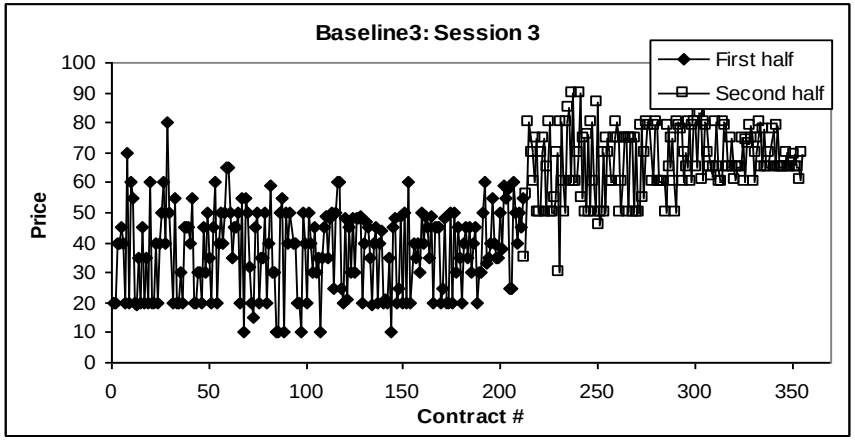
Second half
Price
Contract #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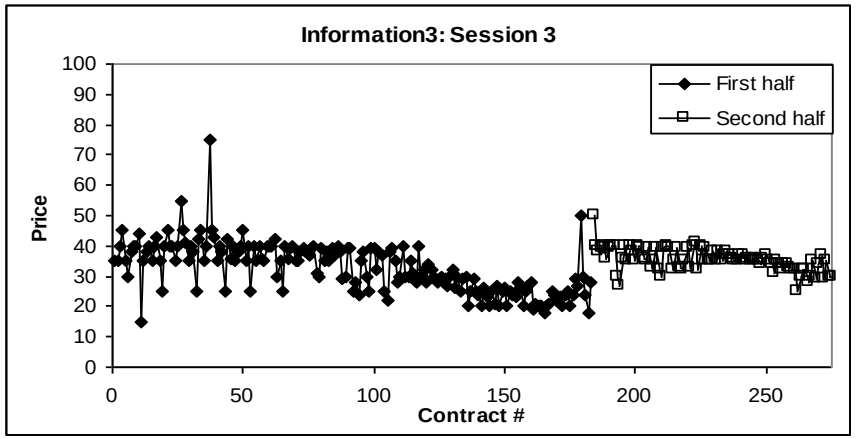
First half
Second half
Price
Contract #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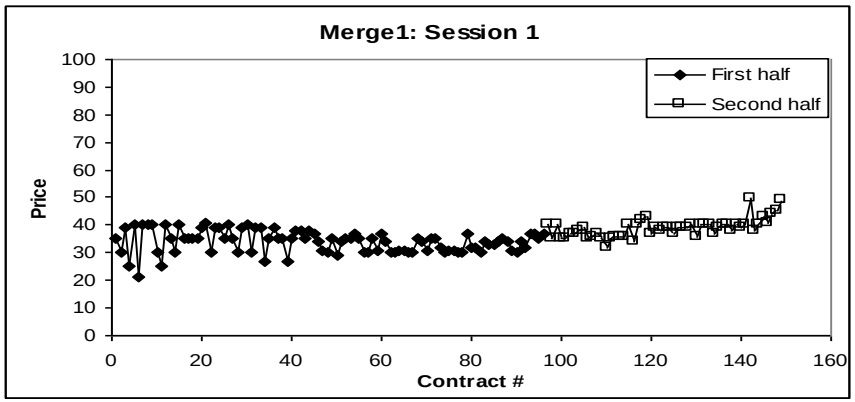
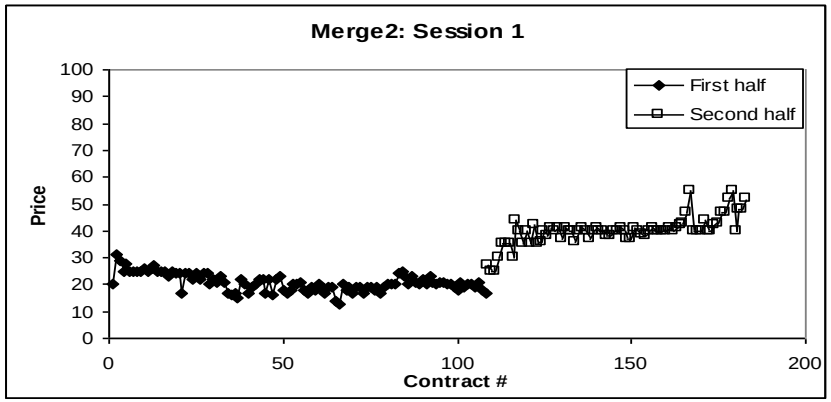
First half
Second half
Price
Contract #


Merge1: Session 1
First half
Second half
Price
Contract #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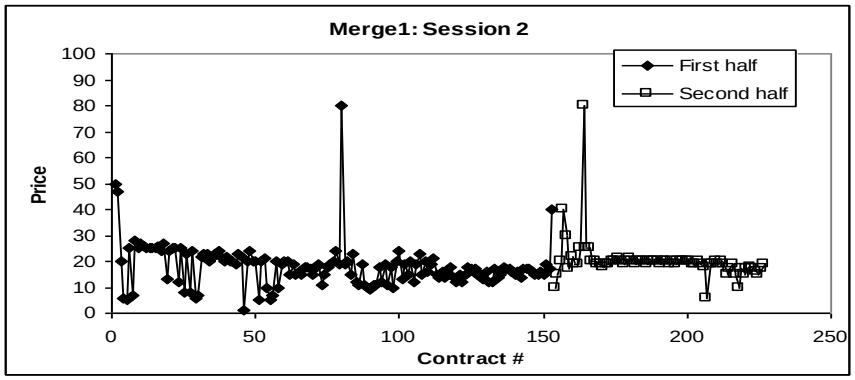
Second half
Price
Contract #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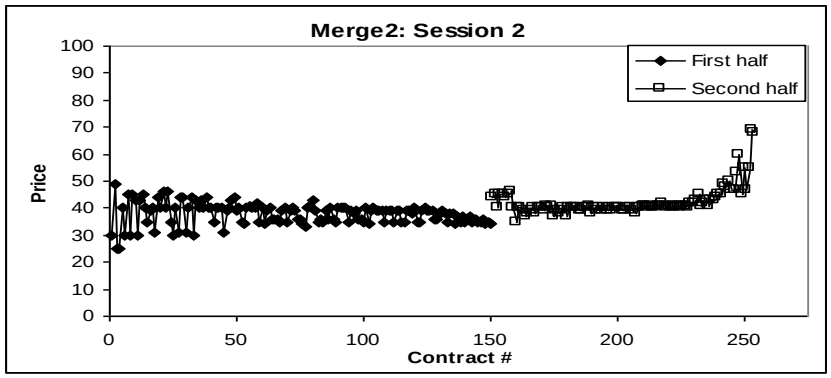
Second half
Price
Contract #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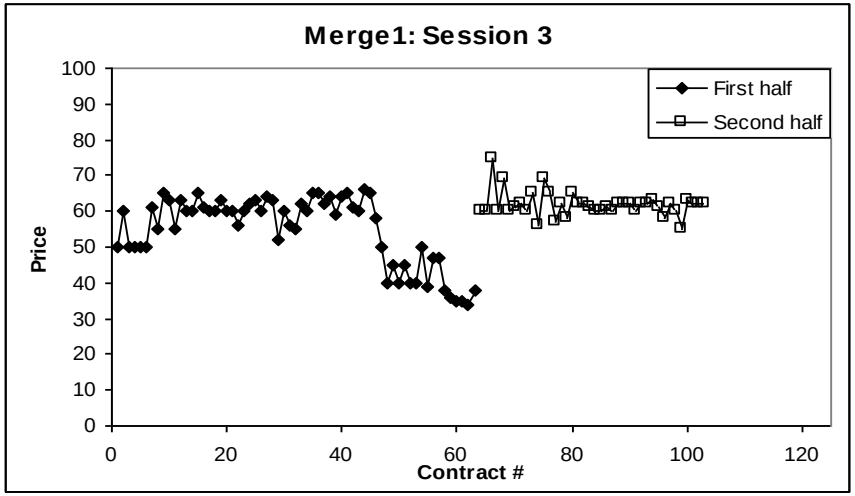
Second half
Price
Contract #


Merge1: Session 3
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Second half
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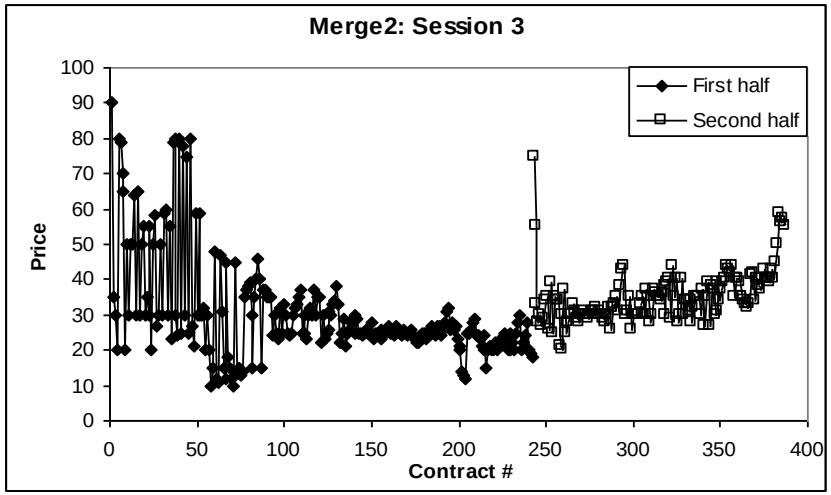
Merge2: Session 3
First half
Second half
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Contract #
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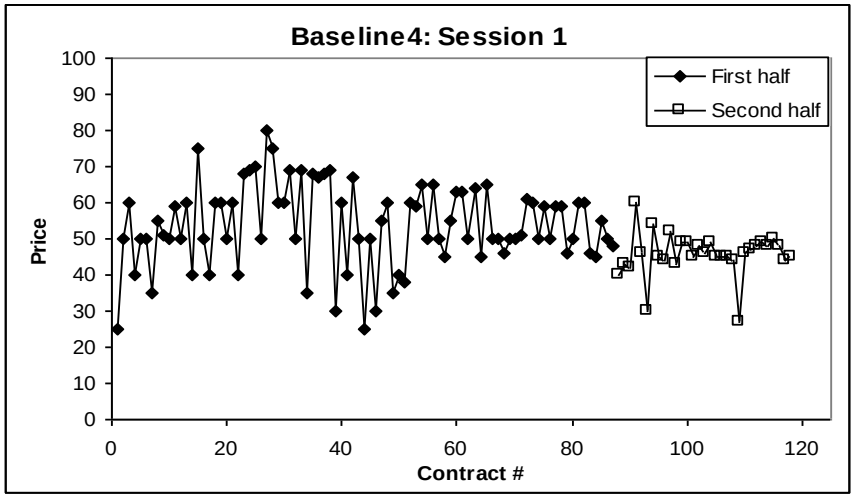
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First half
Second half
Price
Contract #
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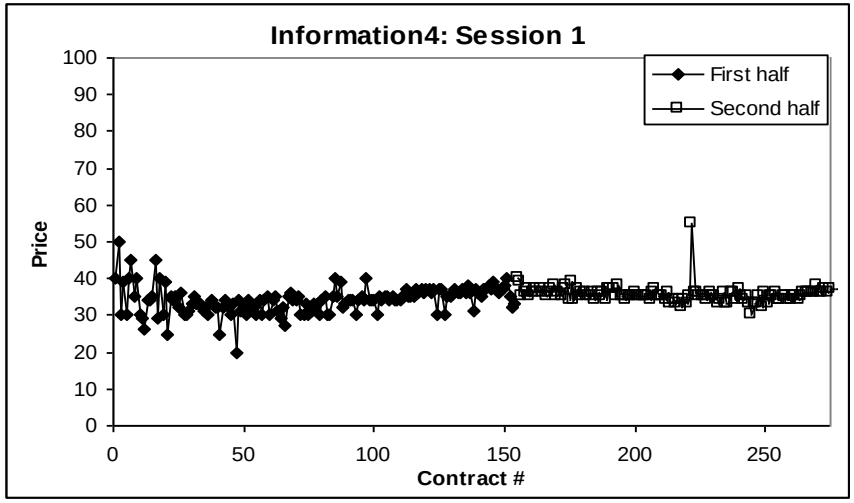
80
100
120


Information4: Session 1
First half
Second half
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Contract #
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200
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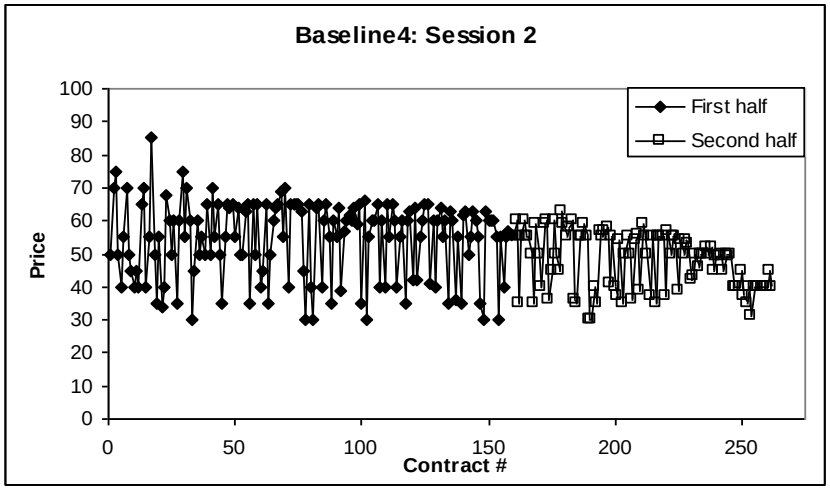
Baseline4: Session 2
First half
Second half
Price
Contract #
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80
90
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50
100
150
200
250

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