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Margin, Short Selling, and Lotteries in Experimental Asset Markets

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The robustness of bubbles and crashes in markets for assets with finite lives 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 pay 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

1. Introduction

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), the stock market boom and crash of the 1920s (Kindleberger 1989; Garber 1990; White 1990), and, more recently, the dramatic increase and subsequent decline in the prices of Internet stocks in the late 1990s. Federal Reserve Chairman Alan Greenspan, commenting on the Internet stock bubble, suggested that the observed price behavior might reflect a lottery effect whereby market participants are willing to pay a premium for some stocks because, though the chance is small, a very significant payoff is

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possible.[1] Downs and Wen (2001) provide evidence of a persistent lottery premium in the stock market.

Prior laboratory studies have examined price bubbles in experimental markets with a *standard* asset—one that pays a positive dividend regardless of the state of nature. We extend this line of research by including a *lottery* asset—one that offers a small probability of a large dividend, but otherwise nothing. As discussed subsequently, individuals may be risk-seeking when it comes to an asset with lottery characteristics, which in turn can lead to a more pronounced price bubble. We conduct 13 experimental markets, each of which includes a standard asset *and* a lottery asset, to compare the occurrence of price bubbles across the two assets.

In addition to including an asset with lottery characteristics, we re-examine whether price bubbles are moderated by two institutional design features: borrowing and short selling. The findings of Caginalp, Porter, and Smith (1998, 2000a, 2000b, 2001) suggest that price bubbles are inflated when cash is injected in the market. Furthermore, price bubbles may increase as the ratio of available cash to available shares increases. Borrowing (i.e., margin purchases) and short selling are two important institutional features that affect this ratio. In our design, borrowing (or allowing margin purchases) provides traders with access to additional cash, whereas short selling allows traders to transact additional shares. We investigate whether price bubbles are affected by these two institutional features and test whether the effect differs for the standard versus lottery asset.

The results indicate that when margin buying is allowed and short selling is prohibited, price bubbles are observed for both assets and are larger for the lottery asset than the standard asset. When margin buying is restricted, price bubbles are dampened slightly and differences between the standard and lottery asset disappear. When margin buying is restricted *and* short selling is allowed, price run-ups and crashes are not observed for either asset. Moreover, the effect is more pronounced on the lottery asset than the standard asset. In some markets, the lottery asset trades at prices well below fundamental value (Haruvy and Noussair 2004).

The remainder of this paper is organized as follows. Section 1 provides background and motivation for the study. Section 2 describes the experimental procedures and design. Section 3 reports the results. Section 4 contains a discussion of the results and concluding remarks.

2. Regularities, Institutional Features, and New Questions

Smith, Suchanek, and Williams (1988) first report bubbles in experimental asset markets. In their study, subjects trade an asset over a finite horizon. The asset had 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 their experiment, 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 (2001), and Lei, Noussair, and Plott (2001), among others. King et al. (1993) investigate whether bubbles are moderated by several treatment variables, including the

[1] For a summary of Chairman Greenspan's remarks, see Mufson and Berry (1999).

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 (1988, 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. However, Lei, Noussair, and Plott (2001) report bubbles in markets in which speculation is not possible, suggesting that a subset of traders behaves irrationally.

What appears to be irrational valuation is also reported in naturally occurring markets. Many argue that instances of mispricing of Internet stocks were abundant in the late 90s.[2] Yet, such 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 (i.e., either zero or a large positive payoff).[5] In this paper, we investigate whether behavior is consistent with a preference for this type of payoff 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 the payoff is zero. If traders are risk-preferring for the lottery-type asset, it should trade at prices that reflect a lottery premium and the premium should exceed that for the standard asset. This leads to the following proposition:

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[2] 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 valuations appear to be incongruous with the performance of each company.

[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. 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 (1992) rank-dependent prospect theory.

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

We also investigate the effect of institutional features on the occurrence of price bubbles. In our base set of markets, traders can finance purchases of the two assets using borrowed funds, with short sales prohibited. The initial treatment provides conditions that are conducive to producing price bubbles and permits a basis to compare the price behavior of the standard and lottery assets. In subsequent markets, we vary the institutional features to determine whether price bubbles can be eliminated. First, we prohibit borrowing, and thus reduce the cash available in the market. Next, we introduce short sales, which increase the number of shares that can be transacted: a trader can sell shares that are not owned as long as the trader covers the dividend on the shorted shares. The effect of borrowing and short sales are discussed later.

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. King et al. (1993) also report that margin buying increases price bubbles in some markets.

In experimental studies where bubbles are reported, traders 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 (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.[7] We conduct some market sessions in which traders use borrowed funds to finance trade and, as a result, have much greater scope for acquiring shares.[8] In other market sessions, traders are endowed with cash that is theirs to keep. By design, we make more cash available to traders when margin buying is allowed than not allowed, as is the case in naturally occurring markets. We investigate whether prohibiting margin buying has a different effect on the price behavior of the standard and lottery assets. We do not have a basis to predict a difference and, as a consequence, test whether prohibiting margin buying moderates price bubbles in markets for both assets. The second proposition is as follows:

Proposition 2. If traders are not permitted to purchase assets on margin, 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

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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 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.

8 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.

proceeds.[9] 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.[10] 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. This amount is then paid to the lender of the stock. In our markets, short sellers effectively borrow stock from the experimenters and must cover dividends paid on shares shorted. As such, the numbers of shares that can be transacted is increased, with the total cash in the market being unaffected.

King et al. (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 et al. 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 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. In a more recent investigation of short sales, Haruvy and Noussair (2004) find that bubbles are dampened when traders have the ability to short sell.

We investigate whether allowing short sales, in addition to restricting margin buying, affects the price behavior of the standard asset differently from that of the lottery asset. As before, we do not have a basis to predict a difference and, thus, test whether introducing short sales mitigates price bubbles for both assets. The third proposition is as follows:

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

[9] 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.

[10] 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).

Table 1. Experimental Setup

Panel A: Experimental Design[a]

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

Panel B: Distribution of Dividends[b]

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		–

[a] In panel A, (N)SS and (N)B denote (no) short selling and (no) borrowing.

[b] In panel B, the fundamental value in period 1 is the expected dividend per period multiplied by the number of trading periods (12).

3. Experimental Method

Nature of the Experiments

The asset market experiments were conducted in the Educational Trading Center at McMaster University. Thirteen market sessions were conducted (in addition to four pre-tests). The experimental design, summarized in panel A of Table 1, includes markets with no short sales and borrowing (NSS/B), markets with no short sales and no borrowing (NSS/NB), and markets with short sales and no borrowing (SS/NB).

Between seven and nine traders participated in each session. All subjects were sophomore, junior, or senior undergraduate business or economics students. All were inexperienced in that none had participated in an earlier session. Students earned from $0 to $148 Canadian dollars for participating, with an average (median) payout of $60.92 ($61.00). Each market session consisted of 12 five-minute periods, organized as computerized double auction markets using the *Financial Trading System* (*FTS*) platform. The *FTS* platform allows subjects to transact in real time over a number of market periods. Subjects can post bids and asks and also act as price-takers. For all sessions, the order book was assigned a depth of one, and traders were permitted to transact each asset one unit at a time.

At the beginning of each session, participants were endowed with two shares each of two securities, referred to in the sessions as stocks A and B. The two stocks represent the standard and lottery assets, respectively. At period end, each asset paid a dividend that was randomly determined using the distributions reported in panel B of Table 1. Dividend draws were cross-sectionally and intertemporally independent. Though the spreads of the dividend distributions are quite different, the expected dividend for both stocks is identical at \$0.72 per period. With 12 periods, both assets have an initial fundamental value of $12 \times 0.72 = \$8.64$. 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.

In the NSS/B treatment, subjects were endowed with \$100, which had to be returned at the end of the session—the \$100 represented borrowed funds. If the final cash balance was below \$100, trading profit was \$0. In the NSS/NB treatment, subjects were endowed with \$40 in cash that did not have to be returned—the funds were theirs to keep. Note that when borrowing is prohibited (NSS/NB), the total available funds in the market are reduced, which has the effect of imposing an institutional constraint on margin purchases. In the SS/NB treatment, subjects were endowed with \$40 of cash that did not have to be returned and short selling was allowed. Shares sold short were not borrowed from other traders, but rather from the market.[11] A trader in a short position was required to pay the relevant dividend. Based on pretests, a short position limit of five shares per security (at period end) was imposed.[12]

In addition to trading the standard and lottery assets, subjects made price predictions. At the beginning of each period, traders recorded their prediction of each asset's closing price for the coming period. The subject with the lowest total absolute prediction error across all 12 periods was paid a \$20 bonus.[13,14]

Conduct of Sessions

Upon arrival, subjects received a set of instructions and were given 20 minutes to read through them.[15] Thereafter, one of the experimenters did an extensive recap while addressing all procedural and technical questions. The sessions generally required 2½ to 3 hours to complete.

At the beginning of each period, subjects predicted the period-end closing price for each asset, after which trading commenced. Four items of information (per security) were announced and publicly recorded at period end: the closing price (if 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). The procedures were repeated each period over the course of the experiment.

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[11] Short sellers of stock in U.S. secondary markets must make an affirmative determination before selling short. In other words, the trader must identify borrowable shares. In our markets, no such identification is necessary as short sellers are free to borrow up to five shares from the experimenter. Thus, in our experiment short selling takes no more effort than selling shares already owned.

[12] Six of 35 participants reached the short sale limit of five shares.

[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 bonus for the price prediction exercise was chosen with two competing effects in mind. First, the compensation should be salient enough so that participants attend to the task. Second, the price prediction exercise should not be so large as to cause distortions in the market for the two assets, wherein participants attempt to control end-of-period prices. Based on pre-tests, a bonus of \$20 seemed to balance these two goals. See also Williams (1987) who considers whether experimental participants' price forecasts are consistent with economic theory.

[15] The instructions are available from the authors upon request.

At the conclusion of the session, the final cash balance was (privately) displayed on a subject's computer screen. For Sessions NSS/B1–4, a trader's profit was the maximum of zero and the final cash balance less the cash endowment of $100.[16] For Sessions NSS/NB1–5 and SS/NB1–4, the final cash balance represented trading profit.[17] 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.

4. Market Behavior

In this section, we provide descriptive data to assess price behavior for Sessions NSS/B, NSS/NB, and SS/NB. For each market set, we plot the median price per period, provide data on the frequency of transactions at prices above and below fundamental value, compute several bubble measures, and conduct nonparametric tests to determine whether deviations from fundamental value differ between the standard and lottery asset. Next, we present the results of a time-series, cross-sectional regression model, which allow us to make comparisons across market sets. The regression model provides the basis to formally assess the effect of borrowing and short selling on price behavior.

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 nor were participants permitted to finance trade with borrowed funds. Consistent with earlier research, prices clearly exhibit substantial deviation from fundamental value.[18]

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. Figure 2 shows similar price paths for the lottery asset, with large deviations in prices from fundamental value. Moreover, prices appear to reach an even higher level for the lottery asset.

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[16] Eight participants in the NSS/B treatment were unable to repay the $100 loan. It is possible that these traders' incentives to behave rationally were compromised when they realized they could not repay the $100 loan and would accrue zero trading profits. If so, this is a potentially contributing factor to the formation of price bubbles.

[17] One trader in session SS/NB4 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.

[18] Caginalp et al. (2002) report the results of an experiment in which multiple assets trade. One asset, referred to as speculative, has higher volatility in returns. They report that liquidity is drawn toward the speculative asset, resulting in a lower price for the other asset. We find significant bubbles for both assets in our experiment in the NSS/B treatment.

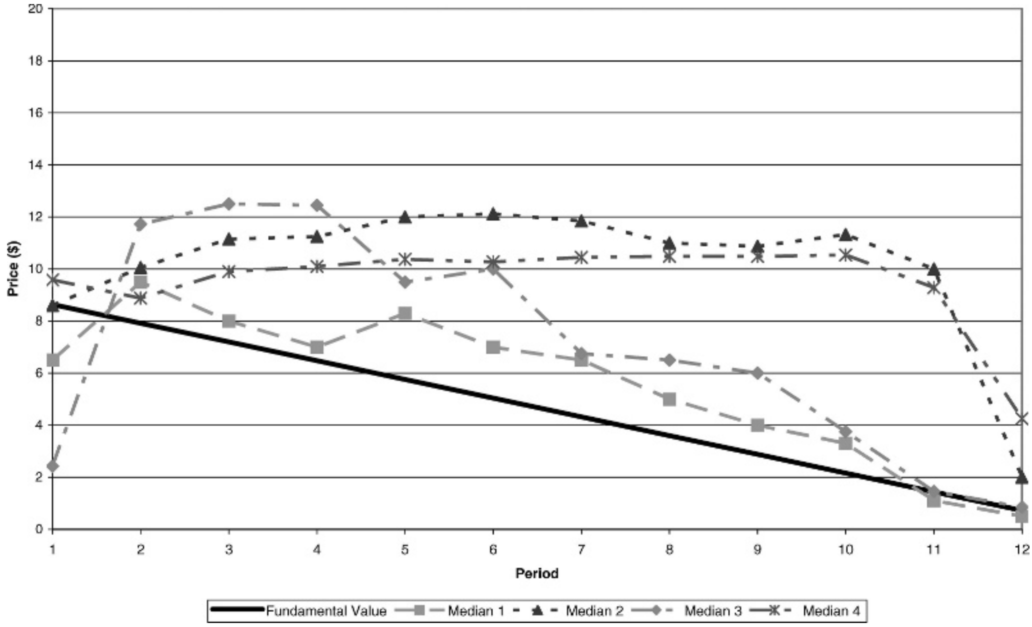

Figure 1. Time Series of Median Transaction Prices, Standard Asset, NSS/B Treatment

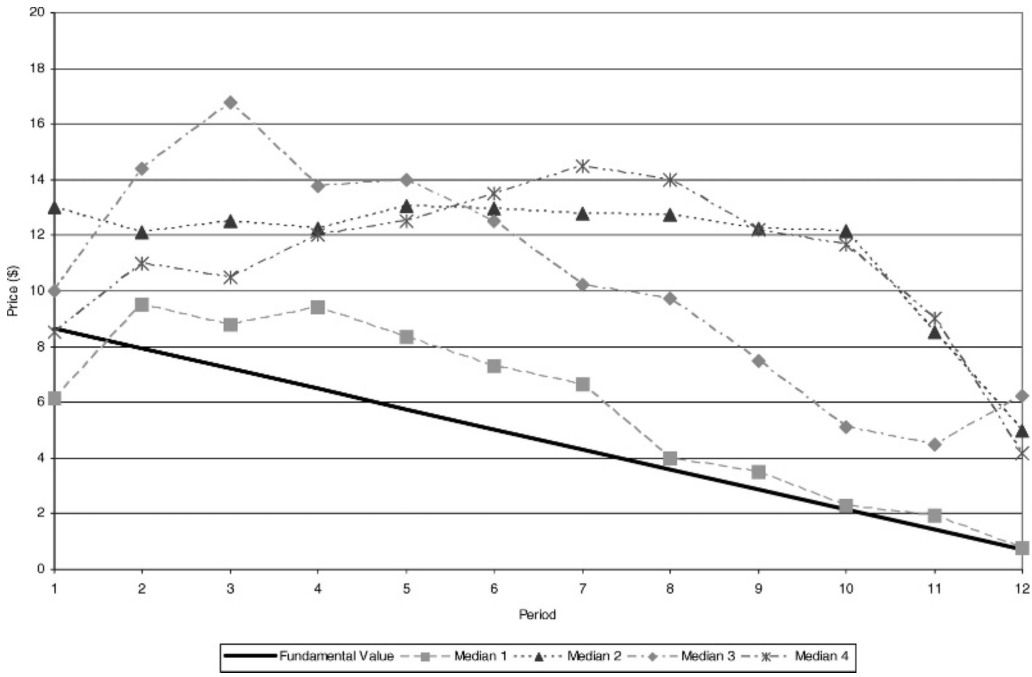

Figure 2. Time Series of Median Transaction Prices, Lottery Asset, NSS/B Treatment

Table 2. 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

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, normalized by the fundamental value $((P_t - FV_t)/FV_t)$. The average positive price deviation is the average deviation in price above fundamental value $(\max(0, (P_t - FV_t)/FV_t))$.

Inspection of the transaction price data indicates that, for both assets, the vast majority of trades occur at prices above fundamental value: 86% for the standard asset and 91.1% for the lottery asset. In addition, 48% of the trades involving the standard asset occur at prices outside the feasible range of future dividends, with 43.5% at prices above the maximum possible dividend payout.[19] This finding is consistent with Lei, Noussair, and Plott (2001).

Table 2 reports several summary statistics on the deviations in price from fundamental value. The empirical measures assume risk neutrality and are designed to gauge the bubble in asset price (if one is observed). For NSS/B1–4, the summary statistics are consistent with the first proposition: the price bubble is larger for the lottery asset than the standard asset. Wilcoxon matched-pairs tests indicate that the price deviation of the lottery asset exceeds that of the standard asset at the 1% level, using the average price deviation, the average absolute price deviation, and the average positive price deviation. Hence, price bubbles are more pronounced for the lottery asset than the standard asset.

[19] For the lottery asset, no trades occur 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. For example, exceeding the maximum possible price in period 1 would require trades above $216.00 when the fundamental value is $8.64.

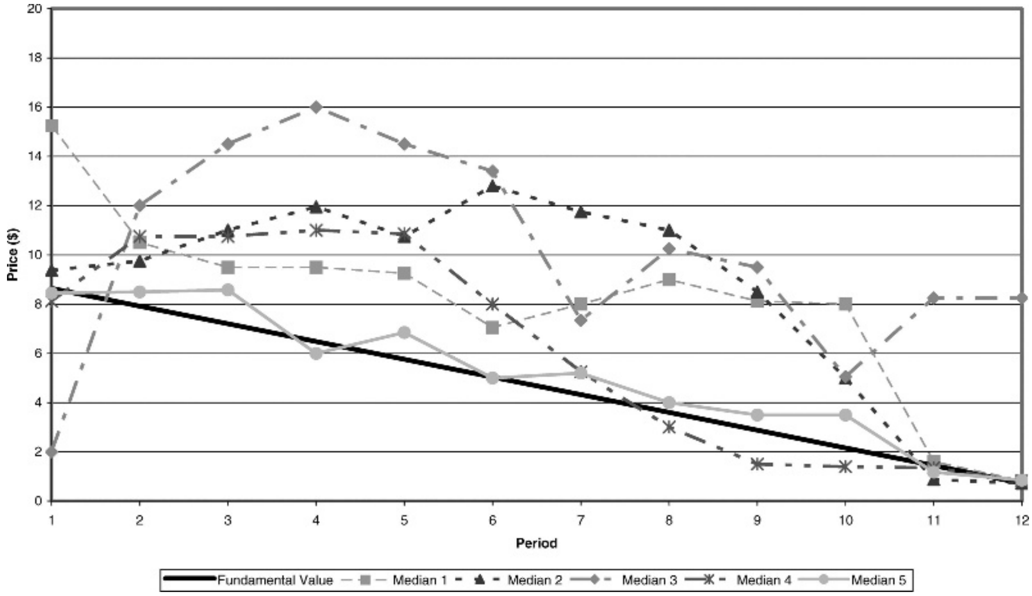

Figure 3. Time Series of Median Transaction Prices, Standard Asset, NSS/NB Treatment

Results for the NSS/NB Sessions

In the next set of sessions, participants were not permitted to finance trade with borrowed funds (i.e., margin purchases were not permitted). 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

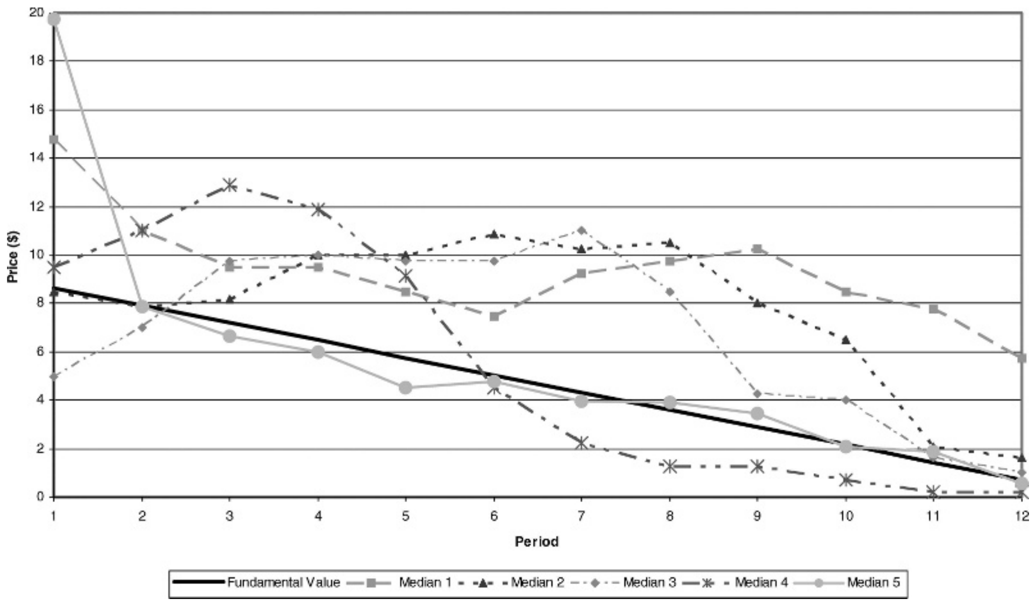

Figure 4. Time Series of Median Transaction Prices, Lottery Asset, NSS/NB Treatment

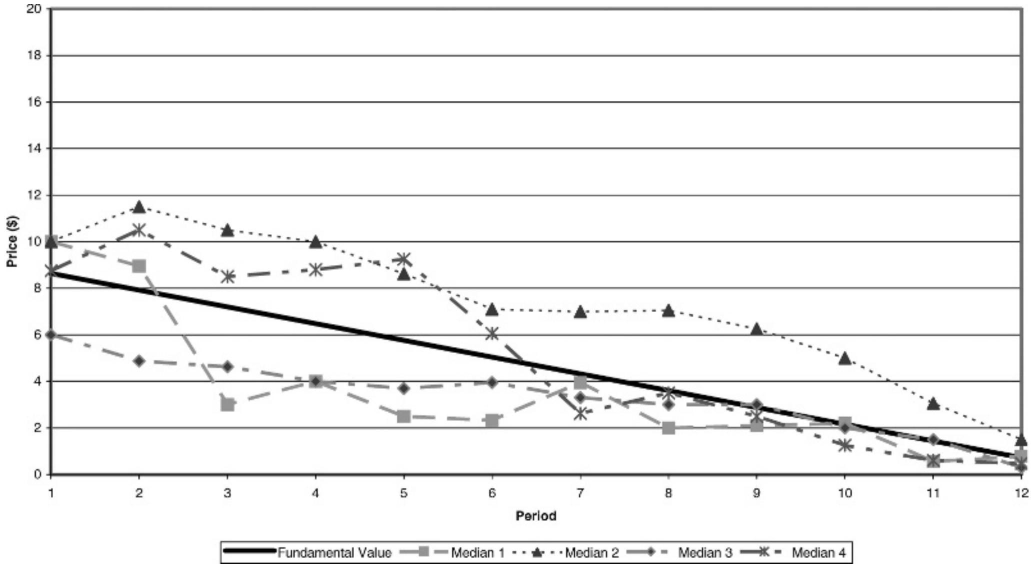

Figure 5. Time Series of Median Transaction Prices, Standard Asset, SS/NB Treatment

trading. Noticeably though, price bubbles do not appear to be magnified for the lottery asset as compared to the standard asset.

The transaction price data indicate that most trades occur at prices above fundamental value: 77.5% for the standard asset and 70.7% for the lottery asset. For the standard asset, 35% of the trades occur at prices outside the feasible range of future dividends, with 30.7% at prices above the maximum possible dividend payout. The bubble measures reported in Table 2 are consistent with price bubbles, though not indicative of differences between the standard and lottery asset. Wilcoxon matched-pairs tests indicate that none of the price deviation measures (average absolute, average, and average positive deviation) are significantly different at the 5% level when comparing the standard and lottery asset. When traders must finance asset purchases themselves (i.e., borrowing is not allowed), bubbles are not exacerbated for the lottery asset as compared to the standard asset, which is contrary to the first proposition.

Results for the SS/NB Sessions

In the third 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.[20] In fact, we sometimes observe trading below the fundamental value for both assets.

[20] In conducting our analysis, we examined the demographic data collected in the post-experiment questionnaire for systematic relationships. Parametric and nonparametric tests indicated that men's trading earnings exceeded women's in only the short selling treatment. The significant difference in the trading earnings of men and women in the SS/NB sessions appears to be driven by men's willingness to short sell. Although 44% of the participants were male, men executed 58% of the short sales. More importantly, the average percentage of short sales that were rationally traded was 56% for men and 10% for women, where rational trades are defined as purchases (sales) below (above) fundamental value.

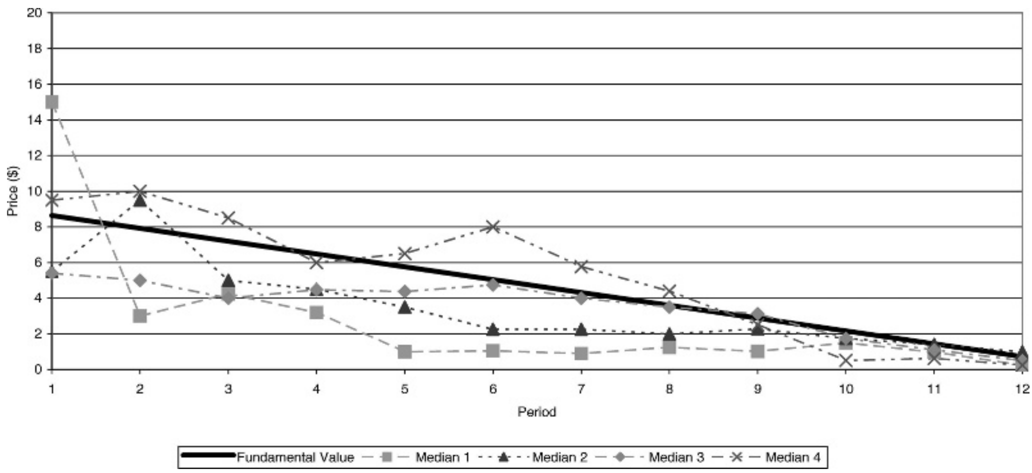

Figure 6. Time Series of Median Transaction Prices, Lottery Asset, SS/NB Treatment

The transaction price data indicate that many trades occur at prices *below* fundamental value: 50% for the standard asset and 63.9% for the lottery asset. For the standard asset, 44.7% occur at prices outside the feasible range of future dividends, with 26.8% at prices *below* the minimum possible dividend payout. From Table 2, the bubbles measures are dampened consistently for both assets as compared to the first two treatments. Moreover, the price deviations from fundamental value are *less* for the lottery asset than the standard asset. Wilcoxon matched-pairs tests indicate that the differences are significant at the 1% level for the average price deviation and the average positive price deviation. The data suggest that when short selling is permitted, the asset with lottery characteristics trades at a discount. Haruvy and Noussair (2004) also provide evidence that short selling can lead to prices below fundamental value. Importantly, although large upward price deviations are not observed in the SS/NB treatment, we do not necessarily observe prices that closely track fundamental value.[21]

Results of Comparisons across Treatments

Figure 7 summarizes asset price behavior across all 13 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 appear to be moderated when traders must finance their own trade *and* short sales are permitted.

To examine more formally 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. We estimate the model

$$\mathrm{NPD}_{i,t} = \beta_0 + \beta_1 \mathrm{DB}_{i,t} + \beta_2 \mathrm{DSS}_{i,t} + e_{i,t}$$

separately for the standard and lottery asset. In each case, the dependent variable is the normalized price deviation (NPD) from fundamental value. The independent variables include

[21] Haruvy and Noussair (2004) report a greater frequency of negative bubbles than we find in our experiment. For the standard asset, two of four markets can be characterized as generating persistent deviations below fundamental value. Future research is required to understand the source of this disparity.

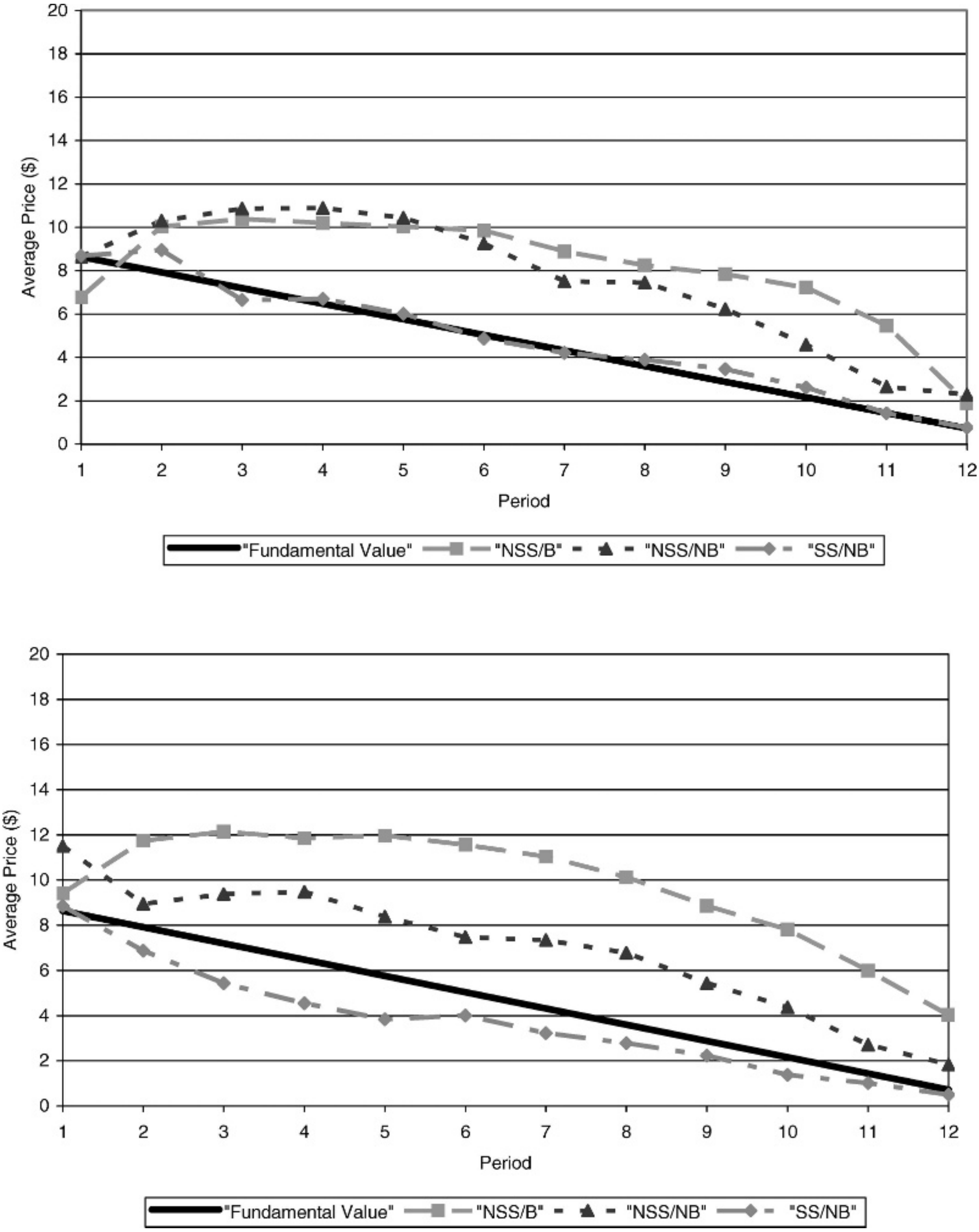

Figure 7. Average of Median Transaction Prices, Standard and Lottery Assets, All Treatments

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. 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. The model assumes that the regression disturbance, $e_{i,t}$, is composed of

Table 3. 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 (0.289)	0.8467 (0.042)
DSS	−0.8025 (0.063)	−1.0492 (0.016)
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	1.74
NSS/NB vs. SS/NB	−1.54	−2.16**
NSS/B vs. SS/NB	1.99*	3.70***

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. The p-values reported in panel A are one-sided values: borrowing restrictions and short selling are expected to dampen price bubbles. In panel B, the table reports t-statistics for paired treatment comparisons. The critical values used to determine statistical significance were computed using the Bonferroni procedure, which controls for simultaneous comparisons. As before, the p-values in panel B are one-sided values.

* Significance at $p < 0.10$.
** Significance at $p < 0.05$.
*** Significance at $p < 0.01$.

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 3 reports the estimation results of the error components model, with p-values reported in parentheses below parameter estimates.[22] Panel B of Table 3 reports t-statistics for pairwise comparisons across the experimental treatments. To determine statistical significance, we compute critical values using the Bonferroni procedure, which controls for simultaneous comparisons (Hollander and Wolfe 1999).

For the standard asset, the results of the error components model indicate that the ability to short sell moderates price deviations from fundamental value, producing a marginally significant effect at the 6.3% level (one-sided p-value). This result provides weak evidence in support of the third proposition. The pairwise comparisons indicate that the price deviation is less in the SS/NB1–4 sessions than in the NSS/B1–4 sessions ($p = 0.072$, one-sided p-value). Borrowing restrictions and the ability to short sell, *in combination*, are necessary to dampen

[22] 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. The latter definition focuses on periods in which price exceeds fundamental value.

price bubbles when making comparisons, for the standard asset, across the experimental treatments.

For the lottery asset, the results of the error components model indicate that price deviations are moderated by borrowing restrictions ($p = 0.042$, one-sided value) and the ability to short sell ($p = 0.016$, one-sided value). The pairwise comparisons indicate that the price deviation is less in the SS/NB1–4 sessions than in the NSS/NB1–5 sessions at the 4.8% level (one-sided p-value). With borrowing restrictions, the ability to short sell significantly lessens price deviations, which provides support for the third proposition. We also find that the price deviation is less in the SS/NB1–4 sessions than in the NSS/B1–4 sessions at the 0.5% level (one-sided value). The *combined* effect of borrowing restrictions and the ability to short sell substantially mitigates price deviations.

Overall, the findings highlight the importance of short sales in moderating price bubbles. Moreover, for both assets, the ability to short sell *combined with* borrowing restrictions is 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 allowed. Hence, the institutional design features need to be considered in combination.[23]

5. Discussion and Concluding Remarks

This paper reports the results of experimental asset markets in which market participants traded two assets: a standard asset and a lottery asset. 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 when traders are given the ability to finance purchases with borrowed funds and not permitted to short sell, they will pay even higher prices for an asset with lottery characteristics (i.e., a claim on a large, unlikely payoff). However, 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 bubble 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 in their experiment 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 eliminated (see also Caginalp, Porter, and Smith 1998, 2000a, 2000b, 2001), yet turnover and volume are higher than with other institutional designs. This leads some participants to trade to take advantage of arbitrage opportunities.

[23] Though not reported, we conducted additional analysis to investigate individual behavior. We find that individuals' trading profit is positively associated with the percentage of rational trades, defined as purchases below fundamental value and sales above fundamental value. This analysis is available upon request. We also find evidence that short selling improves the trading profit of short sellers. Lastly, we do not find any evidence that forecasting accuracy is associated with individuals' trading profit (see also Ackert and Church 2001).

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