American Economic Association

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Source: *The American Economic Review*, Vol. 95, No. 5 (Dec., 2005), pp. 1731-1737
Published by: American Economic Association
Stable URL: http://www.jstor.org/stable/4132775

Accessed: 19/10/2008 12:22

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Bubbles and Experience: An Experiment

By Martin Dufwenberg, Tobias Lindqvist, and Evan Moore*

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 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 et al. (1988), laboratory experiments have shown (*inter alia*) that bubbles tend to occur with inexperienced traders and not with experienced traders who have participated many times in the same type of market.[2]

It is not quite clear which result applies, however, because in the nonlaboratory world markets include *both* experienced and inexperienced traders. There is perhaps reason to think that most trading reflects decisions of experienced traders, but conceivably there are enough inexperienced traders to sustain bubbles. Indeed, an informal survey 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

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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 et al. (1993), Steven Peterson (1993), Van Boening et al. (1993), David P. Porter and Smith (1995), Eric O'N. Fisher and Frank S. Kelly (2000), Vivian Lei et al. (2001), Ernan Haruvy and Charles N. Noussair (forthcoming), and Noussair and Steven Tucker (2003). Van Boening et al., in particular, focus on the impact of experience.

[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.

as one-third, 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.

Section I describes our design, Section II reports results, and 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 U.S. cents, with equal probability. Trade takes 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 two 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 to 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 who had participated in the first three rounds were randomly selected, removed, 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 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 two-thirds experienced traders exhibit very similar patterns of behavior as markets with one-third experienced traders. (Statistical support for this claim is reported in the last row of Table 2; 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]

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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.

[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/six assets *or* 600 cents/two assets) were replaced.

[8] We have created a working paper of this paper (Dufwenberg et al., 2005) with experimental instructions and

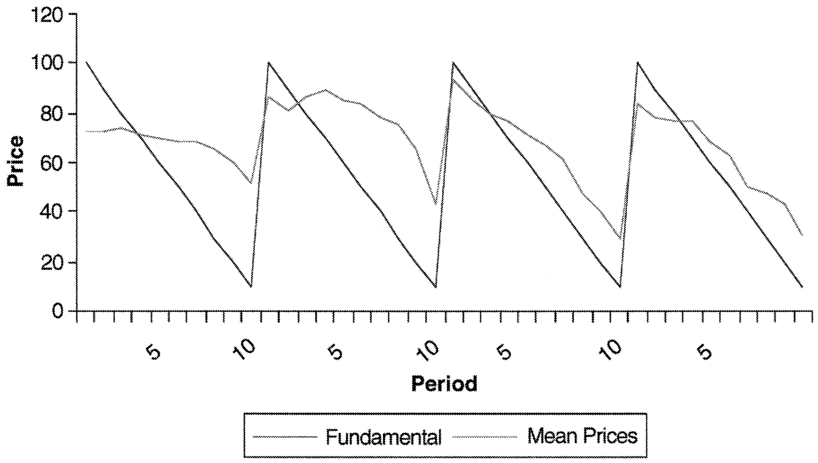

FIGURE 1. OBSERVED MEAN PRICES AND FUNDAMENTAL VALUES

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 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 virtually to 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.

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 and 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 W. 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

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extended analysis in an appendix. This appendix is also available on the *AER* Web site at http://www.e-aer.org/data/dec05_app_dufwenberg.pdf.

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

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

Round	Session 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 two-thirds (one-third) experienced traders in round 4.

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 $t = 1, 2, \ldots, 10$, 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 two-thirds [one-third] experienced traders), and Table 2 reports averages across all sessions, as well as the results of the associated permutation tests for paired replicates.

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-to-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, which 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 devia-

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[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 Web Appendix.

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 two-thirds and one-third 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.

tions ($p = 0.061$). 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. Our data show a marginally significant increase in turnover between rounds 3 and 4 ($p = 0.079$), 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 versa. 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 nonlaboratory markets. A word of caution is in order, as laboratory markets are not the same as other markets. Nevertheless, our results may shift the burden of proof somewhat between those who believe in the madness of the market and the market fundamentalists. Our results speak in favor of the latter position.

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[12] It is interesting to compare this result to findings by Robert L. Slonim (2005), 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 coplayers' 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.

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

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[13] See Shiller (2000, chap. 1) for an account up until 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.

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