Bubbles and Experience: An Experiment

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Abstract: We investigate the occurrence of bubble-crash pricing patterns in laboratory financial markets with a mixture of experienced and inexperienced traders. We find that even with a minority of experienced traders, bubbles are substantially abated.

The main text of this working paper comprises the article "Bubbles and Experience: An Experiment," which was accepted for publication in the *AER* in 2005. The appendix contains a lot of complementary material.

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History contains many colorful examples where speculative trade in some commodity or financial asset generated a phase of rapidly increasing prices, followed by a sudden collapse (see e.g. Edward Chancellor, 1999, or Charles Kindleberger, 2001). One famous case cited by many economists (see Peter Garber, 2000, pp. 127-31 for

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references) is the Dutch "tulipmania" of the 1630s. The prices of certain tulip bulbs reached peaks in excess of several times a normal person's yearly income, and then suddenly lost almost all value in early 1637 (see Mike Dash, 1999). In more recent times, we have the development of the NASDAQ share index up until March 2000, and the subsequent price fall in that market.

Can such pricing developments be understood in terms of market fundamentals (changes in expected values of future dividends, say), or are they 'bubbles' indicative of systematic deviations from fundamental pricing? The outlook varies among scholars,[1] but it is hard to determine the truth because fundamental values are usually not observable. In this connection experiments may be useful. In laboratory markets, fundamental values may be induced and compared to actual prices. One may hope to get insights about the 'real' world by analogy. In this vein, starting with a classic contribution by Vernon L. Smith, Gerry L. Suchanek & Arlington W. Williams (1988), laboratory experiments have shown (*inter alia*) that bubbles tend to occur with inexperienced traders and not to occur with experienced traders which have participated many times in the same type of market.[2]

It is not quite clear which result applies, however, because in the non-laboratory world markets include *both* experienced and inexperienced traders. There is perhaps reason to think that most trading reflects decisions of experienced traders, but

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1 Believers in the latter perspective often invoke terms suggestive of folly or hysteria, like "mania", "panic", or (Alan Greenspan's) "irrational exuberance", as in the titles of Kindleberger's (2001) and Robert Shiller's (2000) books on the topic. The opposing fundamental view is advocated *e.g.* by Garber (1989, 2000).

2 See Ronald R. King, Smith, Williams & Mark Van Boening (1993), Steven Peterson (1993), Van Boening, Williams & Shawn LaMaster (1993), David P. Porter & Smith (1995), Eric O.N. Fisher & Frank S. Kelly (2000), Vivian Lei, Charles N. Noussair & Charles R. Plott (2001), Ernan Haruvy & Noussair (2002), and Noussair & Steven Tucker (2003). Van Boening *et al*, in particular, focus on the impact of experience.

conceivably there are enough inexperienced traders to sustain bubbles. Indeed, an informal survey, which we ran, indicates that most experimental economists think that a small fraction of inexperienced traders is sufficient to create bubbles, at least in the laboratory.[3]

This paper reports results from laboratory financial markets with a mixture of experienced and inexperienced traders.[4] We find that even with as small a fraction of experienced traders as ⅓, bubbles are eliminated, or at least substantially abated. Since experienced traders in the real world probably have a good deal more experience than these experimental subjects, and since they probably account for a large fraction of trade rather than a small fraction, these results cast doubt on the plausibility of the hypothesis that financial market bubbles reflect the choices of inexperienced traders.

Sections I describes our design, Section II reports results, Section III concludes.

I. Design

Following Smith *et al* (1988), we consider markets in which assets generating stochastic dividend streams are bought and sold. An asset's life-span is ten periods. In each period it pays a dividend of 0 or 20 US cents, with equal probability. Trade takes

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[3] At the 2002 meeting of the *Economic Science Association* in Tucson, Arizona, we invited guesses on what would happen in a design with a mixture of experienced and inexperienced traders. The vast majority guessed that bubble-crash pricing patterns would occur with only a few inexperienced subjects.

[4] Smith *et al* (1988) and Peterson (1993) ran a few mixed-experience markets, but the issue of heterogeneity of experience levels was neither the main focus nor systematically explored. King *et al* (1993) performed a related test, but instead of using a mixed-experience population they let some "insiders" read Smith *et al* (1988) before the experiment. Bubbles remained, except in a market that allowed for short-selling.

place in each period, before dividends are determined. The dividend process coupled with a backward inductive argument defines time-dependent theoretical, or 'fundamental', asset values. With k periods remaining the fundamental value is $k \times 10$ cents.[5] Our main interest lies in comparing actual pricing in the lab to these fundamental values, controlling for the experience levels of the traders.

We used the double auction environment of the z-Tree software.[6] The subjects were undergraduate students with no previous experience in any similar experiment. Each market involved six traders, who could both buy and sell assets, and lasted for ten distinct two-minute trading periods. Before a market opened half of the traders each started with a cash endowment of 200 cents and six assets, while each of the other traders started with 600 cents and 2 assets.

A session involved four consecutive markets. In the following, we shall talk in terms of four different rounds. Note the distinction between *rounds* and *periods*; a round (being a market) consists of ten periods. Rounds 1-3 retain the same six-subject groupings so that these subjects gain experience over these rounds. In the fourth round, we created markets in which the interacting traders had different experience levels. We had two treatments. In the fourth round, depending on treatment, two or four experienced subjects that had participated in the first three rounds were randomly selected, removed,

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5 The expected dividend in each period is 10 cents (= ½ × 0 cents + ½ × 20 cents), so, assuming risk-neutrality, in the last period, the fundamental value is 10 cents. If traders anticipate that this will be the trading price in the last period, then with two periods remaining the price should be 20 cents (2 periods × 10 cents per period), etc.

6 Double auction markets mimic the key features of stock exchange markets. Since the pioneering work of Smith (1962), they are known to possess extraordinarily competitive properties. Charles A. Holt (1995; especially sections V.D and VII.B) surveys the experimental double auction literature. Urs Fischbacher (2003) describes the Z-tree.

and replaced by the same number of inexperienced subjects.[7] We ran ten sessions, five of each treatment.

At the end of the experiment participants were privately paid, in cash, the amount of their final cash holdings from each round in addition to the show-up fee of $5. The average expected earnings for a subject participating in all of the four rounds was $37, including the show-up fee.

II. Results

Space constraints force us to present only the most central results. We find that markets with ⅔ experienced traders exhibit very similar patterns of behavior as markets with ⅓ experienced traders. (Statistical support for this claim is reported in the last row of Table 2 below; the hypothesis that round 4 behavior is similar in the two treatments cannot be rejected.) In this article we have therefore elected to pool the data from all sessions, and to refer to fourth round trading as 'mixed-experience markets'.[8]

Here we focus primarily on comparing *pricing* in rounds 1 and 4. We are interested in whether mixed-experience markets behave like inexperienced markets. Does the entry, in round 4, of inexperienced traders cause the pattern of pricing to resemble a first round

[7] Some more details: At the start of each session, we read through the instructions for all subjects, and then let them play one two-minute practice period. The subjects were then randomly assigned to a computer or to a waiting room (two or four of them, depending on treatment). The subjects who went to the waiting room would participate only in the fourth round (as replacement traders). These subjects were paid $10 to complete as much as possible of a crossword puzzle, without communicating with other subjects. In the fourth round, equal numbers of subjects with each initial endowment (200 cents/6 assets *or* 600 cents/2 assets) were replaced.

[8] We have created a working paper of this paper (Dufwenberg *et al*, 2005) with experimental instructions and extended analysis in an appendix. This appendix is also available on the *AER*'s permanent website.

market? In particular, do bubble-crash phenomena 'return'? The null hypothesis is that rounds 1 and 4 are similar; the alternative hypothesis is that prices in round 4 are closer to fundamentals or the magnitude of bubbles is smaller.

If the alternative hypothesis is relevant, we can gain some further insight into *how* fundamental the fourth round mixed experience market is by comparing it to the third round market consisting solely of traders with considerable experience. Previous research has indicated that if a market is thrice repeated, this is sufficient for bubbles to virtually vanish. Our experienced traders start round 4 with the corresponding experience level.

Figure 1 conveys an intuitive account of the central tendencies in the data. It graphs overall mean prices and fundamental values, by period. Through rounds 1 through 3, as the traders gain experience, the deviation of the mean prices from the fundamental values decreases. No bubble seems to resurface in round 4; there is little difference between pricing in rounds 3 and 4.

[FIGURE 1 about here]

This impression is confirmed by statistical analysis. The appropriate statistical tool for our significance testing is the permutation test for paired replicates. This is a nonparametric statistical test used for comparisons in dependent two-sample cases (see, for example, Sidney Siegel & N. John Castellan, Jr. (1988) for a detailed description). Recall that we have data from ten sessions. We take a somewhat conservative statistical approach and count each session as one observation.

We perform our statistical tests using four different measures of the deviation between actual prices and fundamental values:[9]

- The *Haessel-R^2* (Walter Haessel, 1978) measures goodness-of-fit between observed (mean prices) and fundamental values. It is appropriate since the fundamental values are exogenously given.[10] Haessel-R^2 tends to 1 as trading prices tend to fundamental values.
- The *normalized absolute price deviation* is the sum, over all transactions, of the absolute deviations of prices from the fundamental value, divided by the total number of shares outstanding (=24, in each of our sessions).
- The *normalized average price deviation* is similar to the absolute price deviation but sums up the absolute deviation between mean price and fundamental value for each of the ten periods.
- The *price amplitude* is a measure defined as follows: Consider, for each period t=1, 2,…,10, the difference between mean price and fundamental value in that period. Call this the t-diff. The price amplitude of a round is the difference between the highest and the lowest t-diffs of that round, divided by the initial fundamental value (=100).

Table 1 presents the relevant measures, by round and session (columns 1-5 [6-10] come from the sessions with ⅔ [⅓] experienced traders), and Table 2 reports averages

9 These measures have been used and developed by previous authors, *e.g.* King et al (1993), Van Boening et al (1993), Porter & Smith (1995), and Noussair & Tucker (2003).

10 The exogeneity is due to backward induction on expected dividends. By contrast, the usual R^2 measure considers goodness-of-fit between a set of data points and a regression line *endogenously* generated from those points.

across all sessions as well as the results of the associated permutation tests for paired replicates.

[Tables 1 and 2 about here]

Tables 1 and 2 again indicate the central tendencies of the data: increasing goodness-of-fit, and decreasing price deviations and amplitude. A comparison of rounds 1 and 4 reveals a number of significant differences (see third last row of Table 2). We conclude that the presence of experienced players in the market greatly reduces bubble-crash behavior. A comparison of rounds 3 and 4, by contrast, reveals no statistically significant differences between the Haessel-R^2, the normalized average price deviation, and the amplitude (see second-to-last row of Table 2). We conclude that the introduction of inexperienced subjects into the market does not have a significant effect on pricing behavior on average.

Although the pricing in mixed-experience markets resembles the pricing in markets with experienced traders, one must not conclude that these markets are the same in every other dimension. In closing this section we mention some additional results, on turnover, earnings, and market openings, that may bear witness to some subtle differences between mixed-experience markets and markets with experienced traders.[11]

Table 2 documents a marginally significant difference in normalized absolute price deviations (p=.061). This result may be related to an observation we can make regarding *turnover*, the total number of transactions divided by the total stock of the asset traded.

[11] For more details about these results, and additional results concerning the predictive power of excess bids on average prices and the dynamics between rounds, see the appendix of Dufwenberg *et al* (2005).

Our data shows a marginally significant increase in turnover between rounds 3 and 4 (p=.079), suggesting that the level of market activity may increase in mixed-experience markets. Experienced and inexperienced traders are contributing similarly to this increase in turnover. The normalized absolute price deviation sums up all the deviations from all the transactions and tends to generate a higher deviation if turnover is high and vice verse. The normalized average price deviation, by contrast, controls for the transaction volume, and with this measure the significant p-value vanishes.

Another example of the impact of mixed-experience trading concerns *market openings*. Who takes the initiative in the mixed-experience markets? That is, who is first to enter the market and make a bid or an ask (not necessary implying a trade)? The experimental software allows us to observe this, as these 'market openings' are made visible on the screen for all traders. No inexperienced trader was ever the first to enter in period 1 (of round 4), in any of the ten sessions, and only once an inexperienced trader was the second trader to enter this way.

We have a final intriguing result regarding *earnings*. Although pricing seems fairly fundamental, the fit is not perfect and one may wonder who makes more money in the market. Do the experienced traders somehow manage to take advantage of the inexperienced ones? That is indeed the case in our data. The average expected earning in each round is \$8 by design (the realized earnings may of course deviate from \$8, depending on the realizations of the dividends). In the experiment, however, 20 out of 30

experienced traders made more than $8 while 21 out of 30 inexperienced traders made less than $8. This difference is significant.[12]

III. Concluding Remarks

Our results show that bubble-crash pricing patterns are not very salient in mixed-experience laboratory financial markets. The ultimate interest of this result depends on its relevance for understanding non-laboratory markets. A word of caution is in order, as laboratory markets are not the same as other markets. Nevertheless, our results may somewhat shift the burden of proof between those who believe in the madness of the market and the market fundamentalists. Our results speak in favor of the latter position.

In retrospect, the following perspective seems reasonable to us: The history of finance contains many reputed bubble-crash stories, but it is actually not full of them all the time. For example, judging by price-earnings ratios, the U.S. stock market of the twentieth century contains but few cases, spearheaded by the crashes of 1929, 1987, and 2000.[13] Perhaps markets are best understood as being in a fundamental mood, most of the time. It may be that only every now and then the majority of traders get caught up in a speculative bubble. Our experimental findings do not contradict this view. In the laboratory one can run many sessions, but it is difficult to get so many observations that

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[12] It is interesting to compare this result to recent findings by Robert L. Slonim (2002), who studies the nature of mixed-experience interaction in so-called "beauty contest games". He finds that inexperienced persons do not condition their behavior on their co-players' experience levels, but learn to do so as they gain experience. In Slonim's design, experienced players have higher earnings than inexperienced ones. His findings rhyme well with ours.

[13] See Shiller (2000, ch. 1) for an account up till early 2000. What constitutes a bubble/crash is of course a definitional matter. Events in 1901 and 1966 may qualify as well. Nevertheless, five in a century is rather infrequent.

one can accurately record very unusual events. Perhaps the best way to understand our results is as suggesting that *bubbles in mixed-experience markets are rare.*

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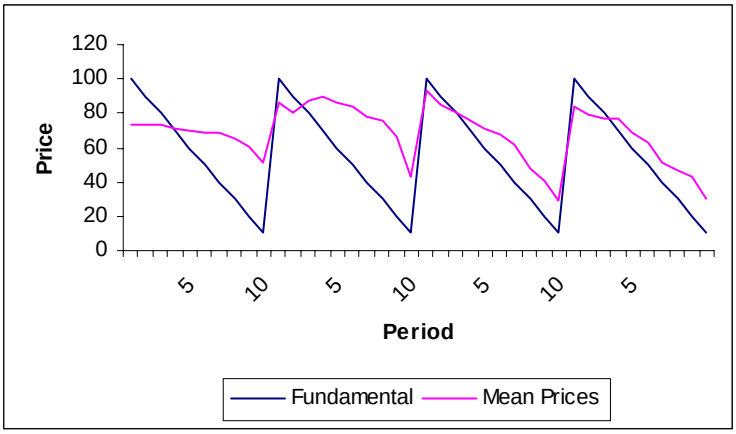


FIGURE 1. OBSERVED MEAN PRICES AND FUNDAMENTAL VALUES.

TABLE 1. VARIOUS MEASURES, BY ROUND AND SESSION. [a]

	Session									
Round	1	2	3	4	5	6	7	8	9	10
					Haessel-R^2					
1	0.014	0.082	0.822	0.268	0.582	0.895	0.834	0.065	0.002	0.112
2	0.290	0.256	0.856	0.311	0.270	0.948	0.976	0.395	0.134	0.217
3	0.239	0.806	0.903	0.772	0.541	0.986	0.969	0.296	0.123	0.773
4	0.001	0.924	0.925	0.868	0.954	0.978	0.951	0.027	0.118	0.799
					Normalized Absolute Price Deviation					
1	2.403	1.747	1.386	2.057	1.671	0.409	1.170	2.347	1.734	1.750
2	2.042	1.685	2.502	1.027	1.274	0.263	0.470	1.413	1.114	4.331
3	1.406	0.793	1.378	0.431	0.428	0.215	0.302	1.485	0.797	0.890
4	1.918	0.771	1.204	0.178	0.257	0.386	1.103	1.070	1.316	2.428
					Normalized Average Price Deviation					
1	0.116	0.177	0.111	0.174	0.124	0.048	0.118	0.115	0.106	0.095
2	0.097	0.264	0.146	0.144	0.113	0.017	0.102	0.119	0.120	0.316
3	0.084	0.190	0.100	0.072	0.084	0.032	0.060	0.111	0.122	0.067
4	0.110	0.069	0.070	0.059	0.028	0.014	0.077	0.111	0.120	0.094
					Price Amplitude					
1	0.902	1.319	0.635	0.828	1.063	0.267	0.477	1.011	0.844	0.804
2	0.885	1.079	0.462	0.742	0.933	0.249	0.439	0.903	0.833	1.450
3	0.786	0.886	0.511	0.396	0.609	0.148	0.425	0.909	0.827	0.431
4	0.890	0.522	0.444	0.497	0.223	0.174	0.313	0.851	0.912	0.648

[a] Columns headed by 1-5 [6-10] correspond to sessions with ⅔ [⅓] experienced traders in round 4

TABLE 2—AVERAGE MEASURES AND SUMMARY STATISTICS

Round (R)	Haessel- R^2	Normalized Absolute Price Deviation	Normalized Average Price Deviation	Price Amplitude
1	0.37	1.67	0.12	0.81
2	0.47	1.61	0.14	0.80
3	0.64	0.81	0.09	0.59
4	0.65	1.06	0.08	0.55
p-value R1=R4 [a]	0.004***	0.032**	0.011**	0.003***
p-value R3=R4 [b]	0.618	0.061*	0.897	0.819
p-value R4-⅔=R4-⅓ [c]	1.000	0.421	0.310	0.841

[a] Null hypothesis: R1=R4 (meaning, round 1 measure equals round 4 measure); alternative hypothesis: R1<R4 for Haessel-R^2 and R1>R4 for the other measures

[b] Null hypothesis: R3=R4; alternative hypothesis: R3>R4 for Haessel-R^2 and R3<R4 for the other measures

[c] Wilcoxon-Mann-Whitney test with null hypothesis R4-⅔=R4-⅓ (meaning, equal round 4 measure for sessions with ⅔ and ⅓ experienced traders); alternative hypothesis R4-⅔≠R4-⅓ (cf. Table 1)

* Significant at the 10-percent level; ** Significant at the 5-percent level; *** Significant at the 1-percent level

APPENDIX

The preceding text comprises the article "Bubbles and Experience: An Experiment," which was accepted for publication in the American Economic Review in 2005. Space constraints forced us to omit many details from that article. This Appendix contains complementary material.

The appendix has three parts. Part A.I contains the experimental instructions. Part A.II reports more detailed results (the data is disaggregated for the 1/3- and 2/3-experienced treatments, additional statistical tests are reported, more figures and tables are referred to, etc). Also included are avenues for further research. Part A.III reproduces figures and tables.

A.I) INSTRUCTIONS

1. General instructions

This is an experiment in the economics of market decision-making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment. The experiment will consist of a sequence of trading periods in which you will have the opportunity to buy or sell in a market. All trading will be in terms of *cents*. Please do not speak with any other participants during this experiment. The experiment will last for approximately three hours, including one hour of instructions and practice.

Market description:

At the beginning of the market half of you will have an endowment of 6 goods (called X) and 200 cents and the other half will be endowed with 2 goods (called X) and 600 cents. 6 traders will participate in the market.

The market has 10 periods. In each period, you may buy or sell units of a good called X. X can be considered an asset with a life of 10 periods, and your inventory of X carries over from one trading period to the next. Each period lasts for 2 minutes.

At the end of each trading period, each unit of X pays a dividend. The dividend will be either 0 or 20 cents, which is randomly decided by the computer with a 50 % chance of each dividend. Thus, the average dividend per period is 10 cents.

Your profits in the market will be equal to the total of the dividends that you receive on units of X in your inventory at the end of each of the market periods plus the cash you have at the end of the market. The way to calculate your earnings is described in section 3.

Experimental procedure:

The market, as described above, will be repeated four times. Before the first market starts, two (four) people in this room will be randomly selected and asked to leave the room for one hour. These people will not participate in the first three markets and they will not be doing anything connected with this experiment during these markets. In the

fourth market they will replace two (four) randomly selected persons among the six that already have participated in three markets.

2. Average Value Holding Table

You can use the table in section 4 to help you make decisions. There are 5 columns in the table. The first column, labeled Ending Period, indicates the last trading period of the market. The second column, labeled Current Period, indicates the period during which the average holding value is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the market. The fourth column, labeled Average Dividend Value Per Period, gives the average amount that the dividend will be in each period for each unit held in your inventory. The fifth column, labeled Average Holding Value Per Unit of Inventory, gives the expected total dividend for the remainder of the experiment for each unit held in your inventory for the rest of the market. That is, for each unit you hold in your inventory for the remainder of the market, you receive in expectation the amount listed in column 5. The number in column 5 is calculated by multiplying the numbers in columns 3 and 4.

Suppose for example that there are 4 periods remaining. Since the dividend paid on a unit of X has a 50% chance of being 0 and a 50% chance of being 20, the dividend is in expectation 10 per period for each unit of X. If you hold a unit of X for 4 periods, the total dividend paid on the unit over the 4 periods is in expectation $4 \times 10 = 40$.

3. Calculate Your Earnings

Your earnings in each period equal the value of the dividends you receive at the end of the period for the units of X in your inventory at the end of the period. That is,

YOUR EARNINGS FOR A PERIOD =

DIVIDEND PER UNIT × NUMBER OF UNITS IN INVENTORY AT THE END OF PERIOD.

However, when you spend money to buy units of X, the total amount of cash that you have after period 10 is reduced by the amount of the purchase. If you sell units of X, the total amount of cash you have after period 10 increases by the amount of the sale. Your total earnings for one market are the total of your earnings for periods 1-10 plus the amount of cash that you have at the end of period 10. That is

YOUR TOTAL EARNINGS IN THE MARKET =

EARNINGS FOR PERIOD 1 + EARNINGS FOR PERIOD 2 + EARNINGS FOR PERIOD 3 + EARNINGS FOR PERIOD 4 + EARNINGS FOR PERIOD 5 + EARNINGS FOR PERIOD 6 + EARNINGS FOR PERIOD 7 + EARNINGS FOR PERIOD 8 + EARNINGS FOR PERIOD 9 + EARNINGS FOR PERIOD 10 + CASH ON HAND AT THE END OF PERIOD 10.

Your profit for the entire experiment is the sum of the profits from all of the markets that you participate in. Note that you do not have to calculate your profit by yourself. The computer does all the work.

There will also be a show up fee of $5 to all participants. The two people that have to leave for one hour will receive an extra $10 each (plus the $5).

4. Average Value Holding Table

Ending Period	Current Period	Number of Holding Periods	×	Average Dividend Value Per Period	=	Average Holding Value Per Unit of Inventory
10	1	10		10		100
10	2	9		10		90
10	3	8		10		80
10	4	7		10		70
10	5	6		10		60
10	6	5		10		50
10	7	4		10		40
10	8	3		10		30
10	9	2		10		20
10	10	1		10		10

5. Information about the screen

Remaining time (sec) This shows the time remaining in the period in seconds. Each period lasts two minutes so the timer counts down from 120 seconds to 0 seconds.

Period This shows the number of the period you are in for each market. There are 10 periods in each market.

Cents The number of cents that you have.

Units of good X The number of units of good X that you have.

Buttons at the bottom of the screen

Sales ask Type the amount, in cents, that you are willing to sell a unit of good X for in the box marked "Sales ask". Then press the "Sales ask" button at the bottom of the screen to offer the unit for sale.

Purchase bid Type the amount, in cents, that you are willing to pay for a unit of good X in the box marked "Purchase bid". Then press the "Purchase bid" button at the bottom of the screen to place your bid.

Sell Press the "Sell" button if you would like to sell a unit of good X for the highlighted amount in the "Purchase bid" column.

Buy Press the "Buy" button if you would like to buy a unit of good X for the highlighted amount in the "Sales ask" column.

Columns in the middle of the screen

Sales ask column Shows all of the available "Sales asks" in descending order so that the lowest price is at the bottom.

Transaction price column Shows all of the prices at which a unit of good X has been bought or sold in the current period.

Purchase bid column Shows all of the available "Purchase bids" in ascending order so that the highest price is at the bottom.

Earnings Report

The earnings report appears at the end of each period. After seeing your earnings, press the "Continue" button to go to the next period. The next period will begin once all of you press the "Continue" button.

A.II) ADDITIONAL RESULTS

To facilitate overview, the following list presents the contents of section A.II:

A. Prices by sessions and related statistical tests

B. Pricing in the ⅔-EXPERIENCED treatment

C. Pricing in the ⅓-EXPERIENCED treatment

D. Excess bids and price changes

E. Correlations of average prices between rounds

F. Additional results [on turnover, market openings, and earnings differences]

G. Further research

All figures and tables referred to below appear in section A.III.

A. *Prices by sessions and related statistical tests*

Figure 1A plots mean trading prices and fundamental values for each session. Sessions 1-5 [6-10] correspond with the ⅔ [⅓]-EXPERIENCED treatment. The session numbers, matching those provided in Table 1, are also provided. Table 1A, which follows, provides summary values of the statistics provided in Table 1 for each round.

[Figure 1A here]

[Table 1A here]

B. *Pricing in the* ⅔-EXPERIENCED *treatment*

Our main interest is to examine differences between rounds 1 and 4, comparing how well trading prices conform to fundamental values in inexperienced and mixed-experience markets. Using Table 1A, observe that the goodness-of-fit increases in all but the first session.[14] Overall, we can reject the null hypothesis of a similar fit in the two rounds at marginal significance levels (p=0.063); a market with a two-thirds majority of

[14] In session 1, the Haessel-R^2 starts and ends very low. Prices actually *increase* across the ten periods, a pattern opposite to the fundamental. We suspect some subjects in this session did not understand the market.

experienced traders is trading closer to fundamental values than a market where every trader is inexperienced. Similarly, the normalized absolute and average price deviations, and the price amplitude, are all statistically significantly (p=0.031) lower than in the first round.

A comparison of round 4 prices to round 3 prices allows one to judge if trading in a mixed-experience market is similar to that in a market with experienced traders. Recall that the received wisdom is that bubbles virtually vanish by the third time a market is repeated. We find that the entry of the inexperienced traders in round 4 does not affect prices relative to the outcome in round 3. The null hypothesis of a similar goodness-of-fit in rounds 3 and 4 (against the alternative hypothesis of a better fit in round 3) cannot be rejected (p=0.719). With two-thirds experienced traders, prices are as close to the fundamental price as in a thrice-repeated market (*i.e.*, a market consisting solely of traders with considerable experience). Note that none of the other pricing statistics are significantly different between these rounds.

Main result in the ⅔-EXPERIENCED treatment: Bubble-crash pricing phenomena do not occur in a market containing a majority of experienced subjects.

C. *Pricing in the* ⅓-EXPERIENCED *treatment*

We next report on our second treatment where, in round 4, we mix four inexperienced with two experienced traders.

Again using Table 1A, the goodness-of-fit increases in all but the third session. Just as before, we can reject the null hypothesis of a similar fit between rounds 1 and 4 at marginal significance levels (p=0.063). A market with a minority of experienced traders is also trading closer to fundamental values than a market without experienced traders. The other measures are lower, as expected, in round 4. However, this difference is not statistically significantly for either price deviation. The price amplitude is statistically marginally lower (p=0.063).

And as for mixed-experience markets versus experienced, we again evaluate this by comparing round 4 prices to round 3 prices. We find that the entry of the inexperienced traders in round 4 does not affect prices relative to the outcome in round 3. The null

hypothesis of a similar goodness-of-fit in rounds 3 and 4 (against the alternative hypothesis of a better fit in round 3) cannot be rejected (p=0.281). The normalized average price deviation and price amplitude are not significantly different, while the difference in normalized absolute price deviation is marginally significant at the 10 percent level.

Main result in the ⅓-EXPERIENCED treatment: Bubble-crash pricing phenomena do not occur in a market containing a minority of experienced subjects.

D. Excess bids and price changes

Earlier experiments have observed a positive relationship between prices and the number of offers to buy and sell (e.g. Smith, Suchanek & Williams, 1988; Lei, Noussair & Plott, 2001). The equation used to test for this is

$$P_t - P_{t-1} = a + b(B_{t-1} - O_{t-1})$$

where P_t and P_{t-1} are the average transaction prices in period t and t-1 respectively, B_{t-1} is the total number of offers to buy, and O_{t-1} is the total number of asks to sell in period t-1. Theoretically a is –10 and b is zero since the price should not be reflected in demands in the previous period.

Table 2A presents the results from regression analyses for all rounds for each treatment.

[Insert Table 2A here]

The coefficient a is significantly different from -10 in 7 of the 10 sessions in round 1 and 6 of the 10 sessions in round 2. The coefficient b is positive in 7 of the 10 sessions in round 1. Positive b values are usually indicative of a price bubble. However, the coefficient is significantly different from zero (p-value < 0.05) in only one of these cases.

The coefficient *b* is positive in 6 of the 10 sessions in round 2, with 3 of these values significantly different from zero (*p*-value < 0.01 and *p*-value < 0.05).

Both coefficients do not essentially diverge from round 3 to 4 in either treatment. The coefficient *a* is significantly different from –10 in 4 of the 10 sessions in round 3 and 5 of the 10 sessions in round 4. These estimates are in line with former results indicating that the market price does not fully reflect fundamental values. The coefficient *b* is positive in 7 and 5 of the 10 sessions in rounds 3 and 4 respectively. It is significantly different from zero (*p*-value < 0.05) in only 1 of the 10 sessions in each of rounds 3 and 4 respectively. This suggests that changes in prices between periods do not appear to be driven by excess demand or supply conditions, which is a typical finding when bubbles are present.

E. *Correlations of Average Prices Between Rounds*

Table 3A presents correlations of average trading prices between rounds by session.

[Insert Table 3A here]

The high correlation between average prices in rounds 3 and 4 in both treatments is not surprising given our earlier findings. There is some disparity between the average correlations of rounds 1 and 4 between the treatments (-0.03 vs 0.40). Both values are considerably less than 1. Looking at results from other measures, this disparity has more to do with the seemingly somewhat random trading in round 1 rather than with differences between round 4 in each of the treatments.

F. *Additional results*

So far we have only looked at market prices, but other characteristics of the market may differ between rounds. In this section we report results regarding turnover, market openings, and earnings differences.

Turnover

Our findings on pricing suggest that there is no considerable difference between mixed-experience markets (round 4) and markets where all of the traders are experienced (round 3). However, we find significant differences between the mixed-experience markets and markets where all of the traders are inexperienced (round 1). Do analogous results carry over to turnover? Turnover is the volume of trades divided by the total number of outstanding assets, i.e. the total number of trades divided by 24 for each round. Table 4A gives details for each of our ten sessions.

[Insert Table 4A here]

In both treatments the turnover falls as subjects gain experience in rounds 1 through 3. However, with the introduction of inexperienced players in round 4 the turnover increases above the levels in round 3. The marginally significant differences (*p*-values of 0.063 and 0.094 for the individual treatments and 0.079 when the treatments are pooled) in turnover suggest that the level of market activity does increase.

> **Result on Turnover:** The turnover in mixed-experience markets is marginally significantly greater than in markets where all traders are relatively experienced.

This result made us curious. Is it the experienced or the inexperienced traders who are responsible for the increased trade in round 4? Table 5A reports the number of trades between traders by experience level. For example, in session 1 of the 2/3 experienced treatment, there are 4 trades between inexperienced subjects. The data reported in this table shows that both categories have similar trade volumes. It seems like the experienced traders tried to exploit the inexperienced traders, and that in this process the trading volume increased.[15]

[Insert Table 5A here]

15 This motivation was mentioned by many subjects during the debriefing after the experiment.

Market Openings

Who takes the initiative in the mixed-experience markets? That is, who is first to enter the market and propose a trade? To answer this question we look into the data in round 4, where traders have mixed experience, for all of the sessions. In the beginning of round 4 of each session, *i.e.* the first seconds of period 1, we observe who first offers a bid or makes an ask (not necessary implying a trade). These 'market openings' are made visible on the screen for all traders.

It turns out that *no* inexperienced trader was ever the first to enter in period 1, in any of the ten sessions. In the ⅔-EXPERIENCED we did not observe any inexperienced trader as second enterer either.

In the ⅓-EXPERIENCED treatment two of the six traders are experienced. Assuming random entering, the probability that all traders first entering period 1 are experienced in all of the five sessions of this treatment is $(2/6)^5$, which is less than 0.005. The corresponding probability that all first *and* second traders are experienced is 0.017 ($\approx(4/6)^{10}$) in the ⅔-EXPERIENCED treatment. We conclude that random entering can be rejected in both treatments.

Result on Market Openings: Experienced traders always open the market.

Earnings Differences

Do differences in experience generate differences in earnings? One may suspect that in a mixed-experience market the experienced traders somehow manage to take advantage of the inexperienced traders that just entered. We begin our test of this conjecture by summarizing the average fourth round earnings in Table 6A.

[Insert Table 6A here]

The average expected earning per round is \$8 (by design), but the realized earnings may deviate from \$8 depending on dividend realizations. As seen in Table 6A, on average experienced traders earned more, and inexperienced traders less, than \$8. In the ⅔-

EXPERIENCED treatment, 3 out of 10 inexperienced traders and 13 out of 20 experienced traders earned above $8. In the ⅓-EXPERIENCED treatment, 6 out of 20 inexperienced traders vs 7 out of 10 experienced traders earned above the expected average.[16]

Statistical tests confirm that this picture is systematic. We use unpaired *t*-tests to examine the hypothesis that mean earnings are the same for each trader category, and reject the hypothesis for each treatment (p=0.048 in the ⅔-EXPERIENCED treatment; p=0.075 in the ⅓-EXPERIENCED treatment).

Tables 7A and 8A presents earnings differences for the two treatments in more detail.

[Insert Table 7A here]

[Insert Table 8A here]

In the ⅔-EXPERIENCED treatment we have a total of 10 inexperienced subjects and 20 experienced subjects participating in the 4th round. The inexperienced (experienced) subjects start with a total of 40 assets (80 assets) and $40 ($80). The initial conditions are reversed in the ⅓-EXPERIENCED treatment. The driving factor in the earnings differences can be seen in the net trading columns. Note that the inexperienced subjects trade for net losses in the majority of the periods in both treatments. Furthermore, much of this loss occurs due to paying higher average prices while selling for lower average prices during the early rounds.

Result on Earnings: Experienced traders earn more, on average, than inexperienced traders.

G. Further Research

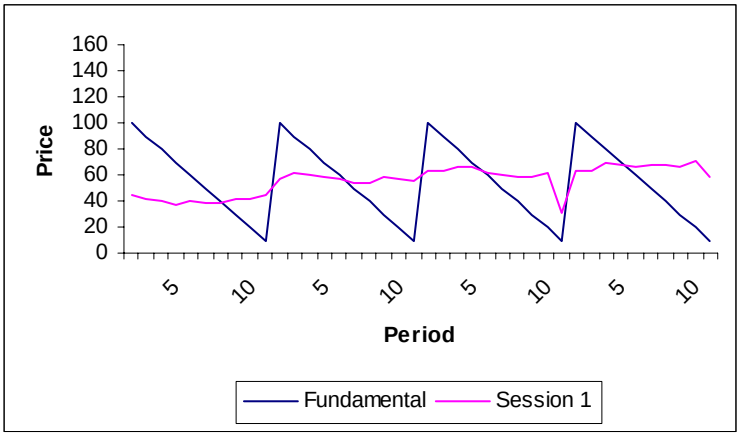
Out of the possible suggestions for future research, let us mention three: First, inexperience may relate to other things than market participation. What is the effect, for example, of changing the stochastic dividend structure after a few rounds? Second, most

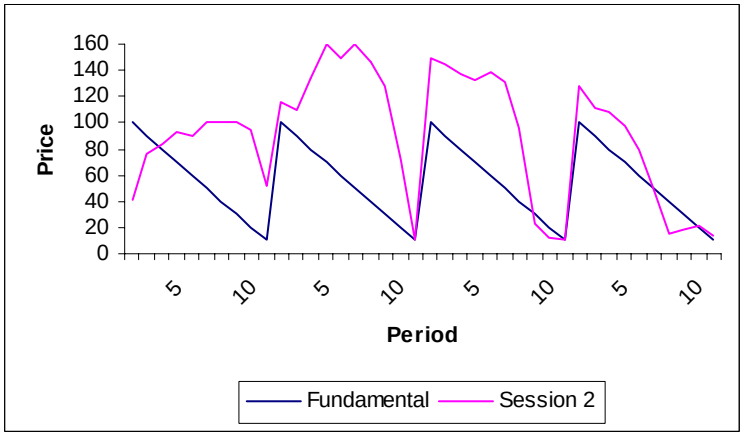
16 An additional inexperienced subject earned exactly $8.00 in the ⅓-EXPERIENCED treatment.

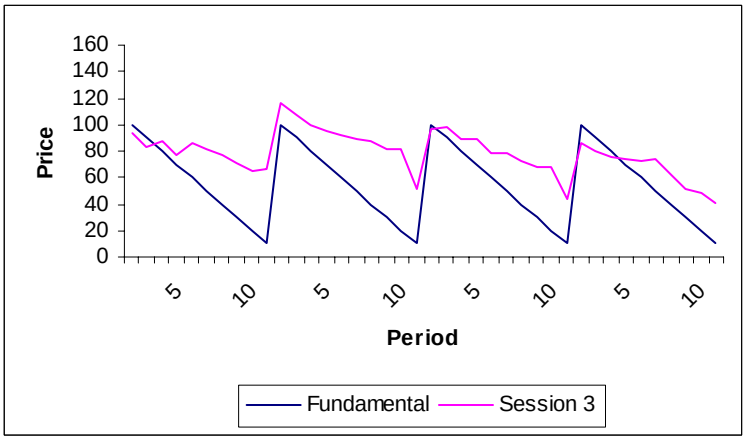
markets outside the laboratory do not have an exogenously given duration. Examining markets with a stochastically determined last period may be interesting. Third, in our design all participants knew when and how many inexperienced participants entered the markets. It may be realistic to consider alternative designs where this information is not given.

A.III) FIGURES & TABLES

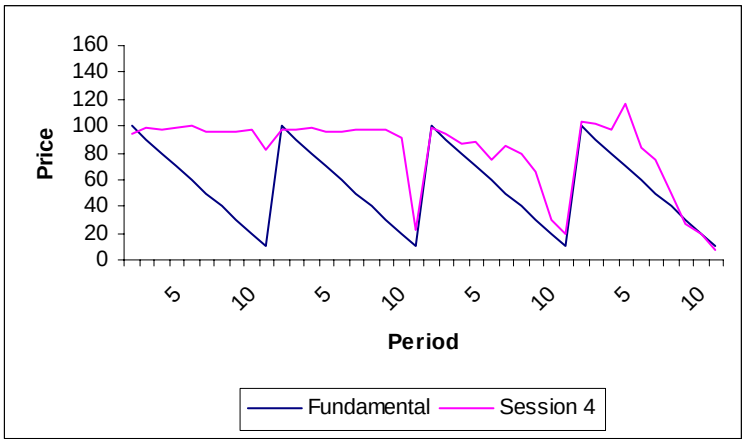
FIGURE 1A. OBSERVED MEAN PRICES RELATIVE TO FUNDAMENTAL VALUE.

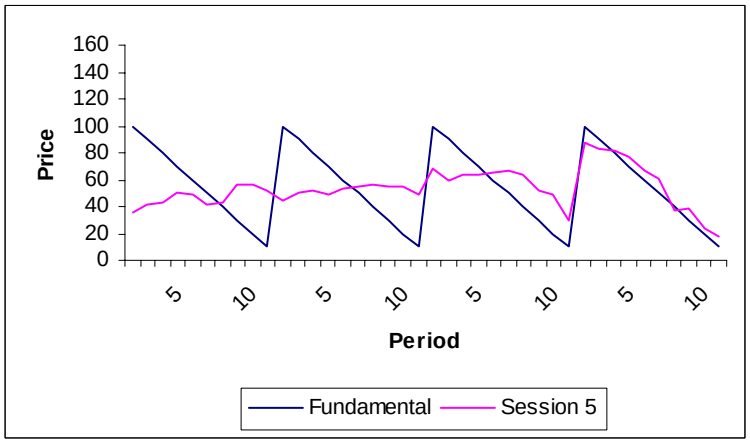


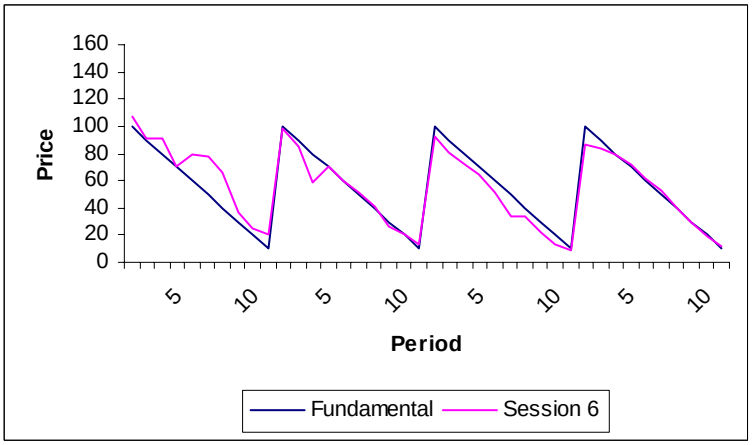




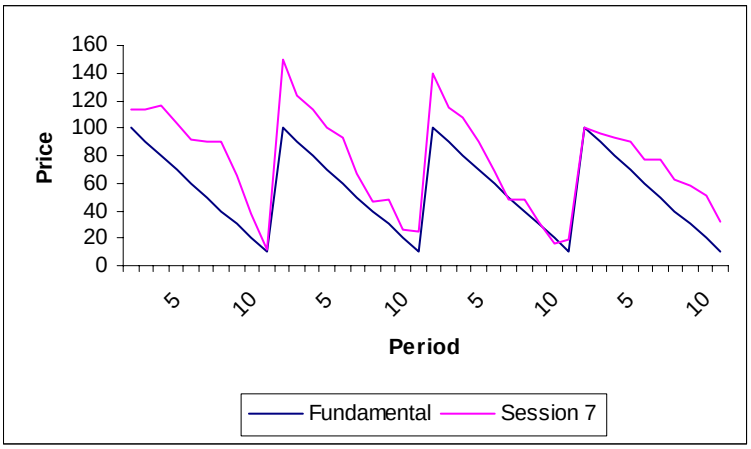
...FIGURE 1A (continued)

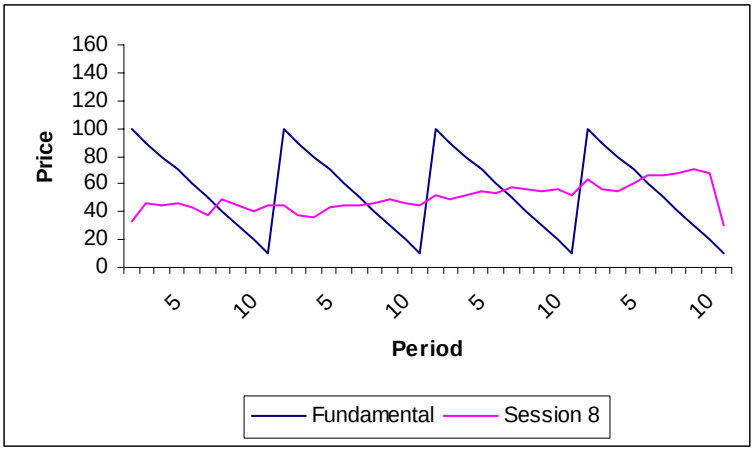


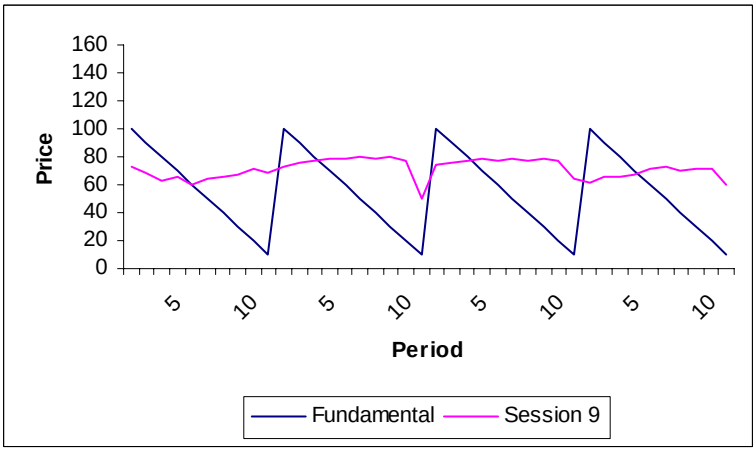




...FIGURE 1A (continued)







...FIGURE 1A (continued)

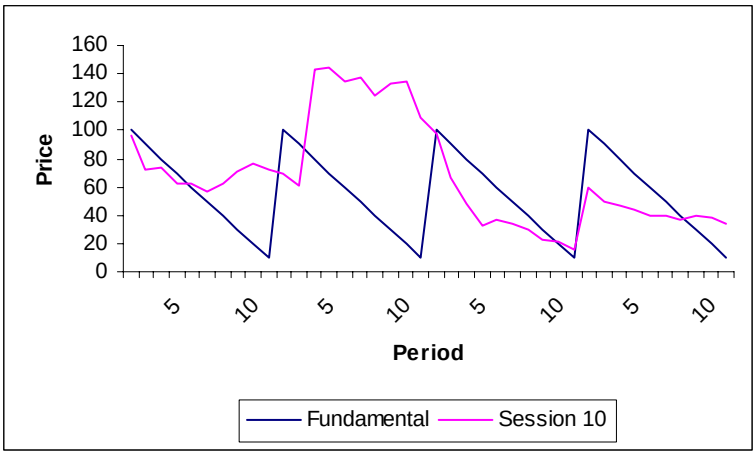


TABLE 1A—SUMMARY STATISTICS

Treatment	Round (R)	Haessel-R^2	Normalized Absolute Price Deviation	Normalized Average Price Deviation	Price Amplitude
⅔-EXPERIENCED	1	0.35	1.85	0.14	0.95
	2	0.40	1.71	0.15	0.82
	3	0.65	0.89	0.11	0.64
	4	0.73	0.87	0.07	0.52
	p-value R1=R4 [a]	0.063*	0.031**	0.031**	0.031**
	p-value R3=R4 [b]	0.719	0.500	0.938	0.813
⅓-EXPERIENCED	1	0.38	1.48	0.10	0.68
	2	0.53	1.52	0.13	0.77
	3	0.63	0.74	0.08	0.55
	4	0.57	1.26	0.08	0.58
	p-value R1=R4 [a]	0.063*	0.281	0.156	0.063*
	p-value R2=R4 [c]	0.656	0.656	0.906	0.875
	p-value R3=R4 [b]	0.281	0.094*	0.281	0.344
BETWEEN TREATMENTS	*p*-value R4-⅔=R4-⅓ [d]	1.000	0.421	0.310	0.841
POOLED DATA	1	0.37	1.67	0.12	0.81
	2	0.47	1.61	0.14	0.80
	3	0.64	0.81	0.09	0.59
	4	0.65	1.06	0.08	0.55
	p-value R1=R4 [a]	0.004***	0.032**	0.011**	0.003***
	p-value R3=R4 [b]	0.618	0.061*	0.897	0.819

[a] Null hypothesis: R1=R4 (meaning, round 1 measure equals round 4 measure); alternative hypothesis: R1<R4 for Haessel-R^2 and R1>R4 for the other measures

[b] Null hypothesis: R3=R4; alternative hypothesis: R3>R4 for Haessel-R^2, R3<R4 for the other measures

[c] Null hypothesis: R2=R4; alternative hypothesis: R2>R4 for Haessel-R^2, R2<R4 for the other measures. A comparison between round 2 and 4 in this treatment tests the effect of the variability of experience levels between market participants, while holding the average level of experience constant. In round 4 the average trader has one round of experience (1/3 have three rounds and 2/3 have none). In round 2 all traders have exactly one round of previous experience. In the same spirit, round 3 and 4 in the ⅔-EXPERIENCED treatment can be compared. As the *p*-values in the table indicate, no differences are observed (as does not the *p*-value=0.156 for Turnover for R2=R4, see more in Table 4A)

[d] Wilcoxon-Mann-Whitney test with null hypothesis R4-⅔=R4-⅓ (meaning, equal round 4 measure for sessions with ⅔ and ⅓ experienced traders); alternative hypothesis R4-⅔≠R4-⅓ (cf. Table 1)

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

TABLE 2A—NUMBER OF OFFERS AND EFFECT ON PRICE CHANGES

⅔-EXPERIENCED												
ROUND 1						ROUND 2						
session	a		t-stat	b		t-stat	session	a		t-stat	b		t-stat
1	0.507	***	(9.46)	0.086		(0.85)	1	-0.245	***	(-9.04)	0.017		(0.25)
2	5.342		(1.60)	0.555		(0.65)	2	7.573	*	(2.06)	2.270	***	(3.54)
3	-3.906	**	(-2.80)	-0.457		(-1.38)	3	-11.116		(-0.24)	-1.392		(-1.21)
4	0.383	***	(4.78)	0.660		(1.39)	4	-5.666		(-0.57)	1.200		(1.24)
5	5.226	***	(5.08)	0.346		(1.55)	5	1.579	***	(8.09)	-0.389		(-1.28)
ROUND 3							ROUND 4						
session	a		t-stat	b		t-stat	session	a		t-stat	b		t-stat
1	-3.642		(-0.77)	0.407		(0.65)	1	-1.732	***	(-3.70)	-0.227		(-1.00)
2	-9.374		(-0.10)	1.534		(1.60)	2	-10.116		(-0.00)	0.629		(1.17)
3	-6.094		(-1.42)	0.325		(0.56)	3	-4.974	***	(-3.80)	0.405		(1.52)
4	-7.507		(-0.54)	0.212		(0.84)	4	-4.534		(-1.08)	1.278	*	(2.20)
5	-4.784	**	(-2.54)	0.590	*	(2.27)	5	-8.379		(-0.40)	-0.110		(-0.18)
⅓-EXPERIENCED													
ROUND 1							ROUND 2						
session	a		t-stat	b		t-stat	session	a		t-stat	b		t-stat
6	-11.108		(-0.17)	-0.247		(-0.31)	6	1.469	**	(2.57)	1.164	**	(2.89)
7	-15.407		(-0.84)	-1.052		(-0.86)	7	-22.706		(-1.67)	-1.368		(-1.29)
8	1.799	***	(3.55)	0.090		(0.23)	8	0.366	***	(5.87)	0.132		(0.32)
9	0.236	***	(7.23)	0.114		(1.44)	9	-2.468	***	(-4.18)	0.622	***	(3.94)
10	4.299	***	(3.65)	0.739	**	(2.43)	10	-10.444		(-0.00)	-0.978		(-0.65)
ROUND 3							ROUND 4						
session	a		t-stat	b		t-stat	session	a		t-stat	b		t-stat
6	-5.548	**	(-2.80)	0.591	**	(3.23)	6	-11.039		(-0.61)	-0.222	*	(-2.00)
7	-16.377		(-1.37)	-0.986		(-0.90)	7	-7.909		(-0.67)	-0.094		(-0.17)
8	-0.458	***	(-9.80)	-0.163		(-1.12)	8	-2.806	**	(-3.18)	0.735	***	(4.94)
9	0.466	***	(4.84)	0.281		(1.04)	9	1.884	***	(5.06)	0.445		(1.13)
10	-18.851		(-1.01)	-0.239		(-1.21)	10	-3.471	***	(-4.67)	-0.153		(-0.85)

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

TABLE 3A—CORRELATIONS OF AVERAGE PRICES BETWEEN ROUNDS

⅔-EXPERIENCED

Session	R1 and R2	R2 and R3	R3 and R4	R1 and R4
1	0.17	0.26	0.51	-0.62
2	0.58	0.68	0.84	-0.38
3	0.84	0.98	0.93	0.93
4	0.91	0.74	0.88	0.61
5	0.43	0.07	0.76	-0.69
Average	0.59	0.55	0.79	-0.03

⅓-EXPERIENCED

Session	R1 and R2	R2 and R3	R3 and R4	R1 and R4
6	0.93	0.96	0.98	0.95
7	0.86	0.99	0.93	0.95
8	-0.16	0.72	0.49	-0.17
9	-0.27	0.99	0.72	-0.41
10	-0.60	-0.73	0.96	0.70
Average	0.15	0.58	0.82	0.40

TABLE 4A—TURNOVER

	⅔-EXPERIENCED						⅓- EXPERIENCED						POOLED
	1	2	3	4	5	Average	6	7	8	9	10	Average	DATA
R1	7.08	3.88	5.00	4.46	5.54	5.19	3.08	3.42	7.71	6.46	7.13	5.56	5.38
R2	7.88	2.83	7.04	2.75	4.38	4.98	2.63	2.00	5.17	3.75	5.50	3.81	4.39
R3	5.42	1.96	5.71	2.67	2.08	3.57	2.54	1.88	5.71	2.63	5.21	3.59	3.58
R4	6.75	3.42	6.88	1.25	3.38	4.33	3.63	6.29	3.54	4.25	10.33	5.61	4.97
p-value R1=R4 [a]						0.156						0.438	0.325
p-value R3=R4 [b]						0.063*						0.094*	0.079*
p-value R4-⅔=R4-⅓ [c]													0.421

[a] Null hypothesis: R1=R4 (meaning, round 1 measure equals round 4 measure); alternative hypothesis: R1>R4

[b] Null hypothesis: R3=R4; alternative hypothesis: R3<R4

[c] Wilcoxon-Mann-Whitney test with null hypothesis R4-⅔=R4-⅓ (meaning, equal round 4 measure for sessions with ⅔ and ⅓ experienced traders); alternative hypothesis R4-⅔≠R4-⅓

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

TABLE 5A—TRADE VOLUME IN ROUND 4

⅔-EXPERIENCED

Session	Inexp vs Inexp	Inexp vs Exp	Exp vs Exp	Exp average trade volume	Inexp average trade volume	*p*-value Inexp=Exp [a]
1	4	61	97	34.50	63.75	
2	6	57	19	34.50	23.75	
3	7	93	65	53.50	55.75	
4	0	18	12	9.00	10.50	
5	8	41	32	28.50	26.25	
Average				32.00	36.00	0.750

⅓-EXPERIENCED

Session	Inexp vs Inexp	Inexp vs Exp	Exp vs Exp	Exp average trade volume	Inexp average trade volume	*p*-value Inexp=Exp
6	37	46	4	30	27.00	
7	33	108	10	43.50	64.00	
8	52	31	3	33.75	18.50	
9	60	42	0	40.50	21.00	
10	137	105	6	94.75	58.50	
Average				48.50	37.80	0.563
Average pooled				43.00	36.60	0.760

[a] Null hypothesis Inexp=Exp (meaning, trade volume by inexperienced equals trade volume by experienced); alternative hypothesis: Inexp≠Exp

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

TABLE 6A—EARNINGS

Subject type	Average Earnings for One Subject ⅔-EXPERIENCED	⅓-EXPERIENCED
Inexperienced	6.45	6.97
Experienced	8.53	9.10
p-value:	0.048	0.075

TABLE 7A—EARNINGS BY EXPERIENCE LEVEL: ⅔-EXPERIENCED (SESSIONS 1-5)

Inexperienced subjects

Period	Assets Bought	Avg Buy Price	Assets Sold	Avg Sell Price	Net trading	Assets at end of period	Net Total Earnings	Avg Dividend
-	40	-	-	-	-	-	40.00	-
1	28	1.15	32	0.91	-2.99	36	41.01	0.11
2	19	0.93	15	0.86	-4.74	40	41.27	0.13
3	16	0.87	13	0.80	-3.45	43	41.22	0.08
4	21	0.80	10	0.79	-8.96	54	34.46	0.04
5	10	0.69	9	0.77	0.10	55	44.16	0.17
6	10	0.67	17	0.65	4.38	48	50.54	0.04
7	12	0.55	12	0.46	-1.01	48	54.93	0.11
8	12	0.46	13	0.51	1.12	47	58.65	0.06
9	15	0.39	15	0.40	0.15	47	67.20	0.18
10	23	0.43	18	0.35	-3.59	52	64.61	0.02
						Average earnings	6.46	

Experienced subjects

Period	Assets Bought	Avg Buy Price	Assets Sold	Avg Sell Price	Net trading	Assets at end of period	Net Total Earnings	Avg Dividend
-	80	-	-	-	-	-	80.00	-
1	60	0.88	56	0.99	2.99	84	93.39	0.12
2	40	0.81	44	0.84	4.74	80	107.53	0.12
3	27	0.79	30	0.83	3.45	77	117.18	0.08
4	29	0.77	40	0.79	8.96	66	128.74	0.04
5	32	0.71	33	0.69	-0.10	65	138.24	0.15
6	35	0.67	28	0.69	-4.38	72	136.75	0.04
7	35	0.56	35	0.59	1.01	72	146.76	0.13
8	33	0.54	32	0.52	-1.12	73	152.64	0.10
9	28	0.41	28	0.40	-0.15	73	163.29	0.15
10	35	0.38	40	0.42	3.59	68	170.68	0.06
						Average earnings	8.53	

TABLE 8A—EARNINGS BY EXPERIENCE LEVEL: ⅓-EXPERIENCED (SESSIONS 6-10)

	Inexperienced subjects							
Period	Assets Bought	Avg Buy Price	Assets Sold	Avg Sell Price	Net trading	Assets at end of period	Net Total Earnings	Avg Dividend
	80	-	-	-	-	-	80.00	-
1	78	0.77	75	0.70	-8.00	83	74.80	0.03
2	58	0.72	51	0.67	-7.70	90	74.70	0.08
3	43	0.64	43	0.56	-3.50	90	82.20	0.12
4	52	0.59	58	0.58	3.13	84	95.73	0.12
5	42	0.58	39	0.59	-2.50	87	99.83	0.08
6	47	0.56	48	0.54	-0.38	86	108.85	0.11
7	39	0.52	37	0.52	-0.85	88	111.60	0.04
8	36	0.50	34	0.51	-0.75	90	118.05	0.08
9	50	0.50	43	0.52	-2.61	97	127.84	0.13
10	46	0.32	49	0.33	1.16	94	139.40	0.11
						Average earnings	6.97	

	Experienced subjects							
Period	Assets Bought	Avg Buy Price	Assets Sold	Avg Sell Price	Net trading	Assets at end of period	Net Total Earnings	Avg Dividend
	40	-	-	-	-	-	40.00	-
1	30	0.72	33	0.90	8.00	37	50.00	0.05
2	21	0.77	28	0.85	7.70	30	59.70	0.07
3	17	0.51	17	0.72	3.50	30	66.60	0.11
4	19	0.63	13	0.68	-3.12	36	67.48	0.11
5	19	0.58	22	0.61	2.50	33	72.98	0.09
6	18	0.53	17	0.58	0.38	34	78.36	0.15
7	19	0.55	21	0.54	0.85	32	80.41	0.04
8	12	0.53	14	0.51	0.75	30	83.56	0.08
9	11	0.47	18	0.43	2.61	23	88.17	0.09
10	16	0.32	13	0.31	-1.16	26	91.01	0.15
						Average earnings	9.10	