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Irrational Exuberance No More

Lucy F. Ackert, Narat Charupat, Bryan K. Church, and
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Working Paper 2002-24
December 2002

Working Paper Series

Federal Reserve Bank of Atlanta
Working Paper 2002-24
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Lucy F. Ackert, Kennesaw State University and Federal Reserve Bank of Atlanta
Narat Charupat, McMaster University
Bryan K. Church, Georgia Tech
Richard Deaves, McMaster University

Abstract: The robustness of bubbles and crashes in markets for finitely lived assets is perplexing. This paper reports the results of experimental asset markets in which participants trade two assets. In some markets, price bubbles form. In these markets, traders will pay even higher prices for the asset with lottery characteristics, i.e., a claim on a large, unlikely payoff. However, institutional design has a significant impact on deviations in prices from fundamental values, particularly for an asset with lottery characteristics. Price run-ups and crashes are moderated when traders finance purchases of the assets themselves *and* are allowed to short sell.

JEL classification: C92, G14

Key words: bubbles, asset markets, laboratory experiments, rational expectations

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Financial support of the Federal Reserve Bank of Atlanta and Social Sciences and Humanities Research Council of Canada is gratefully acknowledged. The authors thank Steve Karan and Sule Korkmaz for research assistance; Steve Bendo and Sanjay Srivastava for technical assistance; and Peter Bossaerts, Ann Gillette, Charles Holt, Ferd Levy, and Ed Maberly for helpful comments. This paper has been presented in the Atlanta Finance Workshop, at the universities of Nebraska-Lincoln and Toronto, and at the 2002 meetings of the American Finance Association. The views expressed here are the authors' and not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System. Any remaining errors are the authors' responsibility.

Please address questions regarding content to Lucy F. Ackert, Department of Economics and Finance, Michael J. Coles College of Business, Kennesaw State University, 1000 Chastain Road, Kennesaw, Georgia 30144, 770-423-6111, lucy_ackert@coles2.kennesaw.edu, and Research Department, Federal Reserve Bank of Atlanta, 1000 Peachtree Street N.E., Atlanta, Georgia, 30309-4470; Narat Charupat, Michael G. DeGroote School of Business, McMaster University, 1280 Main Street, West Hamilton, Ontario, Canada L8S 4M4, 905-525-9140 ext. 23987, charupat@mcmail.cis.mcmaster.ca; Bryan K. Church, DuPree College of Management, Georgia Tech, Atlanta, Georgia 30332-0520, 404-894-3907, bryan.church@mgt.gatech.edu; or Richard Deaves, Michael G. DeGroote School of Business, McMaster University, 1280 Main Street West Hamilton, Ontario, Canada L8S 4M4, deavesr@mcmaster.ca.

Bubbles in Experimental Asset Markets:
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One of the most striking results from experimental asset markets is the tendency of asset prices to bubble above fundamental value and subsequently crash. Explaining the price pattern is a challenge. Yet extreme price movements, at odds with any reasonable economic explanation, are documented throughout history. Examples include the Dutch tulip mania (1634-1637), the Mississippi bubble (1719-1720), and the stock market boom and crash of the 1920s (see e.g., Kindelberger (1989), Garber (1990), White (1990)). More recently, in a speech made on December 5, 1996, Federal Reserve Chairman Alan Greenspan expressed concern that stock prices are inflated by "irrational exuberance."

The current debate over rational valuation centers largely on internet-related companies. Though downward price adjustments have been observed of late, stock prices for many of these so-called dot-coms increased at incredible rates over the last decade despite mounting accounting losses. Price to earnings multiples for some dot-coms (or price to revenues when earnings are negative) were as high as several hundred to one, something unheard of just ten years ago. Chairman Greenspan speculates that the observed price behavior might reflect a lottery effect. Market participants are willing to pay a premium for some stocks because, though the chance is small, a very significant payoff is possible.[1]

This paper reports the results of experimental asset markets designed to examine whether asset prices reflect a lottery premium. The results indicate that traders will pay a premium for a claim on a large payoff, even if the payoff is unlikely. In addition, this study re-examines whether institutional design impacts upward deviations in prices from fundamental values. Unlike previous research that documents the robustness of bubbles formation, price run-ups and crashes are not observed when traders are not permitted to finance purchases with borrowed funds but are allowed to short sell the assets.

The remainder of this paper is organized as follows. Section I provides background and motivation for the study. Section II describes the experimental procedures and design. Section III reports the results. Section IV contains a discussion of the results and concluding remarks.

I. Regularities, Institutional Features, and New Questions

Smith, Suchanek, and Williams (1988) first reported bubbles in experimental asset markets. Typically in bubbles markets, subjects trade an asset over a finite horizon. The asset has a common dividend, determined at period end based on a known, stationary probability distribution. Thus, fundamental value, assuming risk neutrality, is easily computed as the number of trading periods remaining multiplied by the expected dividend per period. In this setting trading yields large upward deviations in prices from fundamental value followed by crashes back to the asset's risk neutral value. The finding has been replicated by Porter and Smith (1995), Ackert and Church (2000), and Lei, Noussair, and Plott (2001), among others. King, Smith, Williams, and Van Boening (1993) investigate whether bubbles are moderated by several treatment variables including the ability to short sell, margin purchases, the presence of brokerage fees, equal endowments across traders, a subset of informed traders, limit price change rules, design experience, and experience in the business world. Only significant design experience (twice-experienced subjects) appears to temper the occurrence of bubbles.

The robustness of bubbles is perplexing and may result from perceived or observed irrationality. Smith, Suchanek, and Williams (p. 1148) conclude that bubbles arise because of "agent uncertainty about the behavior of others." A trader may rationally believe that others are irrational and buy at prices above fundamental value if the trader believes that prices will continue to escalate, providing profitable resale opportunities. In other words, traders perceive that others are irrational regardless of whether they are, in fact, irrational. However, Lei, Noussair, and Plott report bubbles in markets in which speculation is not possible, suggesting that a subset of traders behaves irrationally.[2]

What appears to be irrational valuation is also reported in naturally occurring markets. Many argue that instances of mispricing are abundant in today's market for internet stocks. Shiller (2000) provides some examples of what he refers to as "obvious mispricing." He points out that eToys' stock was worth $8 billion in 1999 when sales in 1998 were only $30 million and the company reported losses of $28.6 million. By comparison, stock in Toys "R" Us was worth $6 billion when the company's sales were $11.2 billion and profits were $376 million. The market's valuations appear to be incongruous with the performance of each company. Yet, this price behavior may have a logical basis.

Gul (1991) proposes a model of preferences referred to as disappointment aversion. His paradigm replaces the independence axiom of expected utility theory yet retains much of the insight of the standard theory. In the standard expected utility framework, preferences display second-order risk aversion so that the risk premium is proportional to the variance of the gamble. In contrast, disappointment aversion utility displays first-order risk aversion and the risk premium is proportional to the standard deviation. These preferences imply a sharp aversion to losses.[3] As Kahneman, Knetsch, and Thaler (1991) illustrate, asymmetry of value, or loss aversion, has been documented in many contexts. An individual with disappointment aversion preferences is risk averse for gambles with a small probability of a large loss and risk-loving for gambles with a small probability of a large gain.[4] With disappointment aversion, traders may prefer and pay higher prices for assets with lottery-type payoffs (zero or a large, positive payoff).[5] In this paper we investigate whether behavior is consistent with a preference for lotteries so that an asset with lottery characteristics trades at a premium, as predicted by disappointment aversion.

Two assets trade simultaneously in our experimental asset markets, as described more fully in the following section of the paper. The assets have equal expected payout but one has a highly positively skewed payoff distribution. This asset has the characteristics of a lottery in that there is a small probability of a large gain, but most often no cash flow is generated. If traders are risk-preferring for the lottery asset, it should trade at prices that reflect a lottery premium. This leads to the following hypothesis.

Hypothesis 1: The price bubble is larger for an asset with lottery characteristics.

In addition to examining whether asset prices reflect a lottery premium, this study re-examines whether bubbles are moderated by two institutional design features: (1) borrowing and (2) short-selling. In some market sessions, traders may finance purchases of the two assets using borrowed funds and in others, traders are endowed with cash that they may keep. In some market sessions, traders may short sell shares of either asset and in others, short sales are not permitted.

The ability to borrow in order to finance the purchase of a security is analogous to purchasing on margin. Historically margin purchases were viewed as destabilizing. In 1934 the U.S. Congress passed the Securities and Exchange Act of 1934 which gave the Federal Reserve Board the power to set margin requirements. The thought was that trade on credit resulted in over-leveraging, excessive speculation, and increased stock market volatility.[6] In contrast, Kupiec (1998) argues that the evidence does not indicate that leverage created by margin produces excess volatility. In terms of experimental evidence, Porter and Smith (1995) conclude that margin buying increases the amplitude of the price bubble in their experimental asset markets.[7]

Traders in bubbles markets are typically endowed with cash or working capital, with the balance remaining at the conclusion of the experiment theirs to keep. However, in other double auction asset markets, traders return the cash endowment (e.g., Sunder (1992)). In such markets, trade is financed using borrowed money, or margin, at zero interest. This design allows traders sufficient funds to trade as much as desired, yet limits the cost of the experiment to the researcher. The impact of the difference in design has not been systematically examined despite the importance of endowment effects.

Prior experimental studies that examine the effect of margin buying on price bubbles typically endow traders with cash *and* provide a margin account. The current study separates the two to isolate their potential effects. In some markets, traders borrow money that is returned at the conclusion of the session.[8] In other markets, traders are endowed with money that is theirs to keep. Distinguishing between borrowed and non-borrowed funds provides insight into the effects of traders' endowments on the formation of price bubbles. Recall from the earlier discussion that risk attitudes in the gain domain are different from those in the loss domain. Because of loss aversion, individual decision-making may differ substantially in a market setting when traders are given an endowment they must return as compared to an endowment they may keep.

In our base case markets, traders finance purchases of the assets with borrowed money. We then examine market behavior when individuals trade using funds they do not have to return, their own money. Because individuals tend to be more risk averse with money that is theirs, the bubble should be smaller when they cannot trade with borrowed funds.[9] Thus, the second hypothesis is as follows.

Hypothesis 2: If traders are not permitted to purchase assets with borrowed money, the price bubble will be dampened.

In addition to borrowing constraints, another important institutional feature is short sales restrictions. In actual practice, few investors can short sell and obtain the full use of the proceeds.[10] Yet, short sellers perform an important function in an efficiently functioning market and short selling may be critical if assets are to be priced efficiently.[11] Diamond and Verrecchia (1987), among others, show that the efficiency of the pricing mechanism is impaired by the market friction imposed by short sales constraints. In the presence of short sales constraints, market participants use alternative mechanisms to move price toward equilibrium and incorporate information. For example, Figlewski and Webb (1993) show that the ability to trade options contributes to the efficiency of the market by alleviating the effects of short sales constraints.

This study re-examines short sales constraints in an experimental asset market. In naturally-occurring markets the practice of short-selling is possible because a trader who does not own a stock can borrow it. The short seller does not ever actually own the stock. If the stock pays cash dividends, the short seller's account is charged for the amount of the dividends and this amount is then paid to the lender of the stock. In our markets, short sellers effectively borrow stock from the experimenters.

King, Smith, Williams, and Van Boening (1993) conclude that the ability to short sell fails to mitigate bubbles in their experimental asset markets. However, this result is inconsistent with evidence from naturally-occurring markets and finance theory. The implementation of the short sales feature here differs in three important ways from the approach chosen by King, Smith, Williams, and Van Boening. In their markets, if a share was short sold and not returned at the end of the trading session, the trader received a penalty of one-half of the asset's initial fundamental value. Short sellers paid no dividends on borrowed shares and were permitted to short sell no more than two shares. In our markets, no penalty is imposed if borrowed shares are not returned because the fundamental value of both assets is zero at the conclusion of the experiment. However, short sellers pay all dividends on shares sold short. In addition, we increase the number of shares that traders are can short sell. Traders are permitted a short position of five shares in each asset at period end. These three changes in institutional design better reflect actual practice and permit traders to exploit potentially profitable opportunities through short sales. Because short selling allows traders to take advantage of imbalances in the market, the third hypothesis is expressed as follows.

Hypothesis 3: If traders are permitted to short sell assets, the price bubble will be dampened.

II. Experimental Method

A. *The computerized environment*

The asset market experiments were conducted in the Educational Trading Center at McMaster University using the *Financial Trading System (FTS)* platform developed by Sanjay Srivastava and John O'Brien at Carnegie Mellon University. This computerized double auction market program allows students to transact in real time over a number of market periods. Participants can post bids and asks, or act as price-takers in accepting the best bids or asks posted by others. After the setting of initial parameters, the *FTS* program allows traders to begin with endowments made up of cash and securities and automatically updates portfolios after transactions and dividend payments. The order book was assigned a depth of one so that posted orders were erased by better bids and asks. Traders were permitted to transact each asset one unit at a time.

B. *Nature of the experiments*

Thirteen market sessions were conducted, in addition to four pre-tests. The experimental design, to be discussed subsequently, is summarized in Table 1. Between seven and nine traders participated in each session which consisted of 12 five-minute periods. All participants were sophomore, junior, or senior undergraduate business or economics students. All were inexperienced in that none had participated in an earlier session.

Subjects were endowed with two shares each of two securities, referred to in the sessions as stocks A and B. Here we will refer to them as the standard asset and the lottery asset. At the end of each period, the assets paid dividends, which were randomly determined by the *FTS* program using the distributions reported in Table 2. Dividend draws were cross-sectionally and intertemporally independent. Note that although the spreads of the distributions are quite different, the expected dividend for both stocks is identical at $0.72 per period. Most often the lottery asset's dividend is zero but there is a small chance (4%) of a large payoff ($18). With 12 periods, both assets have an initial fundamental value of 12 x 0.72 = $8.64. With an endowment of two units of each asset, all traders had a total initial expected dividend payout of $34.56. After the final dividends were paid at the end of period 12, shares ceased to exist and had zero value.

As Table 1 details, three treatments were used: no short selling plus borrowing (NSS/B); no short selling plus no borrowing (NSS/NB); and short selling coupled with no borrowing (SS/NB).[12] Sessions NSS/B1-4 correspond to the borrowed funds/no short selling treatment (NSS/B). Participants were endowed with $100 in cash at the beginning of trading which had to be returned at the end of trading. If the final cash balance was below $100, trading profit was $0. Sessions NSS/NB1-5 removed the borrowed funds condition while maintaining no short selling (NSS/NB). This was effected by endowing each trader with $40 of cash that did not have to be returned (in addition to the two shares of the standard asset and two of the lottery asset). Sessions SS/NB1-4 removed both the borrowed funds and the no short selling conditions (SS/NB). Short sold shares are not borrowed from other traders but rather from the "market." A trader in a short position at the end of a period is required to pay out the relevant dividend. At the end of period 12 after the final dividend is paid out, all shares are worthless because no further dividends are to be paid. In sessions with short selling, a short position limit of five per security at period end was imposed.

Because subjects' price predictions may provide insight into market behavior, participants were also asked to forecast closing prices. At the beginning of each period, traders recorded their forecasts of each asset's closing price for the coming period on price prediction tickets. The subject with the lowest total absolute prediction error across all 12 periods was paid a $20 bonus.[13]

C. *Conduct of sessions*

Sessions NSS/B1-4 and NSS/NB1-5 required roughly two and one-half hours. On arrival subjects were handed envelopes containing a set of instructions and 12 price prediction tickets.[14] They were given about 20 minutes to read through them. Thereafter one of the experimenters did an extensive recap while addressing all procedural and technical questions. This took roughly another 20 minutes. A further five minutes was allotted for consideration of strategy, pricing and prediction, whereupon subjects were asked to fill out the first price prediction ticket. After the tickets were collected, trading commenced. At the end of each trading period, four items of information (per security) were announced and publicly recorded, namely the closing price (assuming a trade occurred), dividend, expected total remaining dividends, and maximum total remaining dividends (the maximum dividend per period multiplied by the number of periods remaining). Then about one minute was provided for subjects to consider and record their next price predictions, after which the next period commenced. Sessions SS/NB1-4 were conducted in a like manner except that extra time was provided to the participants for instruction due to the additional complexity of short selling.

After the final dividends were paid, the final cash balance was (privately) displayed on a subject's computer screen. For Sessions NSS/B1-4, a traders' profit was the maximum of zero and the final cash balance less the cash endowment of $100. For Sessions NSS/NB1-5 and SS/NB1-4 the final cash balance represented trading profit.[15] Participants completed a post-experiment questionnaire that elicited potentially relevant subject attributes such as sex, educational background, economic status, and reactions to the experiment. During this time the experimenters ascertained the winner of the price prediction bonus. Thereupon the experimenters (rounding up to the nearest dollar) filled envelopes with the appropriate amount of cash and called each subject forward (privately) to check and receive his/her cash before filling out a receipt and leaving the room.[16] Median (mean) total compensation in Canadian dollars over the thirteen sessions was $60.92 ($61.00) with a range of $0 to $148.00.

III. Market Behavior

A. *Results for the NSS/B Sessions*

Figures 1 and 2 show the median transaction price per period for the standard and lottery assets, respectively, in markets NSS/B1-4, along with the assets' fundamental value. In this treatment, neither asset could be sold short and participants were permitted to finance trade with borrowed funds. Consistent with earlier research, prices clearly exhibit substantial deviation from fundamental value.

Figure 1 shows that the price of the standard asset does not appear to settle close to the fundamental value until the final periods of trading. The price paths exhibit large run-ups from (declining) fundamental value and do not crash back to the risk-neutral valuation until periods 11-12. Prices reach levels far from fundamental value. For example, in period 3 of market 3 the median transaction price was $12.50 when the fundamental value of the asset was $7.20. In period 7 of market 2 the median price was $11.85 when the fundamental value was $4.32.

Figure 2 shows similar price paths for the lottery asset, with large deviations in prices from fundamental value. Moreover, prices reach an even higher level for the lottery asset, consistent with the first hypothesis: the price bubble is larger for a security with lottery characteristics. For example, in period 3 of market 3 the median price was $16.75 when the fundamental value was $7.20. In period 7 of market 4 the median price was $14.49 when the asset's fundamental value was $4.32.

Table 3 reports the frequency of transactions that occur in various price ranges, including prices less than the minimum possible dividend payout ($p < \min D$), between the minimum payout and the fundamental value ($\min D \leq p < FV$), between the fundamental value and the maximum possible dividend payout ($FV \leq p \leq \max D$), and greater than the maximum possible payout ($\max D < p$). For the standard asset, a significant volume of trade occurs at prices outside the feasible range of possible future dividends. Consistent with the results of Lei, Noussair, and Plott (2001), nearly one-half of trades (48%) occur at prices less than the minimum possible or greater than the maximum possible dividend stream. For the lottery asset, we observe no trades outside the feasible bound because trading below the minimum possible price would require trade at negative prices and trading above the maximum possible price would require prices that exceed even unreasonable limits.[17] For both assets the volume of trade is concentrated at prices above fundamental value, rather than below. For the standard asset (lottery asset), 86% (91%) of transactions occur at prices above the risk-neutral valuation.

Table 4 reports several summary statistics on the deviations in price from fundamental value: the number of periods in which the median price exceeds the fundamental value, positive duration, peak deviation, average absolute price deviation, average price deviation, and average positive price deviation. These empirical measures assume risk neutrality and are designed to gauge the bubble in asset price, if one is observed, and to facilitate comparison across assets and treatments.[18] Positive duration is the number of consecutive periods in which the median price increases relative to fundamental value subject to the constraint that the increase produces a price that exceeds fundamental value, and is calculated as

$$\max[m: P_t - FV_t < P_{t+1} - FV_{t+1} < \ldots < P_{t+m} - FV_{t+m}] \text{ s.t. } P_{t+1} > FV_{t+1}$$

where P_t is the median price and FV_t is the fundamental value in period t (t = 1, …, 12). Peak deviation measures the magnitude of the bubble using peak deviations in the median price from fundamental value, the maximum of $[(P_t - FV_t)/FV_1]$, where the deviation in price from fundamental value is normalized by the total expected dividend value over the life of the asset, FV_1. The average (absolute) price deviation is the average of the (absolute) deviation in the median price from fundamental value, normalized by the fundamental value (FV_t). Finally, the average positive price deviation is the average of all deviations in the median price above fundamental value, i.e., the average of the maximum of zero and the price deviation. Because this statistic focuses on price deviations above fundamental value, it gives another measure of the size of the price bubble.

For the first treatment (NSS/B1-4), the statistics reported in Table 4 are consistent with the hypothesis that the price bubble is larger for the lottery asset. The price of the lottery asset more often exceeds the fundamental value than does the standard asset's price. Positive duration is higher for the lottery asset (5.00), as compared to the standard asset (4.50), suggesting that upward price deviations from fundamental value are more persistent for the lottery asset. In addition, the peak price movement above fundamental value is larger, on average, for the lottery asset (0.9327), as compared to the standard asset (0.7557).

For each asset Table 4 also reports the average absolute, average, and average positive price deviation from fundamental value, normalized by the fundamental value. In all three cases the price deviation for the lottery asset exceeds that of the standard asset. For example, the average median price deviation from fundamental value for the lottery asset is 1.6901, whereas for the standard asset it is 1.1444. To formally test for a difference across the two assets, we used nonparametric Wilcoxon matched pairs tests of the hypothesis that the price of the lottery asset deviates more from fundamental value than does the price of the standard asset. The lottery asset's price deviation from fundamental value is significantly larger (at the 1% level) using all three measures of price deviation. This provides support for the hypothesis that individuals will pay a premium for an asset with lottery characteristics.

B. *Results for the NSS/NB Sessions*

In the next set of sessions, participants were not permitted to finance trade with borrowed funds. Thus, margin purchases were not permitted and participants used their own funds to buy shares. Again, neither asset could be sold short. Figures 3 and 4 show the median asset price per period for the standard and lottery assets, respectively, in markets NSS/NB1-5, along with the assets' fundamental value. As in the first set of markets, price deviates substantially from fundamental value. Prices do not appear to settle down to fundamental value until very late in trading. Importantly, the bubbles do not appear to be magnified for the lottery asset, as compared to the standard asset.

The frequency of trades in various price ranges, reported in Table 3, again suggest that some irrational trades occur. For the standard asset, 35% of the trades are at prices less than the minimum possible or greater than the maximum possible dividend payout. For both assets, more transactions are at prices above fundamental value with 78% (71%) of trades above the risk-neutral valuation for the standard asset (lottery asset). A decline in the percentage of irrational trades and the frequency of trades above fundamental value are observed in the NSS/NB1-5 sessions as compared to the NSS/B1-4 sessions.

Bubble measures reported in Table 4 indicate that bubbles are also reduced in the NSS/NB1-5 sessions, compared to the NSS/B1-4 sessions. The median price exceeds fundamental value in fewer periods. Positive duration for both assets is lower when borrowing is not permitted. The peak price deviation is also lower, indicating that the bubble is moderated when traders must finance their own trades.

As Table 4 reports, the average price deviations (absolute, average, and positive) from fundamental value for the lottery asset are smaller than those of the standard asset. When traders must finance asset purchases themselves, they will not pay a premium for an asset with lottery characteristics. This result is contrary to the first hypothesis.

C. *Results for the SS/NB Sessions*

In the next set of sessions, participants were permitted to short sell both assets. Figures 5 and 6 show the median asset price per period for the standard and lottery assets, respectively, in markets SS/NB1-4, along with the assets' fundamental value. The price paths contrast sharply with those observed in markets that do not allow short selling. Large run-ups with crashes back to fundamental value are generally not observed. Instead, in many markets trading below fundamental value is observed for both assets.

As in the first two treatments, the frequency of trades in various price ranges, reported in Table 3, suggests that many irrational trades occur. For the standard asset, 45% of the trades are at prices less than the minimum possible or greater than the maximum possible dividend stream. However, unlike the first two treatments, with short selling more transactions for both assets are at prices below fundamental value with 50% (63.9%) of trades below the risk-neutral valuation for the standard (lottery) asset.

Bubble measures reported in Table 4 provide further evidence that short selling moderates price bubbles. Comparing sessions SS/NB1-4 to NSS/NB1-5, there are fewer periods in which the median price exceeds fundamental value. Positive duration and the peak price deviations are also substantially lower for both assets with short selling.

As Table 4 reports, the average price deviations (absolute, average, and positive) from fundamental value are larger for the standard asset as compared to the lottery asset. The average price of the lottery asset is below the fundamental value, rather than above it. When traders can short sell, the asset with lottery characteristics trades at a discount, contrary to the first hypothesis.

D. *Comparisons Across Treatments*

Figure 7 summarizes asset price behavior across all 14 sessions. The figure shows the average of the median asset price per period for each treatment and asset. Consistent with the results reported above, traders may pay a premium for an asset with lottery characteristics. However, price deviations from fundamental value are moderated when traders must finance their own trade and short sales are permitted.

To more formally examine the effects of the treatments on deviations in prices from fundamental value, a time series, cross-sectional regression method is used. Each market is a cross-sectional unit consisting of 12 time series observations. Ordinary least squares is inappropriate because the observations from each market session are not independent. An error components model is an alternative approach in this pooled setting. This model assumes that the regression disturbance, $e_{i,t}$, is composed of three terms

$$e_{i,t} = u_i + v_t + w_{i,t}$$

where u_i is the cross-sectional error component, v_t is the time-series error component, and $w_{i,t}$ is the residual error. Each component is normally distributed and $e_{i,t}$ is homoskedastic. The best linear unbiased estimator is the two-step generalized least squares estimator (Fuller and Battese (1973, 1974)).

For each asset, Panel A of Table 5 reports the estimation results of the error components model. The dependent variable is the normalized median price deviation from fundamental value each period.[19] The independent variables include two dummy variables. The first dummy variable measures the effect of the ability to borrow (DB) where the dummy takes the value of one when borrowing is permitted. The second measures the effect of the ability to short sell (DSS) where the dummy takes the value of one when short selling is permitted. The p-values are reported in parentheses below parameter estimates.

Panel B of Table 5 reports t-statistics for paired treatment comparisons, with p-values below in parentheses.[20] For the standard asset, only the *combined* effect of borrowing restrictions and the ability to short sell moderates the price deviation from fundamental value. For the lottery asset, both borrowing restrictions and the ability to short sell significantly reduce price deviations. These results provide weak evidence for the second hypothesis: the price bubble is dampened if traders cannot purchase assets with borrowed money. The price bubble is moderated when a borrowing constraint is imposed for the asset with lottery characteristics, though not for the standard asset. The results provide evidence to support the third hypothesis for the lottery asset: the price bubble is dampened if traders can short sell. Short selling has a significant impact on price deviations from fundamental value for the lottery asset, but not for the standard asset. However, for both assets, the ability to short sell *combined with* restrictions on the ability to borrow are critical to driving price to fundamental value. The price bubble is dampened if traders are not permitted to purchase assets with borrowed money *and* if short sales are permitted. Thus, institutional design features need to be considered in combination.

To provide further insight into market behavior, we examine how individual behavior translates into market performance. For each treatment, Table 6 reports the results of a regression of normalized trading profit for each individual on forecast accuracy (accuracy) and the percentage of rational trades (%rational). The dependent variable is an individual's trading profit over the session normalized by the payout that would have accrued had the trader followed a no trade strategy of holding the initial endowment. Forecast accuracy is the absolute value of the difference between a trader's forecast of the closing price and the closing price, scaled by the session's average absolute forecast error.[21] The percentage of rational trades is calculated as the number of purchases at prices below fundamental value plus the number of sales above fundamental value, divided by the total number of trades.[22]

The accuracy variable is insignificant in all treatment regressions, as well as the overall sample. Forecasting ability does not translate into superior profit-making ability. Consistent with the conclusions of Ackert and Church (2000), pricing efficiency does not hinge on forecasting ability. However, in all three treatments, individuals who make more rational trades generate greater trading profit. Traders who buy and sell when the relationship between the price and fundamental value warrants it, perform better in the experiment.

Competently taking advantage of the ability to short sell also translates into higher profits. The importance of the ability to short sell is evidenced by the results reported in Table 7.

For the treatment in which short sales are permitted (SS/NB1-4), the table reports the results of a regression of normalized trading profit on forecast accuracy (accuracy), the percentage of rational trades excluding short sales (%rational(XSS)), and the percentage of rational short sales (%rational(SS)) times a dummy (DSS) that takes the value of one when a trader short sells at least one share. Profit and forecast accuracy are as defined above. The percentage of rational trades excluding short sales is the number of purchases at prices below fundamental value plus the number of sales above fundamental value, divided by the total number of trades, excluding any short sales. The percentage of rational short trades is calculated as the number of short sales above fundamental value, divided by the total number of short sales. The percentages of rational trades excluding short sales and of rational short sales are *both* significant determinants of trading profit. Individuals who make more rational trades and those who short sell when they should generate greater trading profit.

IV. Discussion and Concluding Remarks

This paper reports the results of experimental asset markets in which market participants traded two assets. Consistent with previous research, this paper documents the tendency of asset prices to bubble above and crash back to fundamental value in markets for finitely-lived assets. The paper also documents that traders will pay even higher prices for an asset with lottery characteristics, i.e., a claim on a large, unlikely payoff. But, the tendency to pay too much disappears when traders must finance purchases of the assets themselves and are permitted to short sell.

Lei, Noussair, and Plott (2001) provide a methodological explanation for bubbles formation that they term the active participation hypothesis. Because participants in an experiment are expected to trade, much of the activity that results in bubbles comes from the fact that participants have nothing else to occupy them. A high volume of trade provides support for the hypothesis. The volume of trade in the markets described in this paper is also large, though the results are not necessarily consistent with the active participation hypothesis. When margin purchases are constrained and participants can exploit potentially profitable opportunities through short selling, price bubbles are moderated. Yet turnover and volume are higher than with other institutional designs (see Table 3). At least some participants trade to take advantage of arbitrage opportunities.

Short selling provides an equilibrating force in the market. Those who excel at it generate greater profit. For an asset with lottery characteristics, short selling is critical to move price toward fundamental value. For an asset with a less skewed payoff, restrictions on borrowing to finance trade *combined* with short selling temper price bubbles.

The results of this study have important implications for the regulation of security markets. Those who oversee these markets are advised to carefully consider any constraints on the ability to short sell. Allowing short selling enhances the pricing mechanism and allows traders to move price to levels justified by fundamentals. At the same time, market regulators should give serious thought to any proposal to ease margin requirements. Our results suggest that margin purchases can be destabilizing, resulting in excessive speculation.

FIGURE 1. Time Series of Median Transaction Prices, Standard Asset, NSS/B Treatment

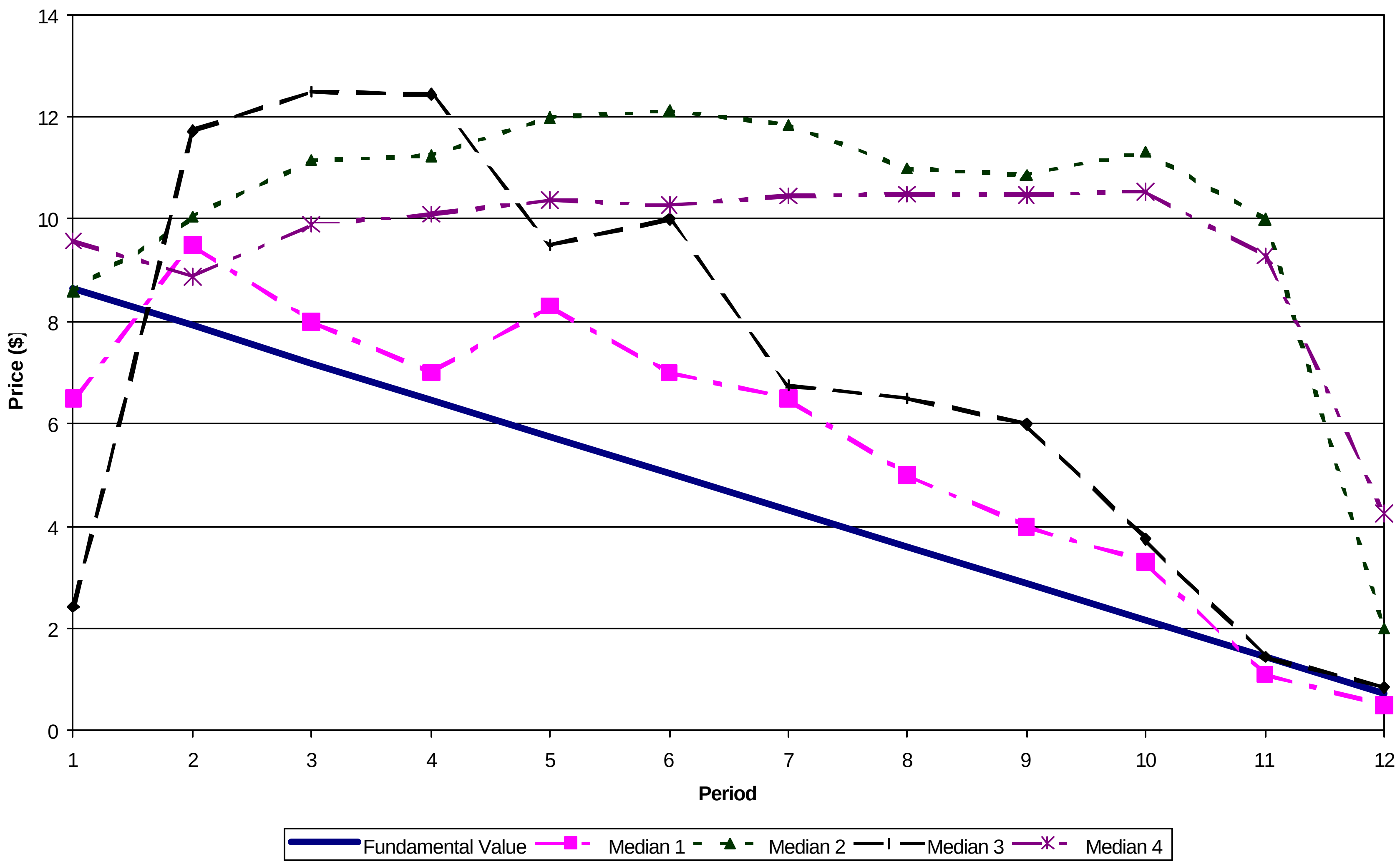


FIGURE 2. Time Series of Median Transaction Prices, Lottery Asset, NSS/B Treatment

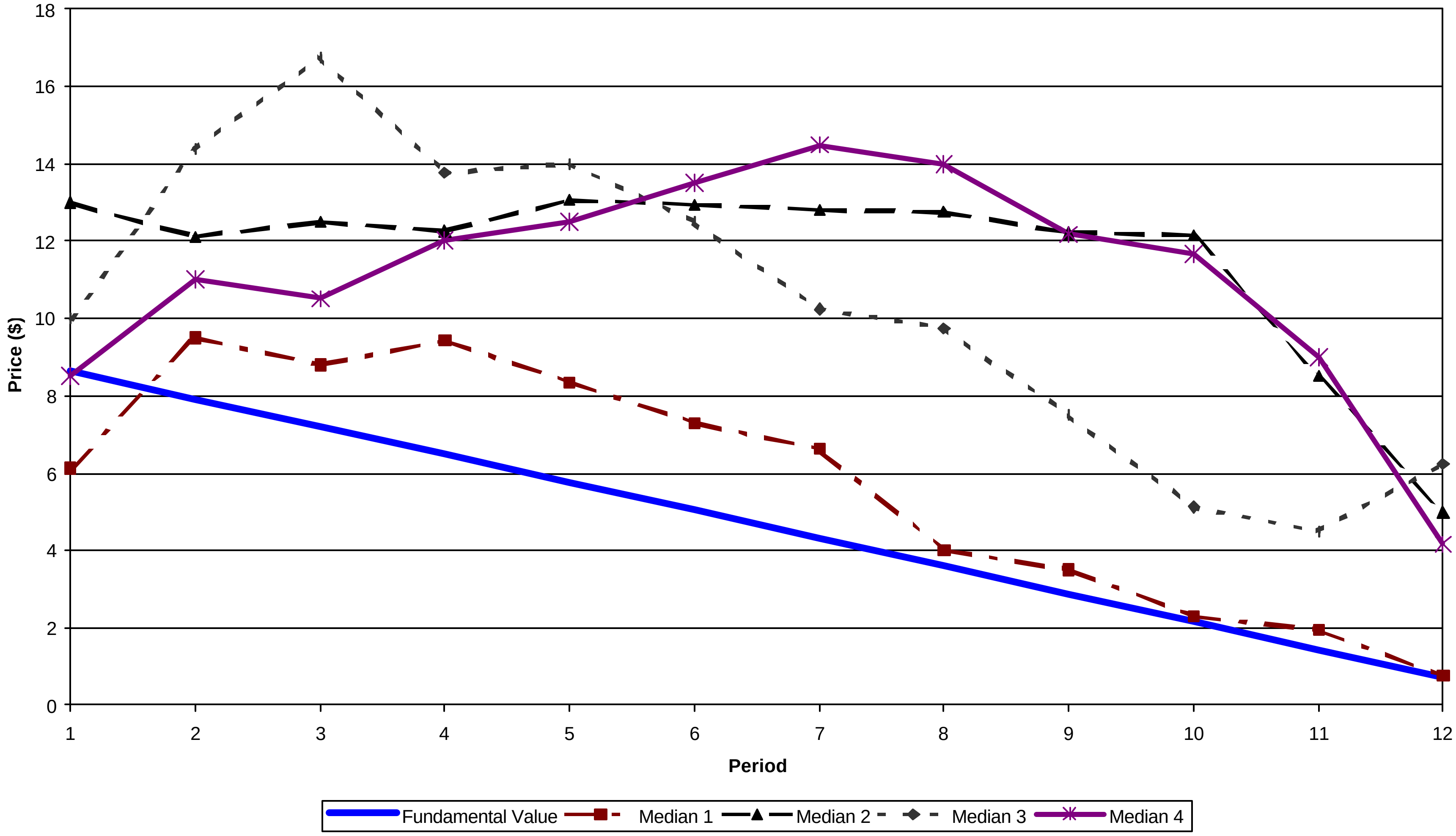


FIGURE 3. Time Series of Median Transaction Prices, Standard Asset, NSS/NB Treatment

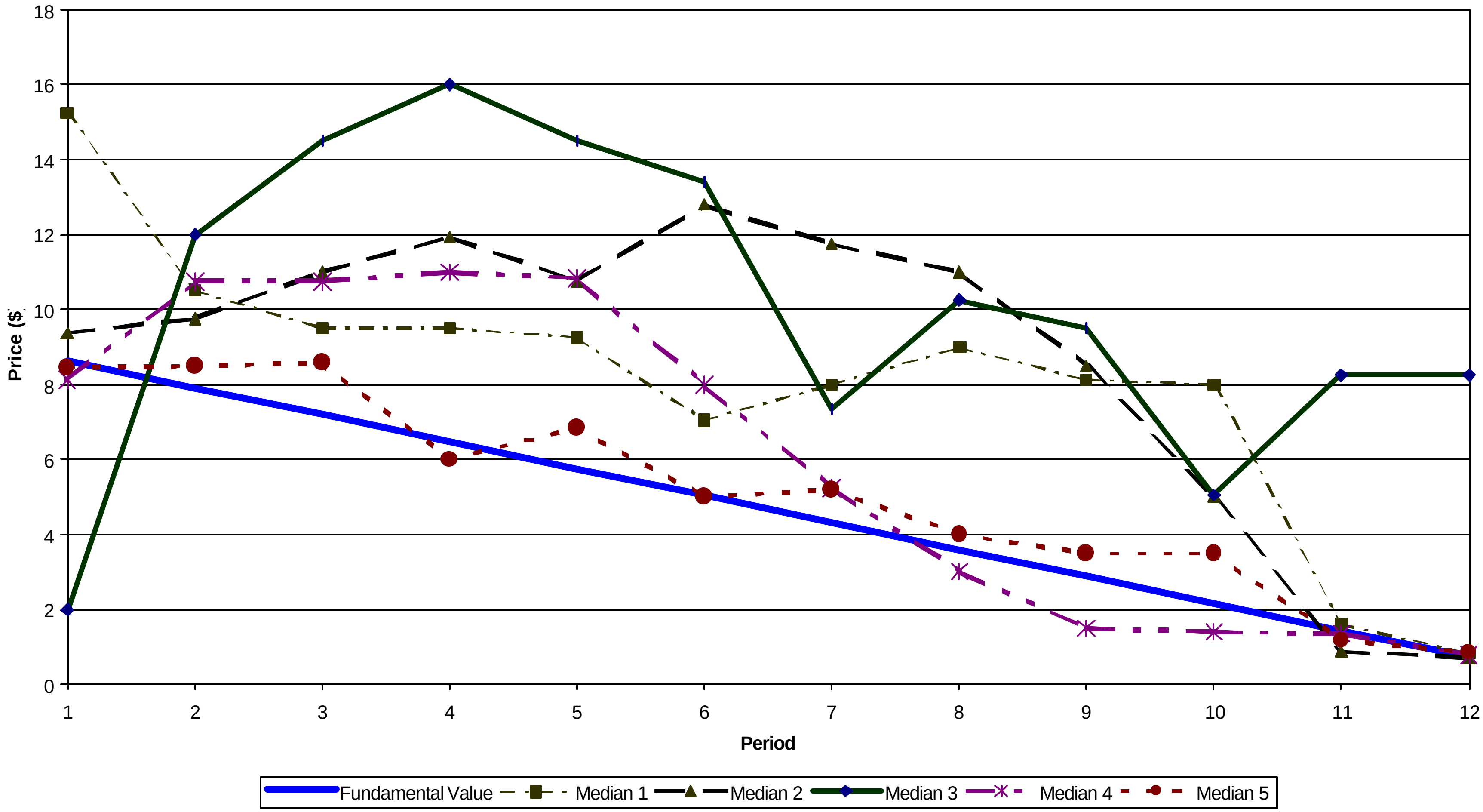


FIGURE 4. Time Series of Median Transaction Prices, Lottery Asset, NSS/NB Treatment

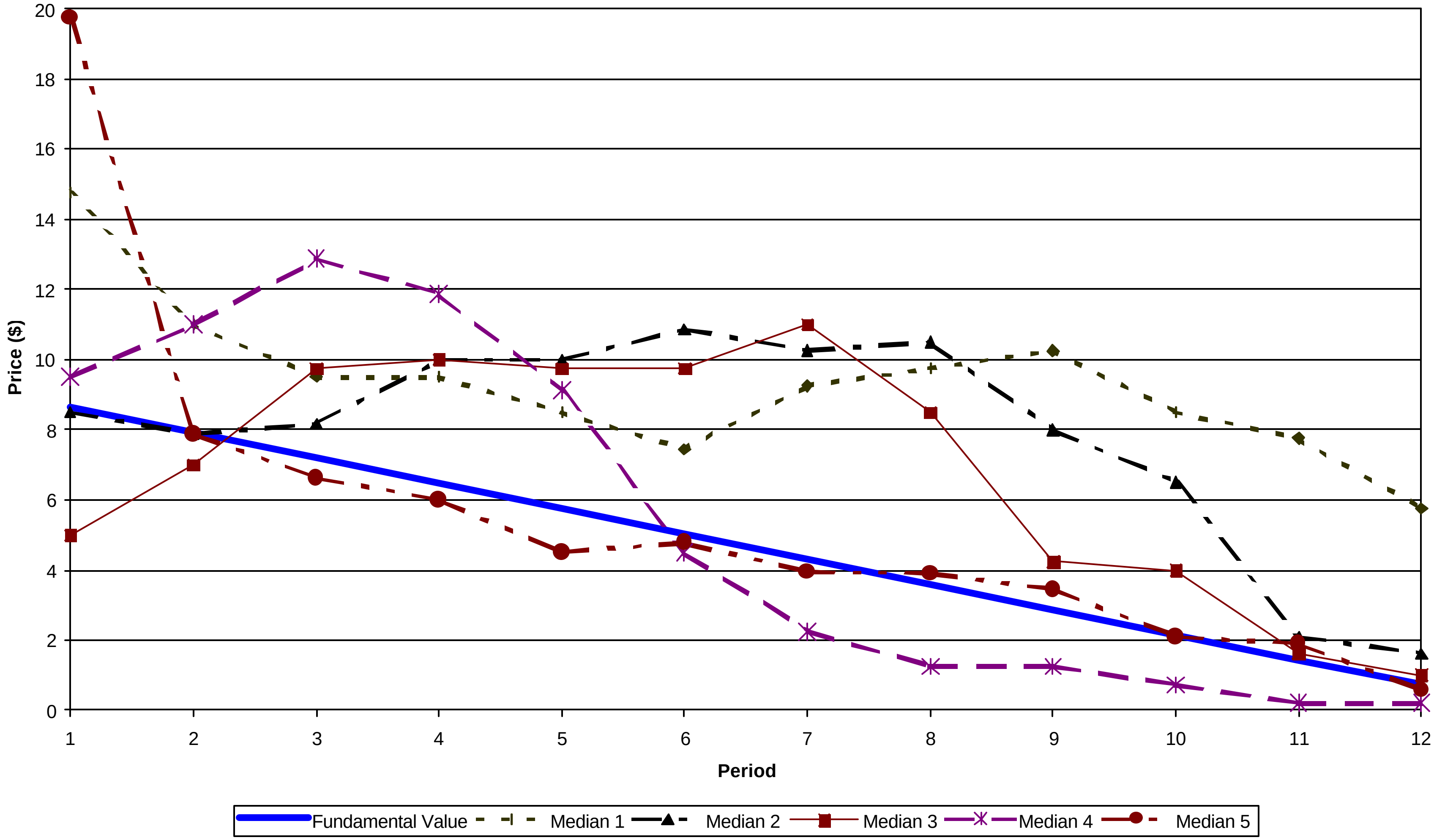


FIGURE 5. Time Series of Median Transaction Prices, Standard Asset, SS/NB Treatment

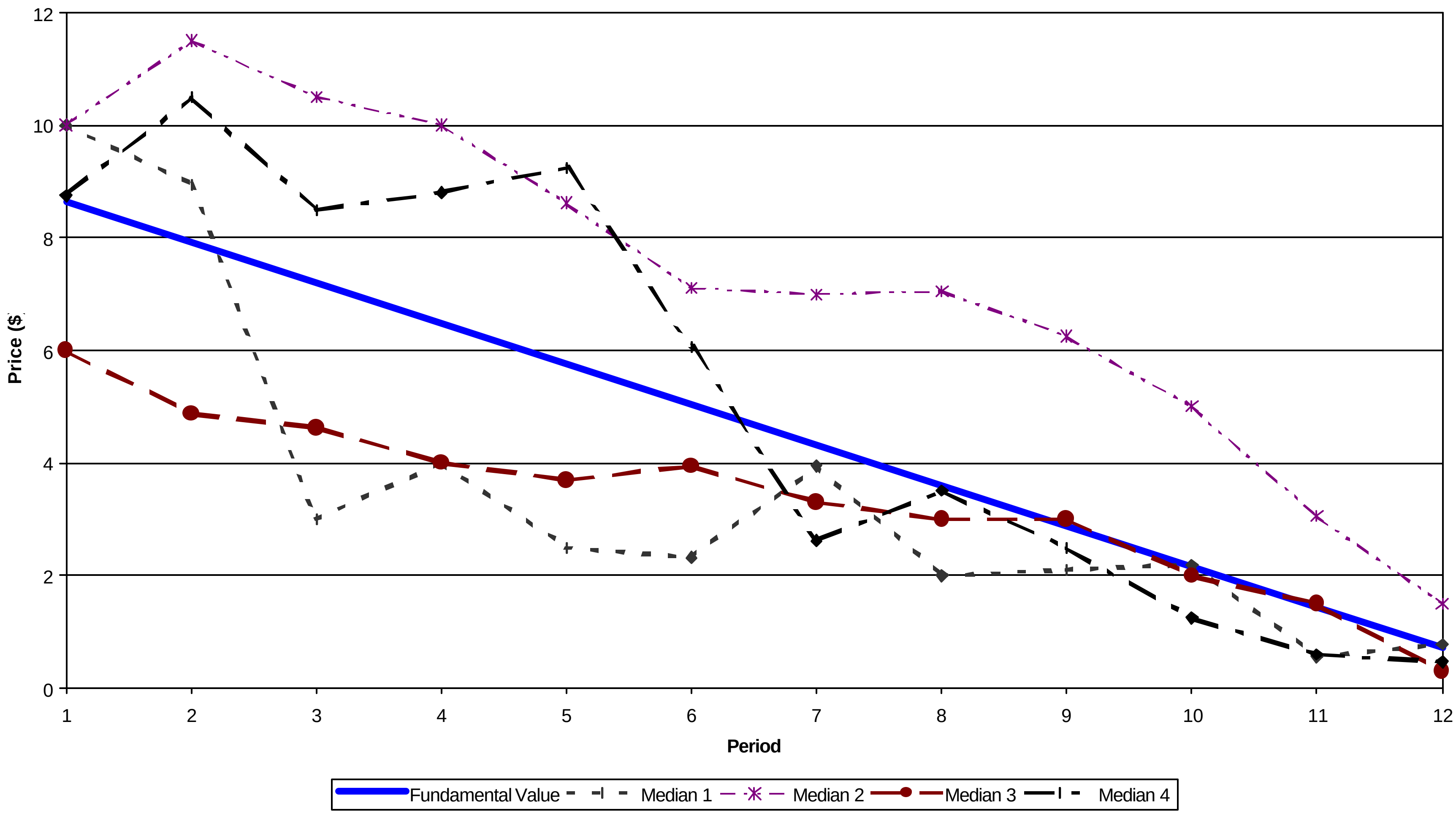


FIGURE 6. Time Series of Median Transaction Prices, Lottery Asset, SS/NB Treatment

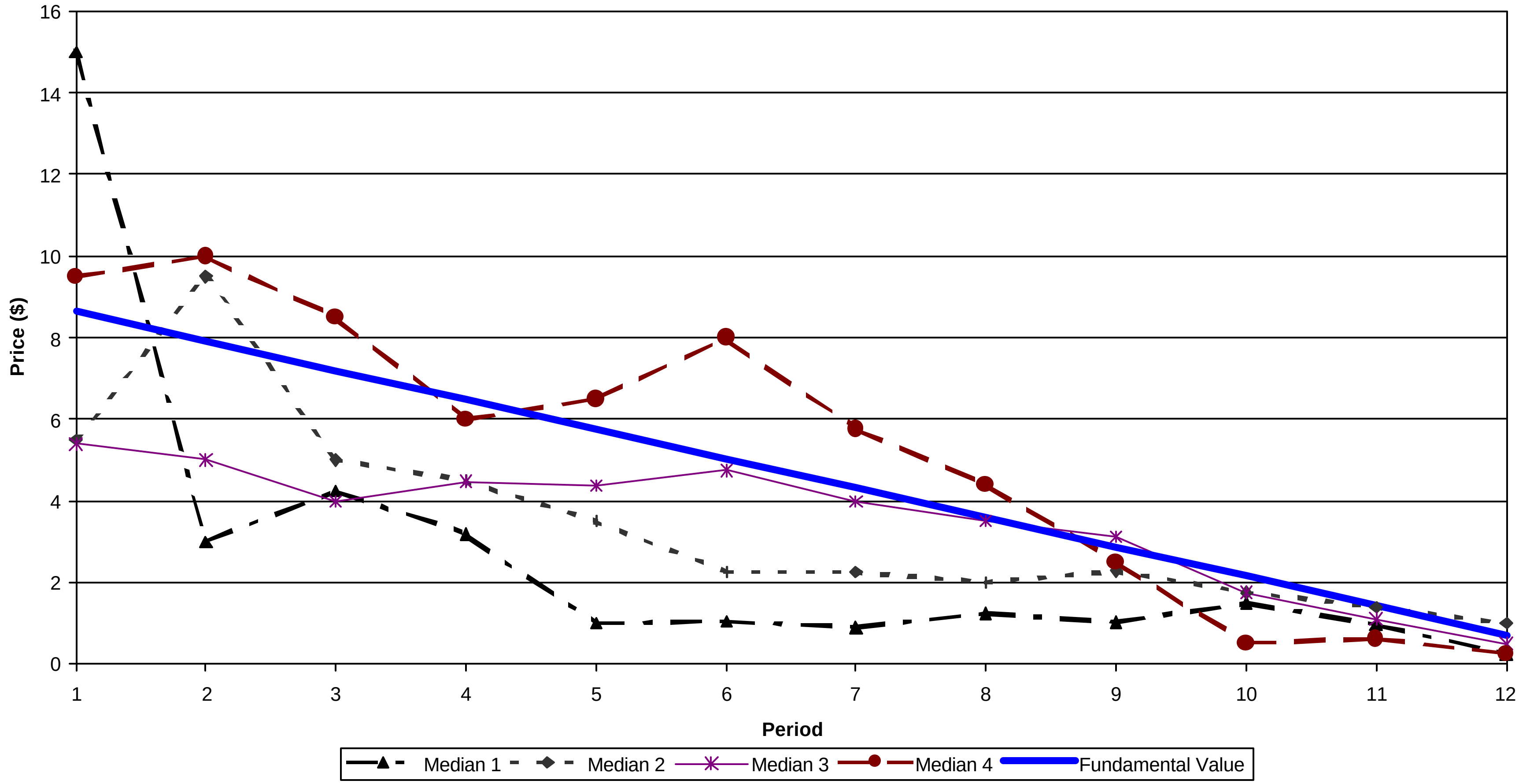
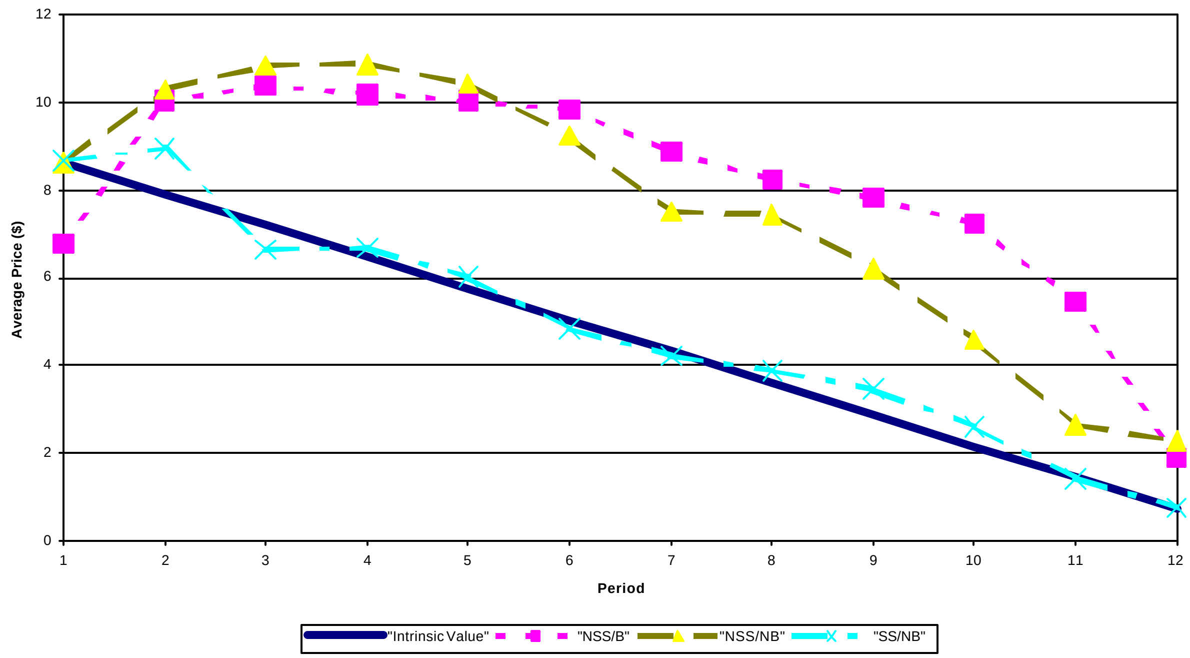


FIGURE 7. Average of Median Transaction Prices, Standard and Lottery Assets, All Treatments

Standard Asset



Lottery Asset

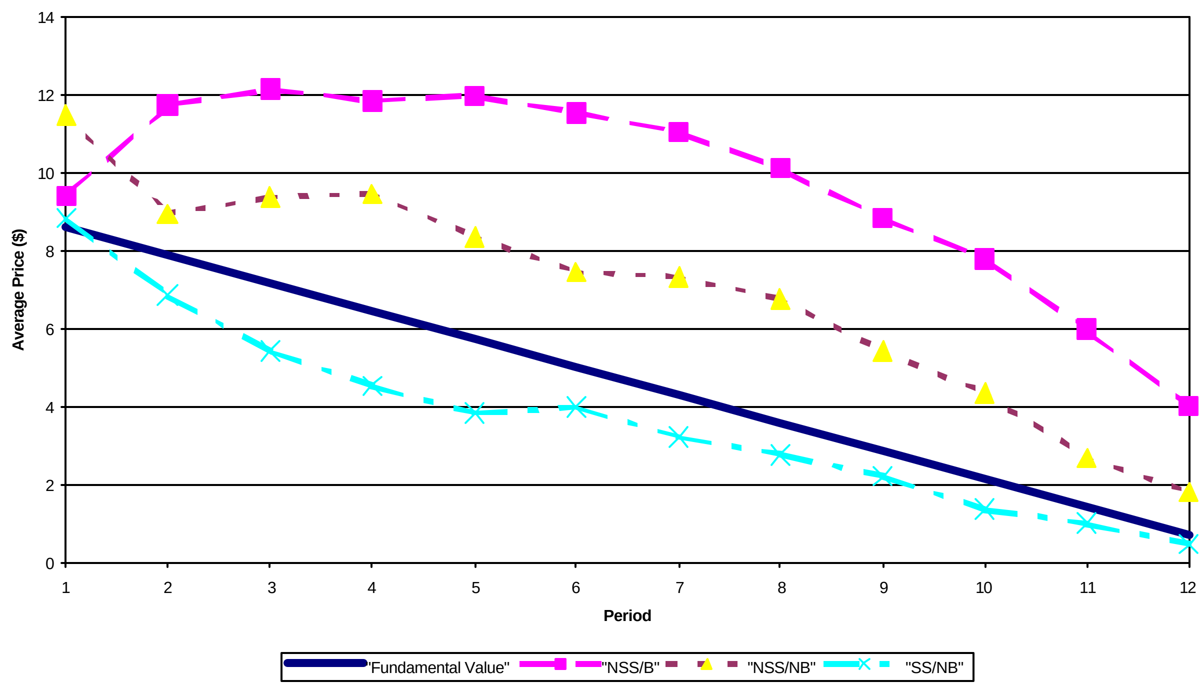


TABLE 1
Experimental Design

Session	Treatment	Number of Traders	Endowment			Borrowing	Short Selling
			Standard asset	Lottery asset	Cash		
1	NSS/B	8	2	2	$100	Yes	No
2		9	2	2	$100	Yes	No
3		7	2	2	$100	Yes	No
4		9	2	2	$100	Yes	No
1	NSS/NB	7	2	2	$40	No	No
2		9	2	2	$40	No	No
3		7	2	2	$40	No	No
4		9	2	2	$40	No	No
5		9	2	2	$40	No	No
1	SS/NB	7	2	2	$40	No	Yes
2		9	2	2	$40	No	Yes
3		9	2	2	$40	No	Yes
4		9	2	2	$40	No	Yes

Notes: (N)SS and (N)B denote (no) short selling and (no) borrowing.

TABLE 2
Distributions of Dividends

Asset Dividend Distributions				Expected Value of Dividends	Fundamental Value in Period 1
Probability	0.48	0.48	0.04	0.72	8.64
Standard asset's dividends	0.50	0.90	1.20		
Lottery asset's dividends	0.00	0.00	18.00		

Notes: The fundamental value in period 1 is the expected dividend per period multiplied by the number of trading periods (12).

TABLE 3
Transaction Volume

Panel A: Standard asset

	Treatment		
	NSS/B1-4	NSS/NB1-5	SS/NB1-4
p < min D	9 [4.5%]	10 [4.3%]	75 [26.8%]
min D ≤ p < FV	19 [9.5%]	41 [17.7%]	65 [23.2%]
FV ≤ p ≤ max D	85 [42.5%]	109 [47.2%]	90 [32.1%]
max D < p	87 [43.5%]	71 [30.7%]	50 [17.9%]
Total Number of Transactions	200	231	280
Turnover	2.99	2.75	3.99

Panel B: Lottery asset

	Treatment		
	NSS/B1-4	NSS/NB1-5	SS/NB1-4
p < min D	0 [0%]	0 [0%]	0 [0%]
min D ≤ p < FV	13 [8.9%]	44 [29.3%]	129 [63.9%]
FV ≤ p ≤ max D	133 [91.1%]	106 [70.7%]	73 [36.1%]
max D < p	0 [0%]	0 [0]	0 [0%]
Total Number of Transactions	146	150	202
Turnover	2.14	1.84	2.88

Notes: For each asset, the table reports the number of transactions at prices less than the minimum possible dividend payout (p < min D), between the minimum payout and the fundamental value (min D ≤ p < FV), between the fundamental value and the maximum possible dividend payout (FV ≤ p ≤ max D), and greater than the maximum possible payout (max D < p). The table also reports the total number of transactions and turnover, which is the normalized volume of trade.

TABLE 4
Summary Statistics

Panel A: Standard asset

	Treatment		
	NSS/B1-4	NSS/NB1-5	SS/NB1-4
Periods when median $P_t > FV_t$	10.7500	9.6000	6.0000
Positive Duration	4.5000	2.8000	1.5000
Peak Deviation	0.7557	0.6894	0.2473
Average Absolute Price Deviation	1.2074	0.9399	0.4037
Average Price Deviation	1.1444	0.8543	0.0518
Average Positive Price Deviation	1.1759	0.8971	0.2278

Panel B: Lottery asset

	Treatment		
	NSS/B1-4	NSS/NB1-5	SS/NB1-4
Periods when median $P_t > FV_t$	11.5000	8.2000	2.5000
Positive Duration	5.0000	3.6000	1.0000
Peak Deviation	0.9327	0.8735	0.3225
Average Absolute Price Deviation	1.7029	0.8520	0.3720
Average Price Deviation	1.6901	0.6735	-0.2376
Average Positive Price Deviation	1.6965	0.7627	0.0672

Notes: The table reports the number of periods in which the median price (P_t) exceeds the fundamental value (FV_t). Positive duration is the number of consecutive periods with price increases relative to fundamental value subject to the constraint that the increase produces a price that exceeds fundamental value. Peak deviation measures the magnitude of the bubble using the normalized peak deviation in price from fundamental value (maximum observed $(P_t - FV_t)/FV_1$). The average absolute and average price deviations measure price departures from fundamental value (FV_t). The average positive price deviation is the average deviation in price above fundamental value ($\max(0, (P_t - FV_t)/FV_t)$).

TABLE 5
The Effects of the Treatments on Deviations from Fundamental Value

Panel A: Parameter Estimates and p-values

	Standard asset	Lottery asset
Constant	0.8543 (0.019)	0.8434 (0.019)
DB	0.2901 (0.579)	0.8467 (0.084)
DSS	-0.8025 (0.126)	-1.0492 (0.032)
R^2	0.03	0.08
F-statistic	2.14 (0.121)	6.88 (0.001)

Panel B: Treatment Comparisons

	Standard asset	Lottery asset
NSS/B vs. NSS/NB	0.56 (0.579)	1.74 (0.084)
NSS/NB vs. SS/NB	-1.54 (0.126)	-2.16 (0.032)
NSS/B vs. SS/NB	1.99 (0.049)	3.70 (0.000)

Notes: For each asset, Panel A of the table reports the estimation results for an error components model. The dependent variable is the normalized price deviation from fundamental value. The independent variables include two dummy variables. The first measures the effect of the ability to borrow (DB) where the dummy takes the value of one when borrowing is permitted. The second measures the effect of the ability to short sell (DSS) where the dummy takes the value of one when short selling is permitted. The p-values are reported in parentheses below parameter estimates. In Panel B the table reports t-statistics for paired treatment comparisons, with p-values below in parentheses.

TABLE 6
The Determinants of Trading Profit

	Treatment			Overall
	NSS/B1-4	NSS/NB1-5	SS/B1-4	
constant	-3.9222 (0.000)	0.5350 (0.042)	-0.6381 (0.180)	-1.3819 (0.002)
accuracy	0.2737 (0.559)	-0.1860 (0.236)	0.4698 (0.122)	0.2137 (0.406)
%rational	8.5992 (0.000)	1.2174 (0.000)	2.1441 (0.000)	4.0172 (0.000)
R^2	0.63	0.42	0.36	0.35
F-statistic	25.16 (0.000)	13.96 (0.000)	8.84 (0.001)	28.44 (0.00)

Notes: For each treatment, the table reports the results of a regression of normalized profit on forecast accuracy (accuracy) and the percentage of rational trades (%rational). Normalized profit is a trader's profit over the session normalized by the payout that would have accrued had the trader followed a no trade strategy of holding the initial endowment. Forecast accuracy is the absolute value of the difference between a trader's forecast of the closing price and the closing price, scaled by the session's average absolute forecast error. The percentage of rational trades is calculated as the number of purchases at prices below fundamental value plus the number of sales above fundamental value, divided by the total number of trades. Numbers in parentheses are p-values.

TABLE 7
Effect of Short Sales on Trading Profit

Treatment	SS/NB1-4
Constant	-0.6631 (0.165)
Accuracy	0.5063 (0.085)
%rational(XSS)	1.8425 (0.001)
%rational(SS)*DSS	0.6461 (0.011)
R^2	0.44
F-statistic	7.89 (0.001)

Notes: For the treatment in which short sales are permitted, the table reports the results of a regression of normalized payout on forecast accuracy (accuracy), the percentage of rational trades excluding short sales (%rational(XSS)) and the percentage of rational short sales (%rational(SS)) times a dummy (DSS) that takes the value of one when a trader short sells at least one share. Profit is a trader's profit over the session normalized by the payout that would have accrued had the trader followed a no trade strategy of holding the initial endowment. Forecast accuracy is the absolute value of the difference between a trader's forecast of the closing price and the closing price, scaled by the session average absolute forecast error. The percentage of rational trades excluding short sales is calculated as the number of purchases at prices below fundamental value plus the number of sales above fundamental value, divided by the total number of trades, excluding any short sales. The percentage of rational short trades is calculated as the number of short sales above fundamental value, divided by the total number of short sales. Numbers in parentheses are p-values.

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ENDNOTES

[1] For a summary of Chairman Greenspan's remarks, see Mufson and Berry (1999).
[2] In some of Lei, Noussair, and Plott's markets, traders were buyers *or* sellers so that they could not buy with the intention of re-selling later.
[3] Gul's theory is not the first to model loss aversion. Kahneman and Tversky's (1979) prospect theory defines utility asymmetrically over losses and gains. Andrew Ang, Bekaert, and Liu (2000) detail the advantages of disappointment aversion over prospect theory. The theory of disappointment aversion compares gains and losses to a reference point that is endogenously determined.
[4] Standard preferences are a special case of disappointment aversion preferences. If individuals are disappointment averse, asymmetry over gains and losses results.
[5] Such behavior is also predicted by Kahneman and Tversky's rank-dependent prospect theory (1992).
[6] Simon and Ewing (2000) argue that purchasing stock on margin can magnify an investor's risk and return. The effect of margin requirements in derivative securities markets is also debated. For example, Weber (2000) expresses concern about margin requirements in futures markets.
[7] In addition, King, Smith, Williams, and Van Boening (1993) report that margin buying increases price bubbles in some markets.
[8] Lei, Noussair, and Plott (2001) conduct several markets in which participants finance trade with borrowed funds. However, the potential effect of borrowing on market behavior is not part of their experimental design and, thus, is not systematically examined.
[9] In our experiments, if a trader cannot return the borrowed funds at the conclusion of a trading session because his final cash balance is too low, trading profit is zero. Thus, it is possible for a trader to perceive that liability is limited. However, as in naturally occurring markets, bankruptcy is a real possibility.
[10] Brokers commonly impose short-selling restrictions. Ironically, while this research was in progress and prior to the publication of Shiller's book, a colleague of one of the authors attempted to short-sell stock in eToys. Believing it was surely over-priced the colleague decided to take action. However, his brokerage firm (a large, well known, firm with a national reputation) refused his request despite his good standing. Apparently, this stock was included on a list of stocks the firm would not allow even good clients to short sell. Of course, it may have been difficult for the brokerage to borrow shares of the stock if none were available in margin accounts.
[11] Short sellers are viewed with suspicion by other investors. In a 1996 *Business Week* article, short sellers are described as "mudslingers" and the "assassins of Corporate America" (Weiss (1996)). A more recent Wall Street Journal article notes that "shorts are reviled for profiting from other investors' misery" (Gasparino and McGough (2000)).
[12] Fine-tuning, additional clarification, and substantial changes were made in the instructions throughout pre-tests. In addition, significant procedural changes were made so the results of pre-tests are not presented. In one pre-test, subjects were not paid for their participation. In another, the order book depth was ten so that a bettered bid/ask stayed on the order book. In all other sessions depth was reduced from ten to one. This substantive procedural change was made to simplify matters for the participants who seemed to be confused by the order book. In two pre-test sessions, it became clear that the concept of short-selling was also difficult for participants to fully understand. Thus, in later sessions with short selling the instructions were expanded and

the experimenters devoted additional time to discussion of short-selling. In addition, to mitigate the bankruptcy risk inherent in short-selling, limits were placed on the number of shares that could be short sold and an ad hoc solvency check was instituted for traders with negative cash balances. These subjects' positive share holdings had to be sufficient to cover the negative cash balance, and failing that, no further trades were permitted.

[13] When no trade occurred in a period, the previous period's close was used. If this happened in the first period, this prediction was omitted from consideration.

[14] The instructions and experimental data are available from the authors upon request. In addition to the price prediction tickets, the envelopes contained a brief introduction to the session, a consent form, a post-experiment questionnaire, and a "price tracking sheet" which was a blank table that allowed subjects, if desired, to record closing prices and personal predictions.

[15] One trader in session SS/NB5 had a negative balance at the end of period 12. The negative balance resulted from paying dividends on shares sold short. This individual's trading profit was set to zero.

[16] In addition, there were several small bonuses and/or penalties. Traders arriving on time received a $2 bonus, and those who agreed to fill out the questionnaire also received a $2 bonus. One trader declined to complete the questionnaire. Further, a $5 penalty was levied on all those posting orders for more than a single share and for short positions in excess of five (during sessions SS/NB1-4).

[17] For example, exceeding the maximum possible price in period 1 would require trades above $216.00 when the fundamental value is $8.64.

[18] These bubbles measures differ from those proposed in other studies. For example, typically duration is calculated as the number of consecutive periods with price increases relative to fundamental value. If the price is below fundamental value, this measure includes a price movement toward fundamental value as evidence of persistence in a bubble. Yet, clearly such an observation does not provide evidence of a price bubble.

[19] Inferences are similar to those reported subsequently if the dependent variable is defined as the absolute price deviation or as the average positive price deviation. Recall that the latter definition focuses on periods in which price exceeds fundamental value.

[20] Note that the p-value for the NSS/B vs. NSS/NB comparison is identical to the p-value for the DB coefficient. This is because the latter coefficient constitutes an intercept shift associated with a move from NSS/NB to NSS/B. Similarly, the p-value for the NSS/NB vs. the SS/NB comparison is identical to the p-value for the DSS coefficient.

[21] Average absolute forecast error is a natural scaling variable because of its link to participants' compensation. A $20 bonus was paid to the participant in each session with the smallest total absolute prediction error.

[22] Clearly this measure of rational trading activity is imperfect. One can envision trades that are irrational and yet classified as rational, or rational trades classified as irrational. For example, it may be rational to buy above fundamental value in the belief that others will continue to bid the price up (Smith, Suchanek, and Williams, 1988). On the other hand, selling below fundamental value may be rational for a trader with a sufficiently high level of risk aversion. Nevertheless, we utilize this measure because of its simplicity.