Chapter 9
The Creation and Control of Speculative Bubbles in a Laboratory Setting

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Abstract Persistent divergence of an asset price from its fundamental value has been a subject of much theoretical and empirical discussion. This paper takes an alternative approach of inquiry – that of using laboratory experiments – to study the creation and control of speculative bubbles. The following three factors are chosen for analysis: the compensation scheme of portfolio managers, wealth and supply constraints, and the relative risk aversion of traders. Under a short investment horizon induced by a tournament compensation scheme, speculative bubbles are observed in markets of speculative traders and in mixed markets of conservative and speculative traders. These results maintain with super-experienced traders who are aware of the presence of a bubble. A binding wealth constraint dampens the bubbles as does an increased supply of securities. These results are unchanged when traders risk their own money in lieu of initial endowments provided by the experimenter.

Keywords Speculative bubbles • Experimental asset markets • Fundamental asset values • Tournament • Market efficiency • Behavioral finance

9.1 Introduction

The purpose of this study is to investigate the formation of speculative bubbles in asset prices under a laboratory setting. Specifically, we investigate how to create, control, and dismantle bubbles, as well as the conditions in which bubbles may or may not arise.

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Speculative bubbles are induced in this study under a pictoria laboratory setting, where a New York Stock Exchange type of double oral auction market (without a specialist) involving many traders is modeled. Speculative bubbles occur when buyers are willing to bid higher and higher prices for an asset, which, in retrospect, is far in excess of its worth based on fundamentals. The bubbles ultimately burst and prices drop to a much lower level.[1] The stock market crash in the U.S. in 1987, in Japan in 1991–1992, the dot com bubble in 2000, and the recent housing bubble in the U.S. are examples.[2] In recent years, academicians and practitioners are slowly but grudgingly coming to the realization that the extant theories of stock market behavior (e.g., efficient market hypothesis and capital asset pricing theory), fail to explain the magnitude of fluctuations in the stock market. Not only have stock prices been found to fluctuate too much relative to fundamentals, but also there have been occurrences of speculative bubbles that could not be explained by arrival of new information. Several plausible explanations for bubbles are offered such as rational bubbles (Shiller 1988; West 1988), irrational bubbles (Ackert et al. 2002; Lei et al. 2001), judgment error (Ackert et al. 2006) and herding behavior (Froot et al. 1992).[3]

[1] Stiglitz (1990), in his overview of a symposium on bubbles, defines the existence of bubbles to be: "if the reason that the price is high today is only because investors believe that the selling price will be high tomorrow – when 'fundamental' factors do not seem to justify such a price." Similarly, he defines the breaking of a bubble as marked price declines that occur without any apparent new information.

[2] Other notable example of bubbles include the Dutch tulip mania in the seventeenth century, the South Sea Islands Company bubbles (Voth and Temin 2003), John Low's Mississippi Company Scheme Bubbles of the eighteenth century, the South Sea Islands Company bubbles, John Low's Mississippi Company scheme bubbles of the eighteenth century, the U.S. stock market boom of the late 1920s, the Florida land price bubbles of the 1920s, the great bull market of the 1950s and 1960s, and the high-tech stock boom of the early 1980s and the boom and bust of the California and Massachusetts housing markets in recent years. However, due to the difficulties in specifying the fundamentals, there is still disagreements as to whether these cases could be explained by the fundamental example of Garber (1990) versus White (1990).

[3] Outstanding surveys of this literature are provided by Porter and Smith (2003), Camerer (1989) and Sunder (1992).

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While some work has been done to show that bubbles can be abated with experience (Dufwenberg et al. 2005), an understanding of the formation of speculative bubbles is still important to researchers for several reasons. First, bubbles could cause significant disruptions in the asset market, not only by creating a large redistribution of wealth among investors, but also by adversely affecting the supply of funds to the market as well as resource allocation among and within firms. Second, the identification of factors affecting the formation of bubbles is crucial in aiding regulators in designing policies to reduce the occurrence or magnitude of bubbles. In particular, if bubbles can be replicated in a laboratory setting, then various proposals to dampen bubbles could also be tested and compared for their effectiveness. Roll (1989) summarizes the difficulty with examining recent empirical results of the 1987 Crash in this regard. Third, an understanding of the dynamic process of bubble formation would contribute to our knowledge of how to model the behavior of asset prices (DeLong et al. 1989; Cutler et al. 1991).

In spite of some interesting recent theoretical developments, empirical research on the existence of bubbles tends to be inconclusive and with low power; for example, Gurkaynak (2005), West (1988), Flood and Hodrick (1990). A major problem is the difficulty of specifying the fundamental value of an asset, as bubbles are defined as the price in excess of the fundamental values (Bierman 1995; Robin and Ruffieux 2001). Without being able to calculate the time series of the asset's fundamental value, price movement could simply be caused by factors affecting the fundamental valuation of the asset; for example, change in risk aversion, arrival of new information, and so forth. And if the fundamental value could only be measured imperfectly using proxies such as past dividends, the imprecise estimates would, of course, reduce the power of any test.

The experimental approach reduces this problem (Cason and Noussair 2001). By design, the value of the fundamentals can be specified in advance; hence there is no measurement problem. Any gross and persistent divergence of the asset price from the prespecified fundamental value can now be attributed to bubbles (Siegel 2003). In addition to reducing the identification/measurement problem, performing laboratory experiments to study asset bubbles has two other advantages. First, it allows different characteristics of the market institutions and participants to be introduced in a controlled manner. That is, relevant factors may be manipulated to create or discourage the formation of bubbles. This is an important feature because some of these factors may not be isolated in the real world for detailed study while other factors are simply proposals in the design of market institutions of the future. Second, by controlling the information available to market participants, we can control the role played by unrelated, or exogenous events (e.g., sunspots). Thus, the laboratory experiment approach to study asset market behavior complements the theory/model building process. The three types of variables chosen for analysis in this study are the following:

1. The compensation scheme of a portfolio manager. Allen and Gorton (1988) have argued that compensation schemes for portfolio managers may induce bubbles even in a finite horizon. Also, recent literature on tournaments (see James and Issac 2000; Ehrenberg and Bognanno 1990 and others) has shown that the level and structure of relative compensation influences participant behavior, while Hirota and Sunder (2005) have found that short horizons are important factors in the emergence of bubbles. Three types of compensation structure are used in these experiments: a linear compensation scheme based on portfolio performance, and two versions of compensation based on relative performance in a short-term horizon.
2. Wealth constraint (tight/loose); supply of securities. An infinite number of trades (e.g., overlapping generations and the availability of credit) is often cited as a prerequisite for bubbles. Ricke (2004) discusses how credit made available from margin could generate bubbles. High liquidity leads to bubbles in the work of Caginalp et al. (2001). Scheinkman and Xiong, (2003), Hong et al. (2006) analyze the effect of a short sales constraint on the formation of bubbles. Therefore, experimenting with wealth constraints may provide valuable insights into the effectiveness of certain policies (such as margin rule change, credit availability, and so forth) to control bubbles.
3. The type of investors in the market (speculative/conservative). This variable tests the Keynes-Hicks theory of speculation where differences in traders' willingness to take risks is the foundation of speculative markets. Traders in the experiments are pre-tested for attitudes toward risk taking.

Bubbles are observed under the following conditions:

1. A market of speculators with short-term investment horizon.
2. A market of mixed conservative and speculative traders with short-term investment horizon.
3. A market of mixed trader types with short-term investment horizon using their own money.

On the other hand, bubbles are dampened under the following investment environments:

1. A market of conservative traders with a short-term horizon.
2. A market of mixed trader types with a long-term investment horizon.
3. A market of mixed trader types when the wealth of the traders, especially the bulls, is constrained.
4. A single-period trading environment.

The remaining part of this paper is organized into four sections. Section 9.2 presents the hypotheses to be tested by incorporating them into the experimental design, which is discussed in greater detail in Sect. 9.3. The results are reported in Sect. 9.4 with Sect. 9.5 summarizing and concluding the paper.

9.2 Bubbles in the Asset Markets

The possibility of asset bubbles has long been recognized; however, more formal theoretical development is of relatively recent vintage. Harrison and Kreps (1978), for instance, suggest that in general the right to resell the asset makes traders willing to pay more for it than they would if obliged to hold it forever. Thus, market price could exceed fundamental value. Literature on rational bubbles emphasizes that once a bubble is started, it would be rational to price the bubble component even if it is expected to burst with positive probability. Brunnermeier and Nagel (2004) examine stock holdings of hedge funds during the recent NASDAQ tech bubble and find that the portfolios of these sophisticated investors were heavily tilted towards (overpriced) technology stocks. However, this does not seem to be the result of unawareness of the bubble on the part of hedge funds.[4] At an individual stock level, hedge funds reduced their exposure before prices collapsed suggesting awareness and implicit pricing of the bubble component. On the other hand, whether bubbles can even get started has been questioned 64 Diba and Grossman (1987). Essentially, if there is a finite number of periods, starting from the next to the last period, the expectation that the bubble might end may be sufficient to keep it from ever starting. By the process of backward induction or an unraveling argument, bubbles will not exist. Moreover, if the number of trades is finite, withdrawal of early trades at a profit means the remaining traders would be at a negative sum game; that is, with finite trades, will there be a "greater fool" who gets stuck when the bubble bursts. Still, perturbing the model by adding uncertainties on the length of the horizon among traders or market size may preserve the possibility of asset bubbles.

Smith et al. (1988) are among the first to investigate the incidence of bubbles. Their design was to give traders common beliefs (according to one of Tirole's requirements) and long horizons of up to 15 trading periods. Bubbles are observed in several of their experimental markets. It is unclear, however, what institutional setting, other than long trading periods, induces bubbles in their study.

In a speculative market where bubbles could be present, speculative traders are more likely to purchase shares (and even more so, if bubbles are rationally priced) than risk-averse traders. Not only are they more willing to put a higher value on risky assets, they are also more likely to take the chance that they might not be able to sell out their inventory before the bubble bursts. Therefore, our first hypothesis is that bubbles are more likely to be formed in a market of risk taking traders (speculators).

The compensation scheme could also affect the behavior of traders. For instance, Allen and Gorton (1988), and Allen and Gale (2000) show that an option-type compensation scheme for portfolio managers could induce speculative bubbles in asset prices. Portfolio managers are encouraged via incentive rewards to generate short-term trading gains even in a finite horizon world. The current practice of publishing and ranking the short-term investment performance of portfolio managers and the very substantial incentives to hedge fund managers' performance that may be based on unrealized gains on illiquid assets could give rise to adverse incentives. Portfolio managers who are concerned about these rankings will either take on a riskier strategy for the possibility of outshining their peers or they will simply play it safe and follow the crowd. Both portfolio strategies could lead to the formation of bubbles. The play safe by "following the herd" strategy will cause asset prices to have a strong positive correlation in the short term. Portfolio managers would be buying when others are buying, thus creating an upward price trend, and selling when others were selling, thus bursting the bubble it created. On the other hand, pursuit of a risky strategy may be sufficient to create price leadership that is followed by others in the market. This would be more likely in an uncertain valuation environment. Voth and Temin (2003) suggest that riding the bubble may actually be a profitable strategy.

Portfolio managers are subject to an occupational hazard: unless they produce winning results, they stand a good chance of being fired. On the other hand, star performers receive seven or even eight figure incomes as new cash flows into the funds they manage. This compensation system is similar to tournament models where participants are paid according to their relative performance among a group of peers rather than on their absolute performance. Tournament systems are likely to produce increased performance when (1) there is difficulty in monitoring the activities of the agent, (2), when the agent possesses valuable information (Baker 1992), and (3) when good performance measures are available (Baker 1992). All three of these conditions exist in the realm of professional money management, and therefore it is probable that a relative performance compensation system

[4] Griffin et al. examine the extant theoretical literature about bubbles that includes models where naive individuals cause excessive price movements and smart money trades against (and potentially eliminates) a bubble versus models where sophisticated investors follow market prices and help drive a bubble. In considering these competing views over the tech bubble period on NASDAQ they find evidence that supports the view that institutions contributed more than individuals to the spectacular NASDAQ rise and fall.

will be effective in increasing manager performance.[5] Thus, it is hypothesized that a tournament incentive scheme that encourages a short-term horizon for portfolio managers is more likely to create bubbles.[6]

Finally, an important policy question has been whether restricting the availability of credit or the supply of securities in a market (by raising the margin requirement or allowing short sales) could reduce or even eliminate the formation of speculative bubbles. (Ackert et al. 2006 find that price run ups and crashes are moderated when traders are allowed to short sell). Most countries, including the U.S. and Japan, have adjusted these conditions in the recent past through adjustments in the use of stock index futures and by easing credit conditions. These changes have tended to occur subsequent to large declines in the country's equity markets. With limited or asymmetric ability to go short versus long, speculators on the long side have an advantage in acquiring funds for investment. Additionally, if the life of a bubble is uncertain and relatively long lasting, costly short sell will not be profitable even if the bubbles eventually burst. The usual experimental design often endows traders with a relatively large initial wealth such that the budget constraint is not binding. This experiment will test the effect of a tighter budget constraint by both reducing the initial endowment and increasing the supply of securities. It is hypothesized that a wealth constraint and/or relative increase in the supply of securities will reduce the incidence of bubbles.

To summarize, the effect of three factors: attitude toward risk, investment horizon, and wealth constraint are examined as to their contribution to the creation and control of asset bubbles. They are tested by incorporating them into the experimental design of a laboratory setting described below, the importance of these factors in the formation and control of asset price bubble, singly and jointly, can now be formally examined.

9.3 Experimental Design

The evolutionary nature of laboratory experimental research is such that the results of any study acts as a catalyst for new questions and therefore new experiments. As with Smith et al. (1988), we note that many of our latter experiments were directly motivated by the results obtained from our earlier ones. This progression of thought and analysis will be apparent in the later section on results. Herein, however, we present the method of our investigation in comprehensive form.

The creation of "bubbles" within asset markets is examined under the control of three primary factors: (1) the degree of trader risk aversion, (2) trader investment horizon, and (3) available investment capital/supply of securities. Table 9.1 summarizes the design of 14 experiments used to investigate these factors on the presence of asset bubbles. Each of these experiments uses a common market mechanism that builds on the earlier work of Forsythe et al. (1982), Plott and Sunder (1982), and Ang and Schwarz (1985). These common features are summarized below.

9.3.1 General Market Design

1. A double-oral auction, similar to that used on the floor of major U.S. exchanges, is replicated. The recruited traders are physically present within a single room during the course of trading. These traders are independent and trade solely for their own account. There are no specialists or other privileged traders.
2. Only those shares of a single generic security are traded. The sole attribute of these shares is the payment of dividends at the end of each period.
3. Each market (experiment) has ten trading periods. These periods are further categorized into five trading years each of which consists of two contiguous trading periods (A and B). Endowments (discussed below) are reinitialized at the end of the second period of each year. Thus, the initial market represents a two-period model with each security entitled to two payoffs (dividends), one at the end of period A and the other at the end of period B.[7]
4. Each trading period last for 6 min, with opening, warning (at 5 and $5^1/_2$ min), and closing bells. Consequently, each experiment has a total of 60 (6 min $\times$ 10 periods) trading minutes. During the 6-min periods, traders can observe the continually updated bid/ask and past transacted prices.

[5] Becker and Huselid (1992) and Ehrenberg and Bognanno (1990) have documented in field studies that such tournament compensation systems are effective in raising performance in professional golf and auto racing competitions.

[6] It is possible that, if there is sufficient number of short horizon portfolio managers herding in the manner described by Froot et al. (1992), a bubble can start on basis of any information. Shleifer and Vishny (1990) also propose that the portfolio managers have short horizon; however, it is the risk of uncertain return from investing in the longer horizon that prevented disequilibrium to be arbitraged away.

[7] In the experiment, a trader has at least the following choices available: (a) Maintain the endowed position by not trading and receiving the stochastic payoffs at the end of each period; (b) Hold the securities through period A and sell in period B, in which case the investor will receive the first period dividend and the selling price; (c) Sell the initial holdings in period A to receive the sale price; (d) Buy additional shares in period A, receive dividends at the end of the period, and then sell the securities in period B; (e) Sell the securities in period A and then buy back securities in period B in order to receive the dividends; (f) Purchase a net amount of shares in both periods; (g) Purchase and sell shares within each period.

Table 9.1 Experimental Design

This table categories five designs of fourteen experiments used to examine the impact of risk aversion, investment horizon, and credit/supply constraints (initial endowment) upon the formation and control of asset bubbles.

Participant Groups[a]	Design	Initial Endowment[b]	Investment Horizon[c]	Risk Aversion[d]	Experiments[e]
Las Vegas	1	2 securities 10,000 francs	Two period	Mixed	1,2,3,5$
Las Vegas	2	2 securities 10,000 francs	ShortenedMixed		4m, 6m$
Las Vegas	3	5 securities 3,000 francs	ShortenedMixed		7x,8x,9t,10t
FSU1	4	2 securities 10,000 francs	Two period	Single Type	11s, 13c
FSU1	5	2 securities 10,000 francs	ShortenedSingle	Type	12sm, 14cm
FSU2	2	2 securities 10,000 francs	ShortenedMixed		15, 16
FSU2	6	10 securities 1,000 francs	ShortenedMixed		17, 18
Albania	1	2 securities 10,000 francs	Two period	Mixed	23
Albania	2	2 securities 10,000 francs	ShortenedMixed		24,25
Albania	6	10 securities 1,000 francs	ShortenedMixed		26
Albania	7	2 securities 5,000 francs	Single Period	Mixed	19
Albania	8	2 securities 5,000 francs	Single Period/Tournament	Mixed	20,21
Albania	9	20 securities 500 francs	Single Period/Tournament	Mixed	22

[a] The participant groups consist of the following:

Las Vegas represents students from the University of Las Vegas at Nevada.
FSU1 and FSU2 represent students from the Florida State University at two different time periods.
Albania represents students from the University of Tirana in Albania.

[b] The initial endowment refers to traders wealth position at the beginning of each trading year of an experiment. This endowment allows traders to sell (using provided securities) or buy (using francs, the currency used in these experiments). The additional securities and reduced currency endowments provided in Design 3 serves to better equate relative purchase and selling abilities.

[c] Investment horizon refers to the horizon within which traders effectively operate. A two-period horizon refers to a market where period A securities are based on the dividends paid in both periods (A & B) of a trading year. In a shortened investment horizon, the trader is induced (via the tournament compensation schedule of Table 9.3) to operate with a horizon which is shorter than the two-period environment in which the securities will pay dividends.

[d] Mixed risk aversion means that traders with various risk preferences were participants within the same market. Single type means that only speculative (s) or conservative (c) traders made up that market. The designations (s) and (c) appear next to experiments 11–14 in the last column.

[e] Notation is as follows:

$ represents a market where traders provided $20 of their own money to trade, the sum of which became the pool of money dispersed according to relative profit performance.
m,x,t represents the number of traders receiving the tournament prize as outlined in Table 9.3. This tournament compensation was used to induce a shortened horizon market and was differentially paid to the top two (t) or the top six (x) traders. In experiments marked (m), the first three trading years paid a bonus to the top six traders followed by years where only the top two traders received bonuses.

9.3.2 Dividend Design

1. At the beginning of each year, each trader is endowed with trading capital and shares of the generic security. Each share pays dividends at the end of the first (A) and second (B) periods. The second period dividend is a liquidating dividend. Reinitializing of position at the beginning of each year allows for replication of decision making in experimental markets.[8]

[8] See Smith et al. (1988) for an example of when reinitialization is not used.

Table 9.2 Dividend Design

This table presents the cash flow payoffs which a single asset will provide to its owner. This payoff is different for Trader Types I, II, and III and therefore provides for different fundamental valuations. Rational Expectations Equilibrium are determined by the trader type with the highest valuation for that period.

Years[a]	Trader Type[b]	Period A Dividend State[c]		Expected Dividend[d]	Period B Dividend State[c]		Expected Dividend[d]	Yearly Expected Dividend[e]
		G	B		G	B		
1	I	350	110	230*	250	150	200	430*
	II	250	150	200	200	140	170	370
	III	200	140	170	350	110	230*	400
2	I	200	140	170	350	110	230*	400
	II	350	110	230*	250	150	200	430*
	III	250	150	200	200	140	170	370
3	I	250	150	200	200	140	170	370
	II	200	140	170	350	100	230*	400
	III	350	110	230*	250	150	200	430*
4	I	350	110	230*	250	150	200	430*
	II	250	150	200	200	140	170	370
	III	200	140	170	350	110	230*	400
5	I	200	140	170	350	110	230*	400
	II	350	110	230*	250	150	200	430*
	III	250	150	200	200	140	170	370

[a] Each experiment is composed of five trading years, each of which contains two trading periods A and B. Ownership of an asset in period A entitles the bidder of both period A and Period B dividends (two-period valuation) whereas period B ownership merits only that period's dividend (single-period valuation).

[b] There are three trader types in each trading year with four traders in each category. These trader types only differ by the amount of dividend cashflows that the single traded asset will provide its holder. The four traders within each category are rotated within the other categories so as to maintain an uncertain valuation environment.

[c] Dividend States refer to the stochastic payoff that will be provided to specific trader types given the occurrence of the G (Good) or B (Bad) state. The realization of the state of nature is determined at the end of each trading period by flipping a fair coin.

[d] Given equal fifty percent probability of occurrence of G or B, the expected dividend is the simple average of period G and B payoffs.

[e] The yearly expected dividend represents the summation of expected dividend for both periods A and B.

*Signifies trader type with the highest expected value

2. The dividends to be paid at the end of each period are stochastic. Two equally likely dividend outcomes are possible, the good (G) state and the bad (B) state. The realized state is announced at the end of each 6-min trading period as determined by the flip of a coin by the experimenter.
3. The dollar amount of the dividends paid at the end of each period depends on the trader's type and the realized state. The 12 traders who make up each market are classified into three types to allow for differences in induced values. The dividend payouts for these three trader types are summarized in Table 9.2. As an example, at the beginning of year 1, the four traders of type I are privately informed that for period A they will receive either 350 or 110 for the good (G) and bad (B) states, respectively, and for period B either 250 or 150 for the good and bad states, respectively.
4. The trader type with the highest expected dividend (0.5 × Good Dividend + 0.5 × Bad Dividend) is rotated each period so as to enhance trader uncertainty about equilibrium prices. Virtually all previous experimental studies have documented that given sufficient learning (through repeated trading) in a stationary dividend payout environment, prices will rather quickly approach the rational equilibrium level. This learning has two sources: (a) observation that one's own payouts are not changing, and (b) observation that market generated bids, offers, and transacted prices are not changing. Our expectation is that the greater the trader's reliance on market generated (as opposed to prior dividend) information, the more likely bubbles are to occur due to bandwagon and other crowd psychologies. If, instead of bubbles, we should observe that prices converge to rational equilibrium prices (as in the constant dividend studies), then this would strengthen our knowledge concerning efficiency in these laboratory markets. This result would also suggest that trading methods based on historical prices alone would not have value.

9.3.3 Investment Horizon

1. Three types of investment horizon are provided within these experiments: a single-period, a two-period, and a shortened-horizon. Initially, at the beginning of each trading year, a trader is entitled to two stochastic dividends for each security held, one each at the end of periods A and B. Therefore, at the beginning of period A, a rational trader will value the security for both its period A and period B stochastic dividends. Hence, all A period

pricing should reflect a two-period investment horizon. Subsequent to the termination of period A trading and the announcement and payment of the period A dividend, period B trading proceeds. As the security is now only entitled to the B period dividend, a single-period investment horizon results for all B periods. Our hypothesis is that a shortened investment horizon increases the possibility of an asset pricing bubble. We test for this by creating a tournament compensation package in period A. The incentive for traders is to concentrate upon their single (A) period performance over the concerns of a rational two-period price. This incentive results in a shortened investment horizon.[9]

2. In this study, Initially, a trader's dollar compensation is defined by the following: we alter the compensation structure to induce a change in the length of a trader's investment horizon profit function:

$$P_i = f[d_{i,j,A} \cdot X_{i,A} + d_{i,j,B} \cdot X_{i,B} + (R_i - C_i)] \qquad (9.1)$$

where P_i, dollar profit per trading year for trader i. It consists of dividend income and trading gains (losses) from both periods; f, the conversion rate of francs into dollars.[10]; $d_{i,j,t}$, the dividend paid in francs to trader i, given state j occurs in period t; j = G or B; t = A or B; $X_{i,t}$, the number of shares held by trader i at the end of period t; t = A or B; R_i, revenues in francs for trader i for all shares sold during periods A and B; C_i, costs in francs for trader i for all shares purchased during periods A and B.

In order to induce pressure for a shortened investment horizon, an additional compensation package is introduced in Period A of some experiments as identified in Table 9.1. This tournament compensation system is based on the traders' relative performance as measured by the Tournament Performance Index (TPI) below:

$$TPI_i = R_i - C_i + MX_{i,A} \qquad (9.2)$$

where R_i, C_i, and $X_{i,A}$ are as previously defined, and M represents the closing market value of the shares. This closing market value is taken to be the price of the second to last transacted price for that period. This procedure is introduced in order to reduce the possibility of manipulating market value by collaboration on a final transaction. It represents a simplified version of the price-averaging process that takes place on most organized exchanges for the setting of opening and closing prices.

3. The tournament compensation system provides traders with an incentive to outperform each other in period A only. This incentive system increases the importance of single-period performance (in A) over two-period concerns; that is, it induces a shorter investment horizon in period A. A trader's compensation is dependent upon his relative rank as summarized in Table 9.3. In Schedule Six, the top six (of twelve) traders are rewarded with francs ranging from 1,500 to 200. Schedule Two is an alternative schedule that is hypothesized to induce even greater competitive pressure as only the top two traders are compensated greatly.[11] Ehrenberg and Bognanno (1990) and

Table 9.3 Tournament Compensation Schedule

This table presents the additional tournament compensation schedule provided to traders based on their relative profitability in period A of certain experiments (see shortened investment horizon listed in Table 1). Relative profitability is measured by:

$$TPI_i = R_i - C_i + M \cdot X_{i,A}$$

where TPI_i is the tournament performance index for trader i, R_i is the revenues received from the sale of assets in period, C_i is the cost of assets purchased, M is the closing market value for the period, and $X_{i,A}$ represents the end-of-period asset holdings. Together the index measures the total of realized and unrealized capital gains.

The addition of the tournament compensation to period A provides an incentive for traders to prefer period A capital gains over equivalent period B dividends and thereby induces a shortened (from the two period model) investment horizon.

Schedule	Rank	TPI	Compensation
	1	Highest	1500 francs
Six	2		1000
(s)	3		700
	4		400
	5		200
	6		200
	7 to 12	Lowest	0
	1	Highest	3000 francs
Two	2		1000
(t)	3 to 12	Lowest	0

[a] Two compensation schedules are introduced. The first provides for those traders who do better than the average (i.e., the top six) receive the additional compensation list. In the second schedule, only the top two "superstars" are richly rewarded. The tournament literature (e.g. Baker 1991) suggests that tournament systems, and especially schedule two, provide effective incentive systems to increase performance. This design is meant to emulate the short-term performance pressures faced by professional money managers.

[9] It is important to note that there is a difference between a one- and two-period horizon and a shortened-horizon. In a one-period model, only a single dividend is valued. In a two-period model, two dividends are valued. In our shortened-investment horizon, the trader is induced to operate within a horizon that is different from that of his operating environment. That is, within a two-period operating environment, the trader is given an incentive to operate with a shorter (possibly single) period horizon. This is quite different from a single-period model. This shortened horizon is a stronger test of market efficiency, in that the pressures are away from rather toward rational equilibrium prices, (as defined in Equation (9.4), subsequently). The methodology is meant to emulate modern portfolio managers operating in an environment of perpetual horizon stock securities yet receiving tournament incentives to outperform colleagues on a short-term basis.

[10] Francs are the currency used within this study. They have been used successfully by Plott and Sunder (1982), Ang and Schwarz (1985), as well as others. Their primary benefit is to avoid the technical problem of dealing with small dollar amounts.

[11] The compensation schemes depict the different ways portfolio managers are being rewarded: those who are above the average or beaten

Becker and Huselid (1992) find that the reward spread does cause increased performance incentives. Therefore, we expect Schedule Two to increase incentives for short-term pricing behavior. Table 9.1 summarizes the experimental use of the performance reward schedule.

9.3.4 Risk Aversion

1. Prior to selection, each potential trader was given a lengthy questionnaire. Intermingled within this material were two psychological tests on risk taking: the Jackson Personality Inventory (1976) and the Jackson et al. (1972) tests.[12] These two tests have been applied in laboratory (Ang and Schwarz 1985) and field studies (Durand et al. 2006) and are more practical to administer than the theoretical risk measures found in the economics literature.[13] Those persons who score in the top 12, signifying the least risk averse, and the bottom 12, or the most risk averse, are invited to participate in the second stage of the experiment.
2. Traders for experiments 1–10 were students from the University of Las Vegas at Nevada and were recruited from a senior level options class. These students had all taken two statistics, a corporate finance, a valuation, a portfolio analysis, and an options course. They were well trained in arbitrage, present value, and expected value. From this pool of students, 12 were chosen to participate based on their attribute ranking in risk aversion. Participants were chosen so that a mix of risk aversion types were represented in the same market. Included were those who ranked at all levels of the scale, from high to low risk aversion. This was done so that differences in individual risk behavior could be tracked within an identical market environment.
3. Experiments 11–14 were conducted at Florida State University (FSU1) and as summarized in Table 9.1, these experiments were designed so that an experimental market consisted entirely of traders that were either relatively more risk averse (conservatives) or less risk averse (speculators). This experimental form allowed for evaluation of whether risk aversion is uniquely a necessary or sufficient condition for the presence of bubbles.
4. Experiments 15–26 were conducted at a later date at Florida State University (FSU2) and the University of Tirana in Albania. This was done to confirm the robustness of our results. We intentionally chose students from two different universities with different backgrounds to represent the two extremes in our test. Experiments 19–26 were administrated to subjects in Albania, who have a low degree of familiarity with capital markets while experiments 15–18 were administered to Florida State University students (FSU2) who had taken a financial engineering course and completed another more involved laboratory asset market experiment. Hence, we consider these FSU2 students to be super experienced relative to the students from Albania.

9.3.5 Validation Procedures

The following procedures are incorporated into the experimental design to insure the reliability and external validity of the results:

1. To guard against the possibility that subjects' experience with trading could change their attitudes toward risk taking, they were retested. Subsequent to the first four experiments, additional risk questionnaires were given to the participants. A Spearman rank correlation (with initial risk rankings) was 902 with a t-statistic of 6.61 indicating that there had been no significant change in the relative risk attributes of the traders.
2. Videos were used to verify recorded information, identify possible irregularities, and to train new subjects.
3. Subjects were given extensive training on the operation of the game; the main experiments were conducted on groups of experienced, if not super-experienced, traders.
4. Lengthy post experiment questionnaires were also given to the subjects. Among other things, these were used to verify that the traders considered their trading strategies taken at the time of trade to be rational.

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the market (Schedule Six), and those who are the superstars (Schedule Two).

[12] The authors are aware of the work of Holt and Laury (2002), which was not available at the time of this study. According to Holt and Laury their experiment shows that increases in the payoff level increase RRA. However, when estimating RRA, Holt and Laury assume that subject's utilities depend only on payments in the experiment. They fail to account for the wealth subjects have from other sources (see Heinemann 2003).

[13] The Jackson Personality Inventory is scientifically designed questionnaire for the purpose of measuring a variety of traits of interest in the study of personality. It was developed for use on populations of average or above average ability. Jackson states (1976), p.9, "It is particularly appropriate for use in schools, colleges, and universities as an aid to counseling, for personality research in a variety of settings, and in business and industry." Of the 16 measurement scales of personality presented, one scale directly measures monetary risk-taking using a set 20 true and false questions. Mean and standard deviation measures for 2,000 male and 2,000 female college students are provided. Jackson et al. (1972) demonstrate four facets of risk taking: physical, monetary, social, and ethical. The authors' questionnaires are situational in that the respondent is asked to choose the probability that would be necessary to induce the respondent to choose a risky over a certain outcome. Jackson (1977) presents high internal consistency correlation between the risk measurement techniques.

9.4 Results and Analysis

9.4.1 Control Experiments

For experiments 1–14, five experimental designs were used to test for the effects of risk aversion, investment horizon, and capital endowment on the presence of asset bubbles. These designs are summarized in Table 9.1. The first design consisting of experiments 1, 2, 3, and 5 were control markets where the two-period model was tested without extraneous influence from the three treatment variables mentioned above. Figures 9.1–9.5 plot the series of resulting prices. Bid and ask prices are represented by a "+" symbol and are connected by a vertical solid line. Transacted prices are identified by a solid horizontal line connecting each trade. From earlier laboratory studies, we would expect prices to converge to rational expectation equilibrium levels after an initial period of learning.

Two relevant concepts of equilibrium prices in these markets have been proposed (see Forsythe et al. 1982). The first is the Naive Equilibrium (NE) Price. The NE is the highest

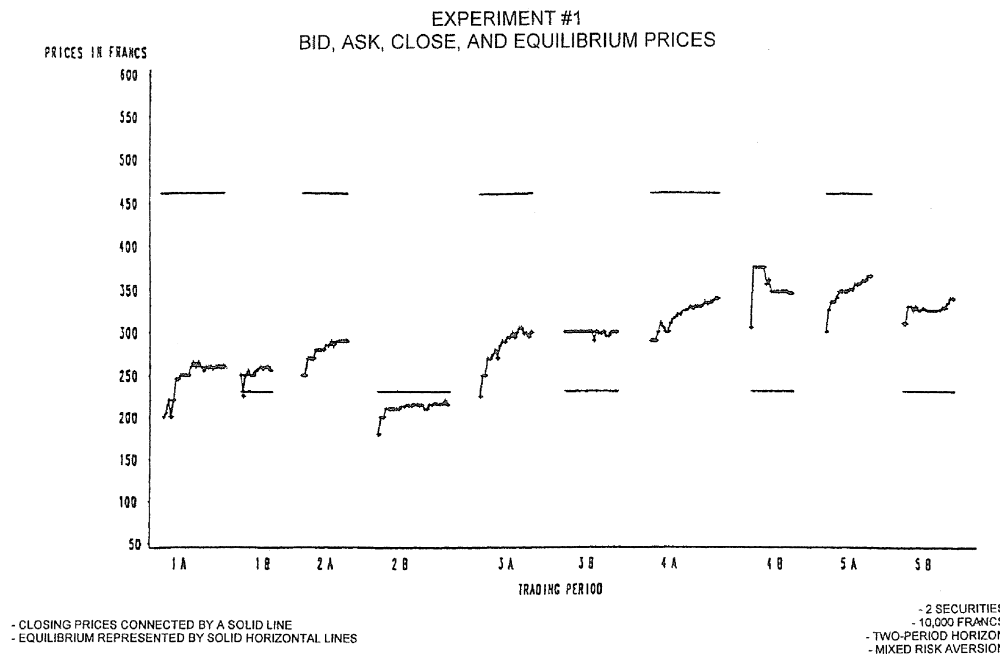


Fig. 9.1 Experiment #1

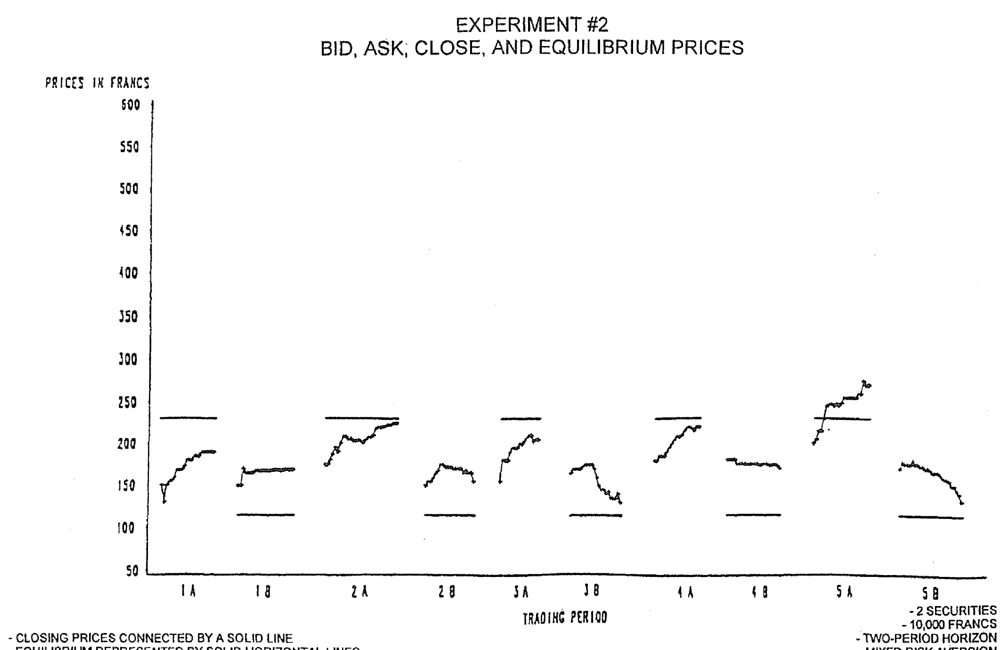


Fig. 9.2 Experiment #2

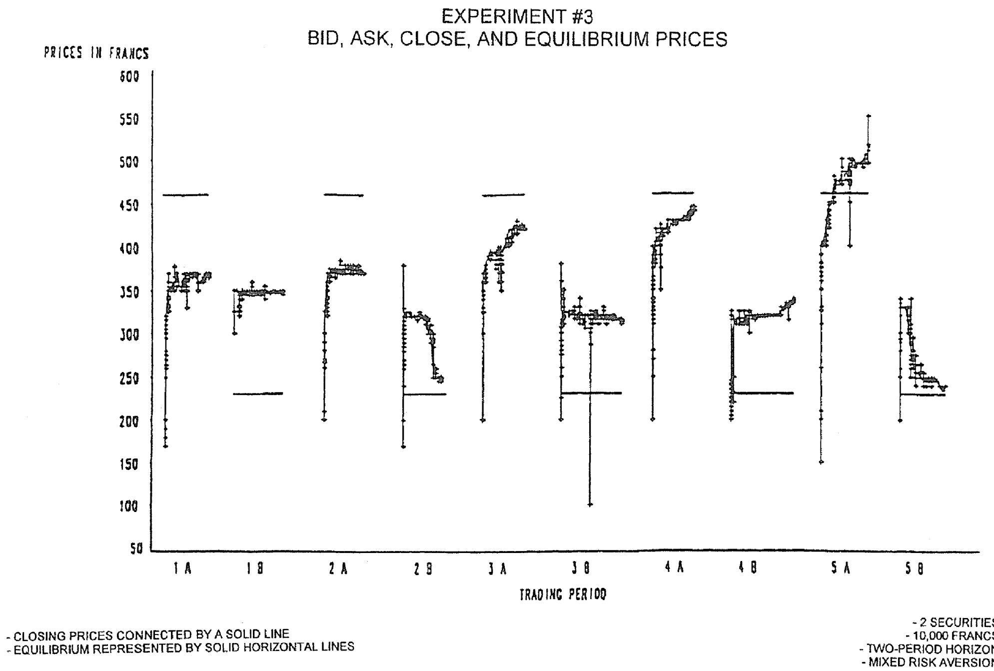


Fig. 9.3 Experiment #3

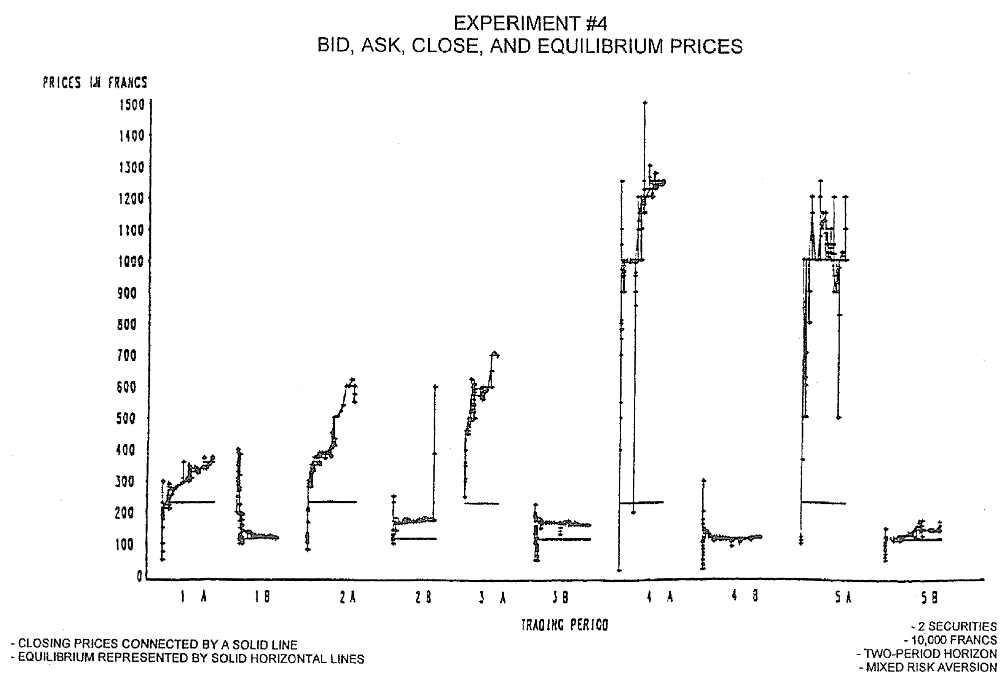


Fig. 9.4 Experiment #4

price any trader in the market is willing to pay based on his individual valuation of the expected dividends for the two periods or:

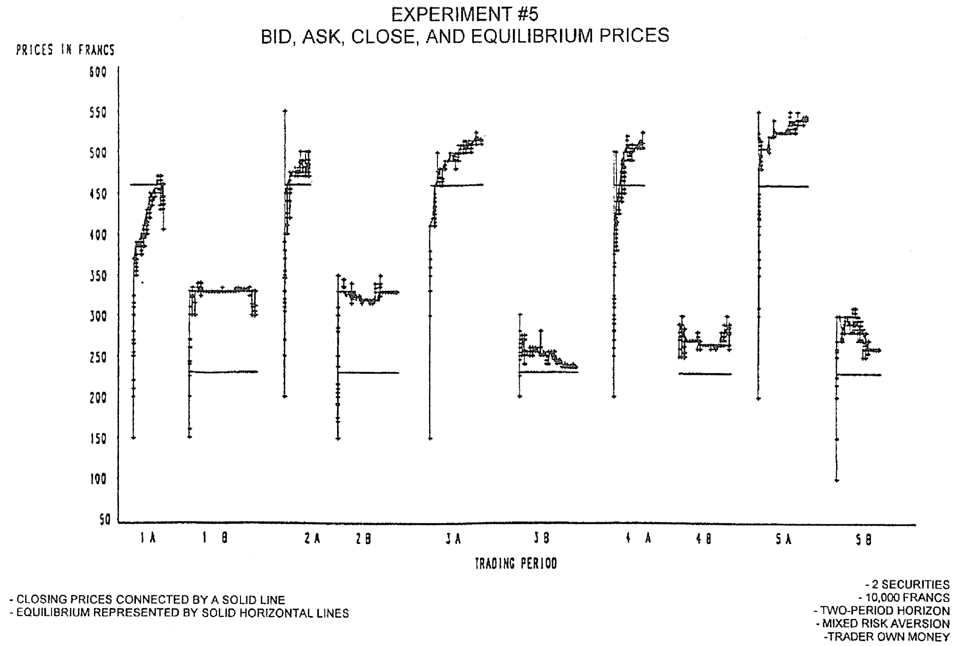
$$NE = \text{Max}\, k[E(D_{A,k}) + E(D_{B,k})] \tag{9.3}$$

where k classifies the trader type (1, 2, or 3) based on prior expected dividend valuations (see Table 9.2). $E(D_{A,k})$ and $E(D_{B,k})$ are the values of expected dividends in periods A and B to the k'th trader type.

The NE price is the market price that will prevail if the traders use only their private information to determine value. It is naïve in the sense that traders do not learn about the valuations of other traders from the market trading information. These traders also ignore the option value to trade (e.g., hold a security for a period and then sell it to another trader who would value it most in the remaining period).

The second is the Perfect Foresight Equilibrium (PFE) price. It is equal to the highest total value that successive owners of the same share will pay; or, in the experiment, the

Fig. 9.5 Experiment #5



sum of the highest expected payoffs for periods A and B for all traders or:

$$\text{PFE} = \text{Max}_k\, E(D_{A,k}) + \text{Max}\, E(D_{B,k}) \qquad (9.4)$$

These prices represent two extreme benchmarks in the continuum of the value of capital market in discovering information through trading. The NE price gives no role to capital market in price discovery, while the PFE price assumes full discovery (i.e., trading in capital market can correctly identify the share's highest value in each future holding period). They define, respectively, the lower and upper bounds of the share's fundamental value. Thus with payoffs to traders and across holding periods under the control of the experimenters, we can now identify with certainty whether a stock is undervalued (when price is below NE), or overvalued (when price is above PFE), or is in a bubble (when price is grossly below NE or above PFE, as in a negative or positive bubble). If the experimental market captures a well functioning capital market, learning and repeated trails would cause prices to converge toward PFE.

There are two properties in (Equations (9.3) and (9.4)) that are worth noting. First, NE and PFE prices are identical in a one period world when price determination is closer to a simple auction of a single period payoff. Second, when the payoff in the equations are dollars, as in cash dividends and capital gains or losses, NE and PFE give the risk neutral prices. In the absence of risk neutrality, a negative difference between observed prices and these prices may be interpreted as a risk premium.

The results illustrated in Figs. 9.1–9.3 establish the validity of our experimental design as we are able to produce results similar to those obtained in previous experimental studies. In particular, we are able to reproduce the result that prices converge to PFE with learning and repeated trials. These prices are plotted as a solid horizontal line and are greater than the NE prices.[14] The inexperience of traders in experiment 1 is greatly reduced in experiments 2 and 3 as traders learn to cope with the large uncertainty in valuations (introduced by design). This pricing uncertainty increases the traders' reliance on "market generated information" in order to determine valuation. A micro-analysis of traders' accounts in experiment 2 shows that some traders became actively involved in arbitrating between the A and B periods of a trading year. As a consequence these prices tended toward their PFE equilibrium levels.

Traders' learning contributed to further pricing efficiencies in experiment 3. Some earlier "irrational" trades by selected individuals had resulted in substantial losses creating a "once-bitten" effect and more rational decisions were

[14] Note that all odd numbered experiments used the dividend design in Table 9.2. In order to differentiate between (1) learning about a stationary environment and (2) learning efficient valuation within laboratory markets, we created nonstationarity in equilibrium prices across experiments. In particular, for all even numbered experiments, the dividend payoffs of Table 9.2 were simply cut in half so that rational equilibrium prices were also one half that of the odd numbered experiments. When this equilibrium dividend rotation is viewed in conjunction with the previously mentioned rotation of trader types, it becomes apparent that each individual trader was likely to view the environment (at least initially) as nonstationary. Consequently, any results that we show regarding equilibrium pricing and convergence would suggest that learning about valuation methods rather than a stationary environment creates rational valuation. That is, we are concerned about learning that takes place within the trader (how he values) not about the environment (stationary value). We are able to pursue this expanded question due to our debt to earlier authors who have already well established the presence of the latter.

followed subsequently. By the end of this experiment, prices in both the A and B periods were close to the PFE price.[15] A final examination of the validity of the experimental design was performed by requiring each trader from Las Vegas experiments 5 and 6 to "invest" his own money ($20) into the markets. As a result, it was possible for traders to lose as well as to win. The results, illustrated in Fig. 9.5, show continued price convergence toward equilibrium levels.[16] Of interest is the pattern of the bid-ask spread within a period. The data suggests that the primary resolution of uncertainty is obtained during the first transaction of a period. Subsequent trading tends to vary little from earlier levels with subsequently smaller bid-ask spread levels.

We conclude the control section noting that the experimental design creates price-revealing trades that foster PFE equilibrium pricing. While consistent with earlier research, these results extend our knowledge into a much more uncertain (nonstationary) valuation environment more typical of real world asset markets. In addition, the validity of these results are not affected by whether or not a dollar investment is required from traders; trading behavior is similar under both environments.

9.4.2 The Formation of Bubbles

With a well-functioning experimental design established, we now sequentially introduce our hypothesized treatment variables. In experiment 4, we introduce the shortened trading horizon with a tournament prize as described in the experimental design. At this point, we have an advantage over previous studies in that we were able to recruit the identical 12 traders back. This level of experience will lead to converging equilibrium prices as opposed to bubble formation.[17]

The effect of the tournament compensation is to shorten the traders' investment horizon in period A from a PFE two-period model. By providing tournament payment based on period A relative ranking, there is an increased incentive to generate period A capital gains over equivalent period B dividends. The tournament compensation, while increasing the incentive to win, does not necessarily equate to higher equilibrium prices. The prize is paid to the largest (realized and unrealized) relative capital gains that can be achieved in either a bull or bear market.

Extraordinary results are shown in Fig. 9.4 where five massive price bubbles are observed in each of the A periods. At this point, a new learning phase was initiated as traders competed strategically for the tournament prize. The dominant initial strategy centered on buying all available assets at increasing price levels thereby creating artificial price support for capital gains. While this often resulted in achieving the prize, it also meant dealing with an inventory of overvalued assets in period B. Some traders actually lost money for the year even though they obtained the prize. It is important to note that the bubbles did not discourage the traders from participating, and at least for awhile the number willing to participate actually increased. Examination of asset holdings reveals that there were four to five active prize seekers in later bubbles versus one to two initially. In addition, seven to nine traders continued to hold securities at the periods' end rather than to sell out at extremely high bubble levels.

The much higher increased tournament reward structure for "superstar" performers of periods 4 and 5 (see Schedule Two of Table 9.3) resulted in the largest bubbles (consistent with our predictions) and with the greatest variability in prices and bid-ask spreads. Again, the buying frenzy in period 5 was led by different traders than those in period 4. This continued rotation in trading leadership highlights that the results are not driven by a few misinformed traders. In fact, period B prices are very stable and efficiently priced. Furthermore, a trader questionnaire survey at the end of experiment 4 revealed that traders were fully cognizant of expected dividend value, yet they looked to both dividends and market generated information to determine value. Traders stated that they were influenced by the behavior of their peers and were motivated to earn as much as possible. Several traders noted that the introduction of the tournament compensation stimulated them to take on more risk. The net result of these effects was to create a herd or bandwagon effect centered on market-generated information.

Despite the earlier findings of experiment 5, we tested the validity of these bubbles in an environment where traders used their own money rather than the experimenters.[18] Would such wild speculation occur when a trader's own money was at risk? Figure 9.6 clearly shows this answer to be yes. In all five A periods, average prices are more than twice the equilibrium value. As before, period B pricing is very efficient

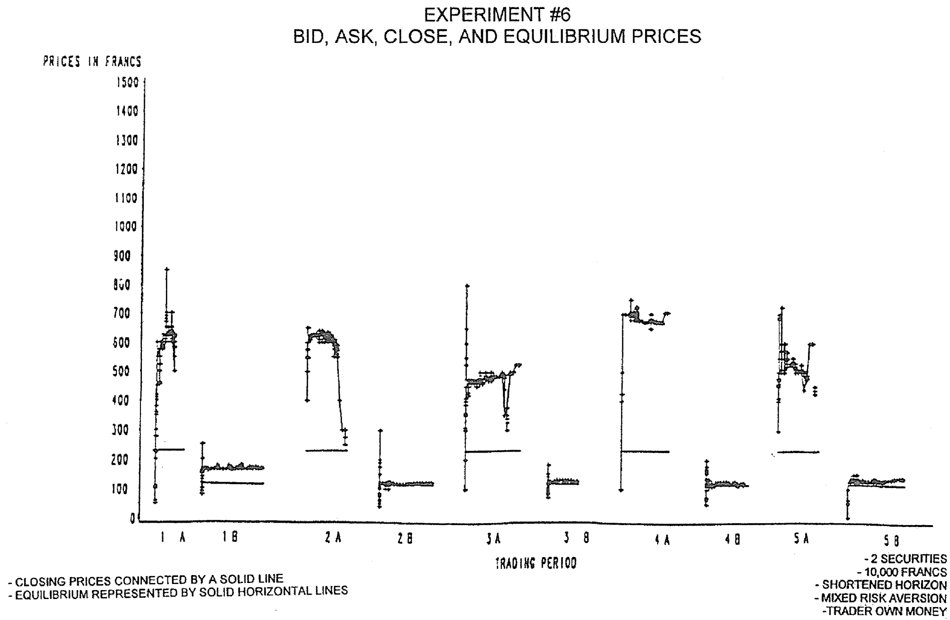
[15] While period A prices exceeded the calculated PFE price of 460, this price is somewhat unknown to traders at this point. Prior trading results had created a history of B period prices averaging 320. Consequently, it was rational for a PFE trader to pay up to 550 (230 for A period plus 320 for B period sales price). The last trade in period 5A of 505 was well below that level. A more detailed presentation of the experimental results further reveals the rationality of these prices and is available from the authors upon request.

[16] Again, period A prices seem to drift upward due to initial excess pricing in period B.

[17] Our design is to eliminate the bubbles effect of miscalculation caused by inexperienced traders as suggested by White (1990) and King et al. (1990). It is more useful and realistic to study the formation and control of bubbles in markets of experienced traders.

[18] To the authors' knowledge, this is the first time traders in an experimental market of this type have used their own money to trade and still produced bubbles.

Fig. 9.6 Experiment #6



and stable. That is, although our traders engaged in bubble pricing, they arrived at it through rational means.

The traders in these markets had now participated in six experiments, the most of any research to date. Yet, even in the presence of super-experienced traders we continue to find bubble formation. In addition, these traders were aware of the situation and made every opportunity to profit from the bubble.[19]

9.4.3 The Control of Bubbles

It became readily apparent from the earlier experiments that restrictions on the supply side of the market were having an influence on market prices. Many traders found themselves bound in their actions by the institutional makeup of the experimental markets. Many of the traders suggested that they be allowed to short-sell in future experiments so as to implement sell strategies in overvalued markets.

As previously mentioned, the tournament compensation system does not alter PFE prices as the prize can be achieved in any type of market environment and with any type of price pattern. Given the results of our previous experiments as well as traders' comments,[20] it appeared that buyers (longs) had an advantage over sellers (shorts). Is it possible that the bubbles we observe were due to differential market position in addition to a shortened investment horizon? In order to answer this question, we conducted four more experiments that provided traders with initial endowments and better equated the position of buyers and sellers. Rather than being endowed with two securities and 10,000 francs of trading capital as before, each trader is initially endowed with five securities and 3,000 francs (see Table 9.3).[21]

The price patterns of experiments 7–10 are as startling as the dramatic bubbles earlier. We find that the market is immediately priced at a discount to PFE.[22] This had never

[19] For instance, new strategies were employed at various stages (which perpetuated continuing uncertainty in the markets). At one time, the market actually stood still for an extended period. Then traders began to liquidate at any price rather than to replicate their earlier strategy of waiting until late in the period to sell out at bubble prices. Other traders began to try and scalp the market by driving prices both up and down thereby generating capital gains in both price directions. Even others began to try and force losses on traders with large inventories and thereby improve their relative ranking. This was accomplished successfully in period 2A by selling at a loss (at a price below market prices) in order to create a low settle price, M (the second to last trade). Other attempts at this strategy followed in all remaining A periods. Nevertheless, bubbles persisted and many traders were frustrated in their inability to arbitrage them away.

[20] Traders completed survey questionnaire at the completion of experiments 4, 6, and 10.

[21] Given that experiment 6, period A prices averaged around 600, initial trading capital of 3,000 francs would provide buying power of roughly five securities. Consequently, the new buying power and selling power were a prior relatively equal. Even though period A prices turned out to be quite a bit lower in experiments 7–10, this did not create a great advantage to buyers since the supply of securities (5 traders $\times$12 traders $=$ 60) was relatively large for a 6-min trading period. As such, there was an ample supply of securities relative to buying power in order to drive prices down should traders turn bearish.

[22] We are unable to recruit all 12 traders back for experiments 7–10 due to graduation, taking of jobs, etc. We were, however, able to retain 7 of the original 12 traders. These traders had now participated in six previous experiments. The five replacements were drawn from the original pool of subjects that had completed the risk attribute questionnaires. These new traders were chosen to replace the risk types that had

happened in any of the tournament periods before. If this had been simply the result of learning, we would have expected a gradual decline from the lofty levels of experiments 4 and 6. Rather, we see an immediate discount price that generally remains at a discount throughout all four experiments.[23] Overall, we consider this to be strong evidence that a necessary condition for the creation of the large bubbles of these markets is that the institutional environment be biased toward more purchasing ability relative to that of selling.

In summary, experiments 7–10 highlight the importance of the supply of securities and the supply of investable funds that may be augmented by short selling. Bubbles observed in experiments 4 and 6 are immediately eliminated when the relative purchasing advantage of long traders is removed. Rational pricing reflecting a modest risk premium results even when traders are faced with a shortened investment horizon.

9.4.4 The Impact of Risk Aversion

The results of previous experiments, especially 6, showed that trader risk aversion was an important factor in determining trader strategy and therefore price patterns. In general, it was found that speculative traders were more likely to seize upon the opportunity created by the introduction of uncertainty (via the tournament period) in search of capital gains. In contrast, the more conservative traders were likely to allow the speculators to act first by creating a positive price trend and would simply sell at inflated prices or they would allow speculators to first initiate the "burst" of the bubble and then follow in their footsteps. Consequently, the conservative traders were often those responsible for the perpetuation of a direction initially set by speculators. The purpose of experiments 11–14 were to further test these relationships.[24]

We chose at this time to create two separate trading groups according to risk aversion, each composed of 12 traders. These 24 traders were chosen from a pool of 70 students that completed the risk-ranking questionnaire described earlier. The 70 respondents were rank ordered from highest to lowest in risk aversion. The top 12 and bottom 12 students were chosen to participate in the experiments. This method allows us to obtain good separation according to risk aversion. Contrary to our previous experiments, these markets would be made up entirely of one risk aversion class. We label these two risk classes as speculators and conservatives. This is a relative nomenclature as all of these traders are considered to be risk averse, and we only presume to provide an ordinal measure of risk aversion Figs. 9.7–9.10.

The design of these experiments follows that of experiments 1–6, as we wish to test for the presence of bubbles and the initial endowments of experiments 7–10 have already been shown to eliminate bubbles. All of these traders had previously participated in two experimental markets and therefore can be considered experienced. Nevertheless, we test for rationality of pricing in experiments 11 and 13 before introducing the shortened horizons in experiments 12 and 14.

Figures 9.11–9.13 reveal that both markets are quite rational in that they charge a discount from PFE as a risk premium. As expected, the conservative traders of experiment 13 charge a larger risk premium than the speculative traders of experiment 11. This result provides strong evidence in support of our measure/separation of risk aversion. We also note that the speculative group exhibits prices above the PFE levels of period B. This is consistent with our earlier results where this was found in the single period case Fig. 9.14.

Experiments 12 and 14 introduce the tournament compensation schedule to induce a shorter investment horizon. As expected, the speculative group seizes upon the opportunity and price bubbles are generated in the latter periods. Also to no surprise, the conservative group does not create

vacated, so that, in general, we maintained a wide dispersion of risk types within the market. In addition, some of these new traders had sat in as observers to previous experiments. Others viewed videos of the earlier experiments. All were instructed in the past experimental results and the various strategies previously used were explained. As such, we do not believe that this change is a critical factor in the continuation of our investigation.

[23] An analysis of many of the last trades of period A for experiments 7–10 often shows either a sharp spike up or down. This illustrates that the traders had become very efficient (through learning) in their manipulation of closing prices. Given the large supply of securities available to squelch a price bubble, speculators were no longer singularly (due to large initial endowments of trading capital) able to create capital gains by driving market prices up. With this constraint, they quickly learned that all they needed to accomplish was to purchase the most securities at current prices and then drive the market up on the final few trades. This was often easily accomplished in that (1) only the second to last trade needed to be higher in line with the calculation rules of the TPI, and (2) as no surprise, there was always many traders who were willing to sell their securities at a price above the current level. The art to this strategy became a matter of timing; do not try to buy the market too early lest you run out of capital, and do not be too late lest you be unable to make the second to the last trade. There did not appear to be too much of a problem for buyers in accomplishing this in experiments 7 and 8; however, starting in experiment 9, some short traders, annoyed at bullish traders getting the tournament prize, began jockeying in these last seconds with the long traders to drive prices down. The results of such feuds appear in periods 3A, 4A, and 5A of experiment 9 and each A period of experiment 10. The winner of these duels increasingly became the trader who was best able to execute his trade. Eventually, trading activity become so frantic in the last 15 s of trading that the open outcry systems of double oral auction began to break down.

[24] Experiments 11–14 were conducted at a second university and, therefore, the results provide information about the external validity of our experiments outside the setting of a single university.

Fig. 9.7 Experiment #7

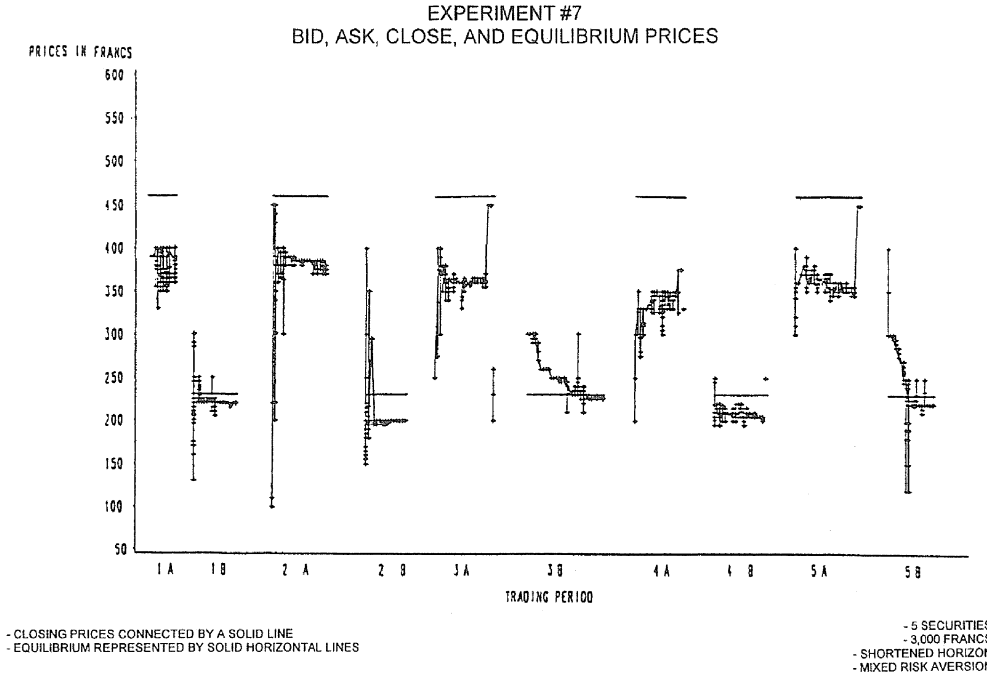
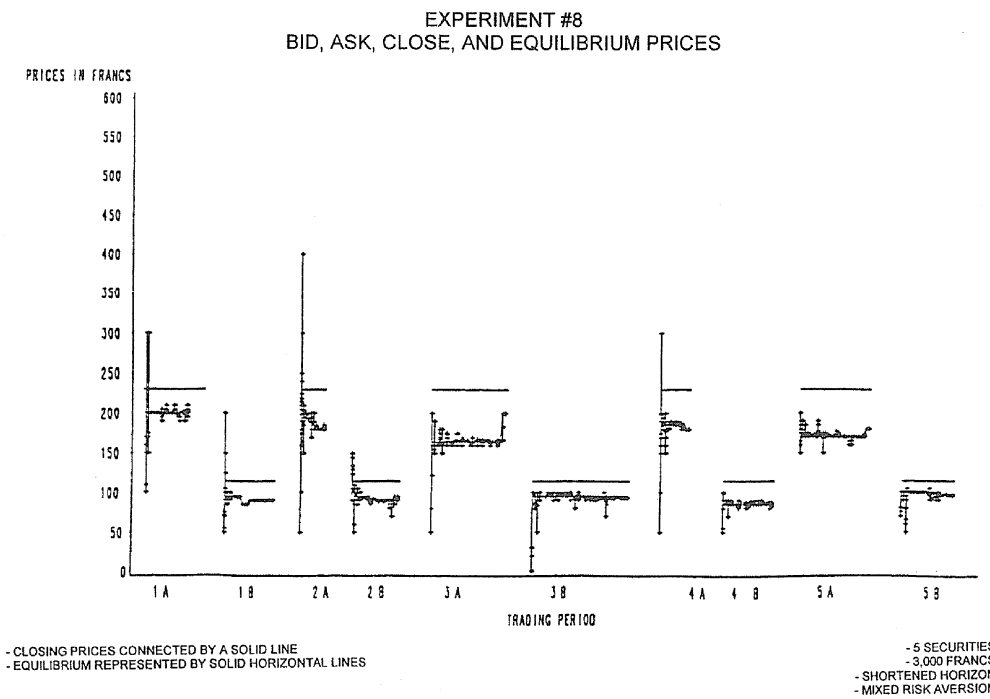


Fig. 9.8 Experiment #8



the pressure necessary to cause bubbles to form. As a result, we conclude that a necessary condition for asset bubbles is the presence of speculators.[25]

9.4.5 The Formation of Negative Bubbles

We have just learned that the effect of the reduced investment horizon is to increase the incentive for short-term speculative

[25] A detailed examination of individual trades reveals the speculative group of traders are found to be more innovative in designing new trading strategies both in the creating and bursting of bubbles. The finding is consistent with the observation made by Friedman (1992) in his review of a dozen NBER working papers on asset pricing. He finds these recent research results demonstrate that rational speculative behaviors such as an attempt by investors to learn from other investors, to affect another's opinion, or to simply engage in protective trading could in some context, such as imperfect information, magnify price fluctuations.

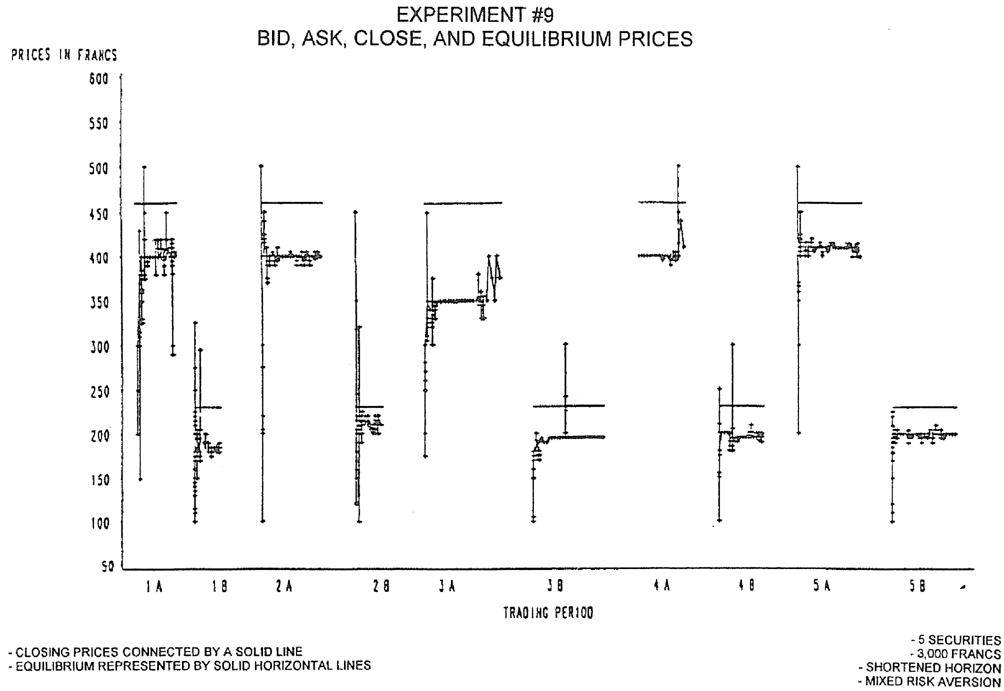


Fig. 9.9 Experiment #9

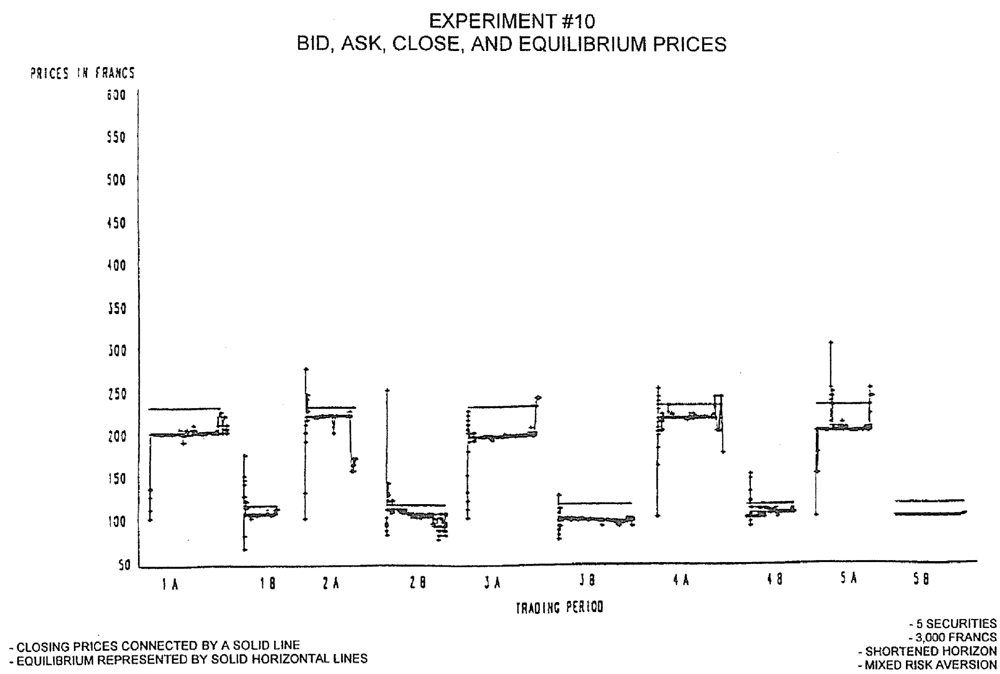


Fig. 9.10 Experiment #10

gains and that speculative traders are those most eager to earn these profits. We now extend the research design to investigate the question of whether negative bubbles are also possible. We test this proposition by conducting four new experiments (labeled as experiments 15–18 in Table 9.1). We conduct experiments 15 and 16 as "controls" to replicate the positive bubble environment found in experiments 4, 6, and 12. Experiments 15 and 16 validate our previous results with a new set of experimental subjects while Figs. 9.15 and 9.16 plot the pattern of close prices relative to the equilibrium level (horizontal line). In both experiments large positive bubbles emerge in most trading years.

We now pose the following question, "Would an environment opposite to that of Design 2 lead to negative bubbles?" We keep the structure of Design 2, but since it was the unequal endowment effect (more purchasing power versus selling pressure, under 2 securities, 10,000 francs) that created the ability to pursue profits in a positive bubble

Fig. 9.11 Experiment #11

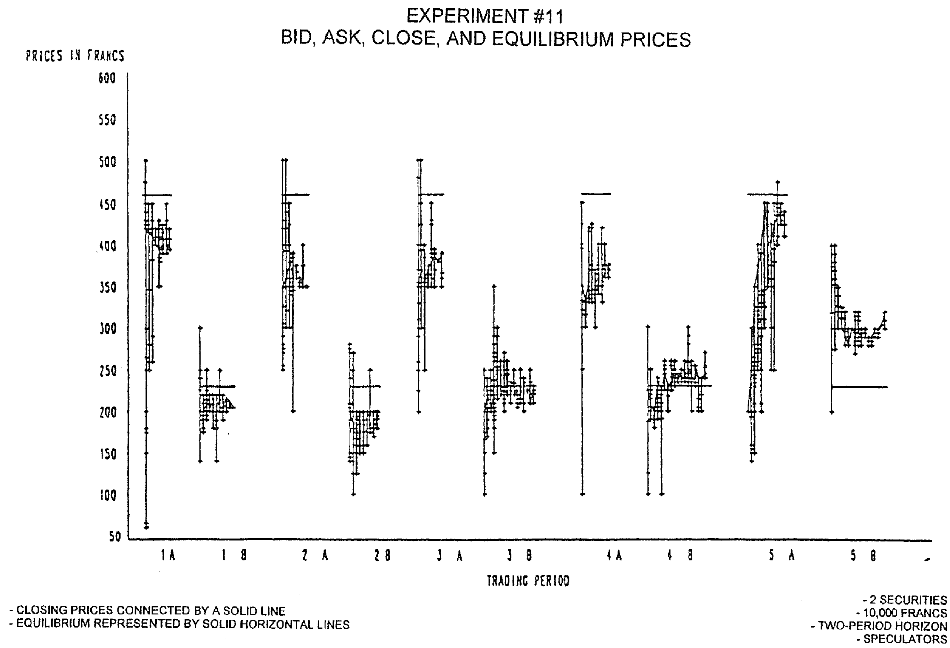
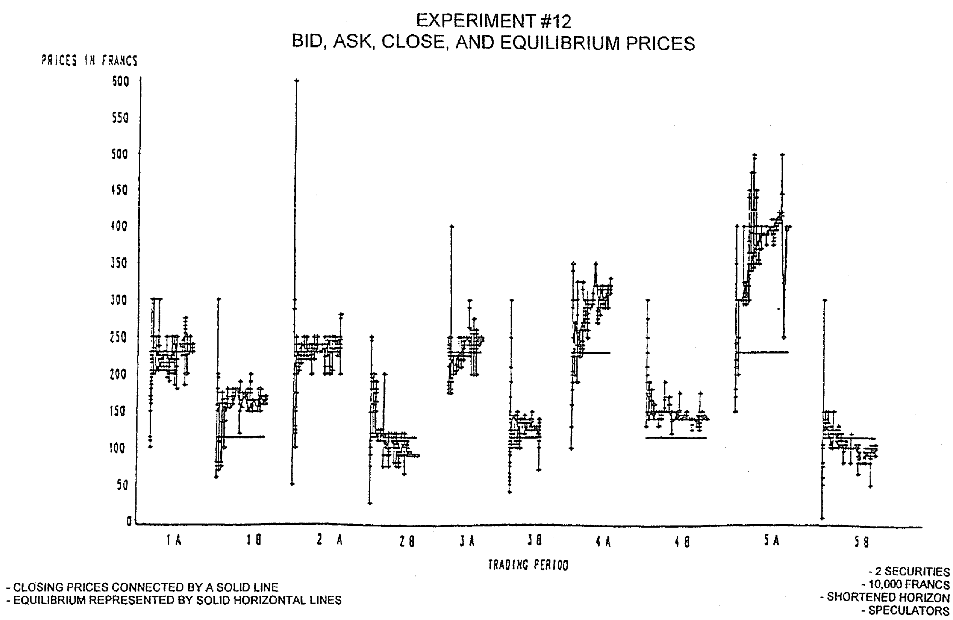


Fig. 9.12 Experiment #12



environment, we reverse the endowment effect in experiments 17 and 18 by providing 10 securities and 1,000 francs to each trader. This one change provides traders in experiments 17 and 18 with a much greater ability to buy relative to sell.

The results plotted in Figs. 9.17 and 9.18 show a preponderance for negative bubbles. While the initial four years of experiment 17 show some learning adjustment to this new and difficult trading scheme, large price discounts emerge to the extent that period 5A's closing price is insignificantly different than period 5B's, which is a single period receiving only a single dividend. By experiment 18, each year shows downward trending markets in each A period. The reader may notice that the positive bubbles seem to burst while the negative bubbles don't. However, since our design did not allow more cash to be made available through borrowing or infusion, correction may not be observed in the short trading period.

9.4.6 Statistical Analysis

Table 9.4 summarizes regression analyses of the impact of the variables just discussed upon the divergence of asset

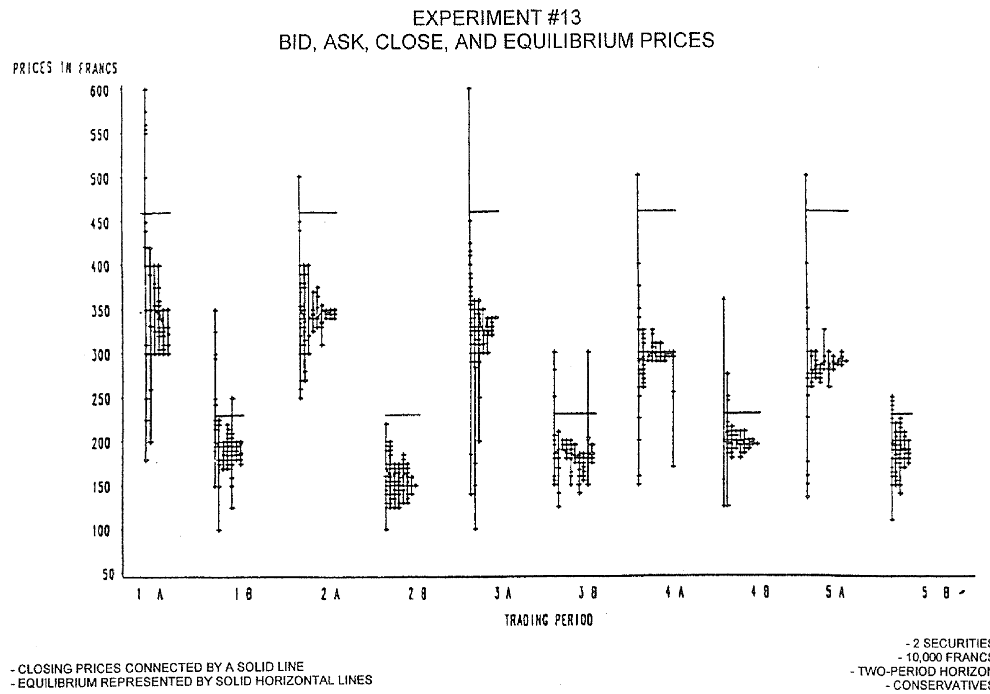


Fig. 9.13 Experiment #13

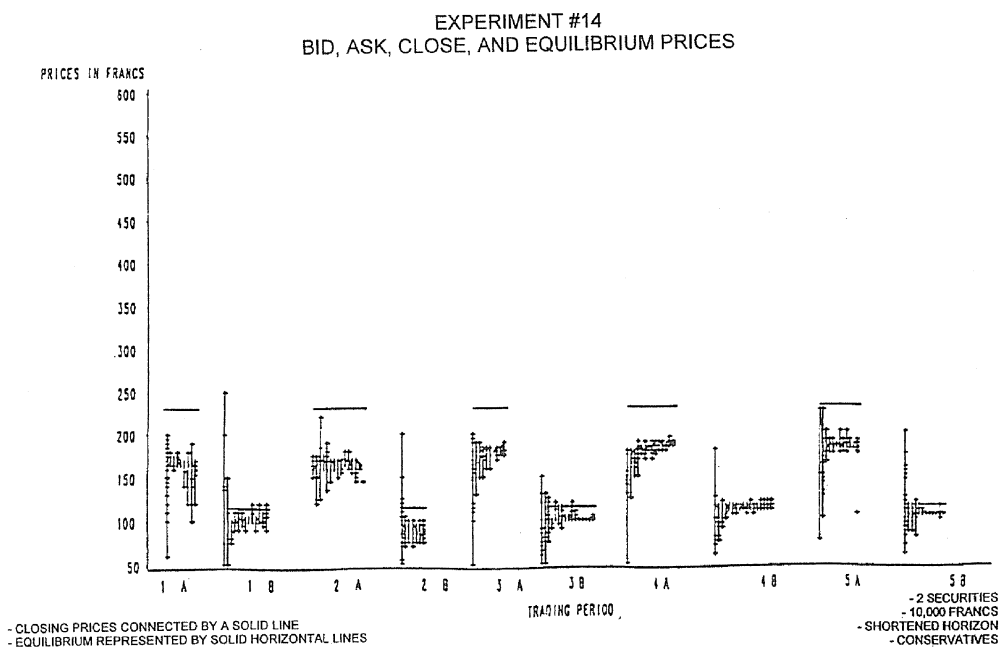


Fig. 9.14 Experiment #14

prices from their PFE levels in period A. In particular, we test the following relation:

$$P^L\text{–PFE} = f(\text{I, E, I*E, T, I*E*T, S, I*S, A, I*A, \$}) \quad (9.5)$$

where P^L-PFE, the deviation from equilibrium for period A of each trading year where P^L is the last trade of the period and PFE is the Perfect Foresight Equilibrium price; f, a linear additive model; I, a dummy variable representing the shortened Investment horizon according to Table 9.1. I = 1 for shortened horizon, and 0 otherwise (i.e., experiments 4,610,12,14); E, a dummy variable representing the Endowment effect according to Table 9.1. E = 1 when 2 securities are issued, and 0 otherwise (i.e., experiments 1–6, 11–14); I*E, an interaction dummy variable representing both a shortened investment horizon and two security endowment (i.e., experiments 4, 6, 12, 14); T, a dummy variable representing the Tournament effect according to Table 9.1. T = 1 when there is a tournament prize for two traders only, and 0 otherwise (i.e., experiments 4, 6, 12, 14 (years 4 and 5) and 9, 10); I*E*T, an interaction dummy variable representing a shortened investment horizon, a two security

Fig. 9.15 Experiment #15

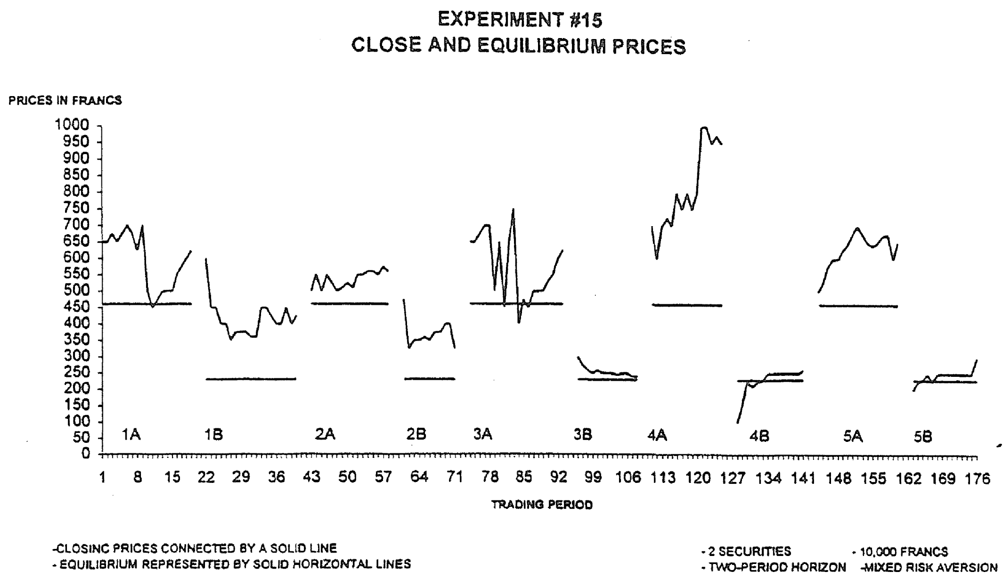


Fig. 9.16 Experiment #16

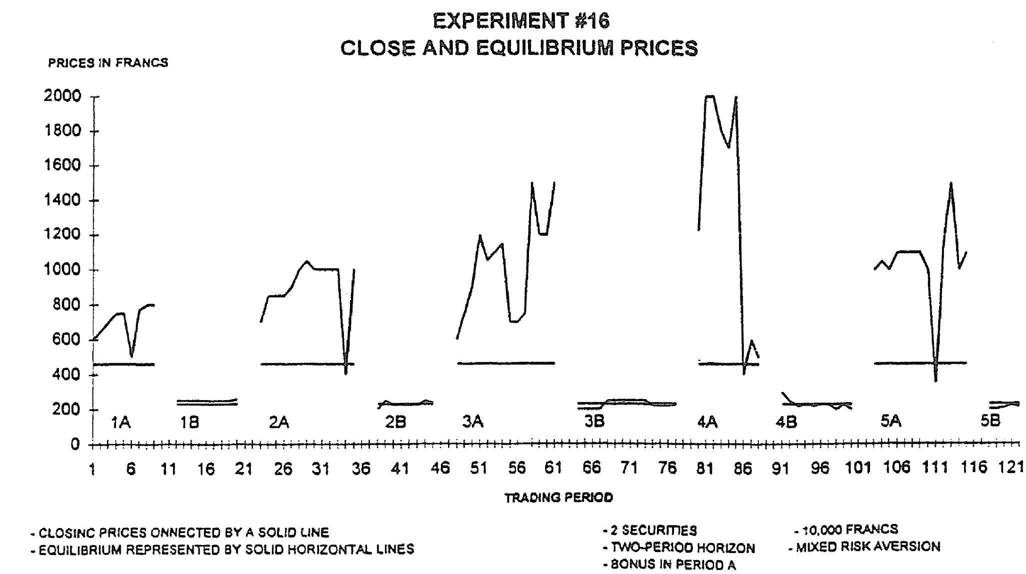


Fig. 9.17 Experiment #17

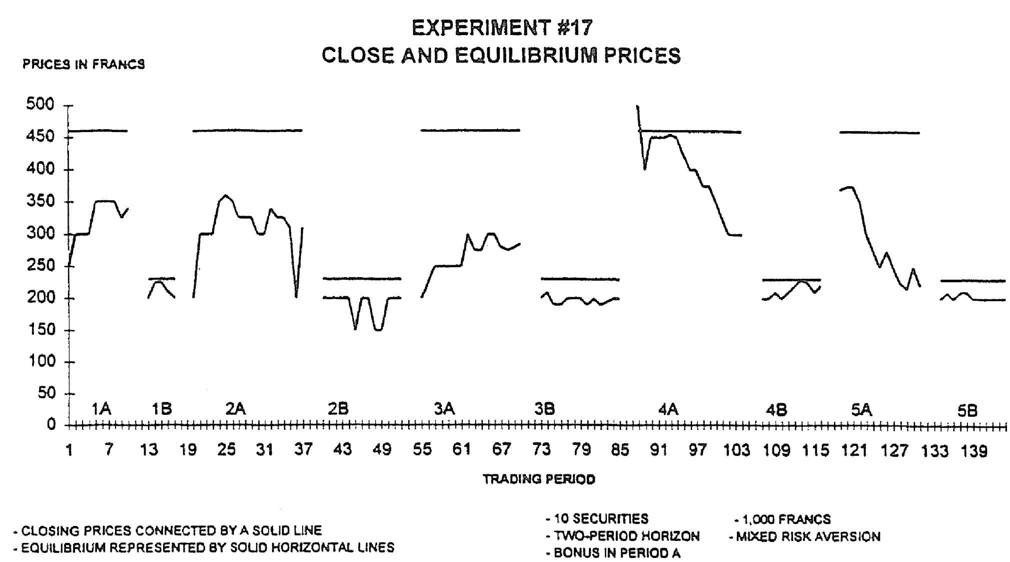
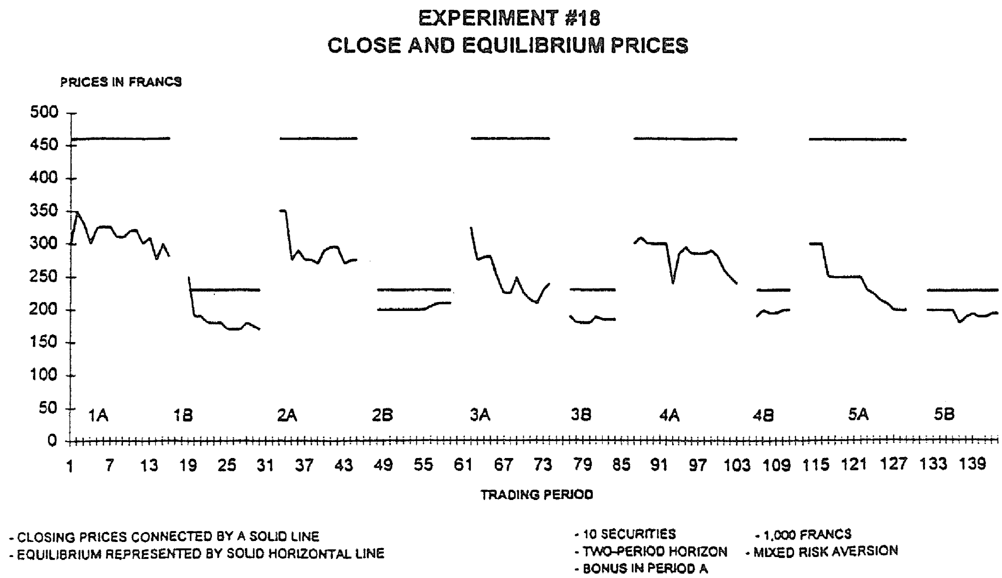


Fig. 9.18 Experiment #18



endowment, and a tournament effect (i.e., experiments 4, 6, 9, 10 (years 4 and 5)); S, a dummy variable representing the extent to which speculators participated in the experiments according to Table 9.1. S = 1 for experiments 11, 12 and 0 otherwise; I*S, an interaction dummy variable representing the shortened investment horizon and a pure speculative trader market (i.e., experiment 12); A, the ratio of end-of-period asset inventory for speculative traders to total asset holdings. Speculative traders are those who scored in the top one-half of the risk measurement questionnaires; I*A, an interaction variable for shortened investment horizon and ratio asset holdings for speculators (experiments 4, 6–10, 12, 14); $, a dummy variable representing experiments where traders risked their own money according to Table 9.1. $ = 1 when own money is used, and 0 otherwise (i.e., experiments 5 and 6).

Due to their differential design, the results for experiments 1–10 appear separately in Panel A and those for experiments 11–14 in Panel B.

Model 1 of Panel A tests the impact of (1) I = 1, a shortened horizon, (2) E = 1, a restricted endowment effect (wealth and supply effects), and (3) I = 1, E = 1, an interaction of a shortened horizon with restricted initial endowment. Given that the regression was run with no intercept, the coefficients represent estimates of each variable's independent impact. The results suggest that neither a shortened investment horizon nor a biased endowment effect (advantage to "bulls" versus "bears") is sufficient to induce bubble behavior. However, the interaction of these two variables is highly significant in explaining the bubble results of these experiments. That is, an environment that provides both the incentive and the ability to profit from a bubble will likely result in positive price divergence.

As hypothesized earlier, we test for the heightened effect of tournament incentives (i.e., T = 1) by examining the effect of "superstar" prizes paid to only the top two traders (as outlined in Tables 9.1 and 9.3). We also test for an interaction effect with a shortened horizon (I = 1) and restricted endowment (E = 1). Model 2 results are consistent with Model 1 in that a tournament effect is not sufficient in itself (t = 0.13 on T variable); however, in conjunction with a reduced horizon and restricted endowment, the tournament interacts to explain a significant part (t = 4.57 on I*E*T) of the bubbles in these experiments.

In Model 3, we observe the impact of speculative traders vis à vis conservatives by introducing a measure of asset purchase activity. The end-of-period asset holdings for the speculative group (the top one half of traders in risk ratings) is compared to the total asset endowment for all traders. In the absence of any effect, assets should be evenly divided and this ratio, A, should be equal to 5. The results of Model 3 indicate that speculators independently do not impact the presence of a bubble (t = 0.01 for A); however, when speculators operate within a shortened horizon (I*A) they do significantly differentiate themselves from conservatives by buying more and contributing to positive price bubbles. Finally, the impact of the use of the trader's own money is shown not to significantly alter the effects of the price bubbles (t = −0.54 for $). The R2 of 80 suggest that the vast majority of price deviation from PFE levels can be explained by investment horizon, endowment effects, and risk aversion.

Panel B reports the results for experiments 11–14 where markets were either composed of all speculators (11, 12) or all conservatives (13, 14). Due to this makeup, variables A and I*A are not defined in these regressions, although S and I*S are substituted in their place and represent the speculative

Table 9.4 The Impact of Investment Horizon, Credit/Supply Constraints, Risk Aversion, and Other Variables

This table shows the extent to which certain variables cause a deviation from perfect foresight equilibrium values.[a] The following regression is estimated separately for experiments 1–10 and 11–14 according to the experimental design of Table 1.

$$P^L\text{-PFE} = f(I, E, I^*E, T, I^*E^*T, S, I^*S, A, I^*A, \$)$$

Model	Intercept	I	E	I*E	T	I*E*T	S	I*S	A	I*A	$\$R^2$
					Panel A Experiments 1–10 (n = 50)[b]						
1	NOINT[c]	−45.1 (−1.48)	−38.5 (−1.26)	512.3*** (8.40)							.67
2	−48.1 (−1.43)		9.6 (.23)	311.8*** (6.28)	6.1 (0.13)	382.3*** (4.57)					.79
3	−178.1*** (−2.73)		145.1* (1.80)	195.9*** (2.23)	17.3 (0.38)	282.5*** (3.08)		0.8 (0.01)	292.4* (1.77)	−23.6 (−0.54)	.80
					Panel B Experiments 11–14 (n = 20)						
4	−150.5*** (−11.17)	109.1*** (6.98)					89.9*** (4.92)				.75
5	−139.0*** (−9.30)	61.8** (2.71)				61.1*** (2.83)	67.0*** (3.17)	45.8 (1.53)			.83

[a] t-values in parentheses. Variables defined as follows:

P^L-PFE	represents the deviation from equilibrium for Period A of each trading year where P^L is the last trade of the period and PFE is the Perfect Foresight Equilibrium price.
I	a dummy variable representing the shortened Investment horizon according to Table 9.1. I = 1 for shortened horizon, and 0 otherwise (i.e., experiments 4,6–10,12,14)
E	is a dummy variable representing the Endowment effect according to Table 9.1 E = 1 when 2 securities are issued, and 0 otherwise. (i.e., experiments 1–6, 11–14)
I*E	is an interaction dummy variable representing both a shortened investment horizon and two security endowment (i.e., experiments 4,6,12,14)
T	is a dummy variable representing the Tournament effect according to Table 9.1. T = 1 when there is a tournament prize for two traders only, and 0 otherwise (i.e., experiments 4,6,12,14 (years 4&5) and 9,10)
I*E*T	is an interaction dummy variable representing a shortened investment horizon, a two security endowment, and a tournament effect (i.e., experiments 4,6 (years 4&5), and 9, 10).
S	is a dummy variable representing experiments composed entirely of Speculators according to Table 9.1. S = 1 for experiments 11 & 12 and 0 otherwise.
I*S	is an interaction dummy variable representing the shortened investment horizon and a pure speculative trader market (i.e., experiment 12)
A	represents the ratio of end-of-period Asset inventory for speculative traders to total asset holdings. Speculative traders are those who scored in the top one-half of the risk measurement questionnaires.
I*A	is an interaction variable for shortened investment horizon and ratio asset holdings for speculators (experiments 4,6–10,12,14)
$	is a dummy variable representing experiments where traders risked their own money according to Table 9.1. $ = 1 when own money is used, and 0 otherwise (i.e., experiments 5 & 6)

[b] As reported in Table 9.1, experiments 1–10 consisted of traders with a wide range (mixed) of risk aversion. Experiments 11 & 12 were composed only of speculative traders with experiments 13 & 14 composed of conservatives.

[c] NOINT means the regression was run by suppressing the intercept.

*,**,*** signify statistical significance levels at .10, .05, and .01, respectively.

Table 9.5 Negative Bubble and Single Period Results

This table shows the extent to which endowment in conjunction with other variables causes a deviation from perfect foresight equilibrium values.[a] The following regression is estimated separately for experiments 15–18, 19–22, and 23–26 according to the experimental design of Table 9.1.

$$P^L\text{-PFE} = f(\text{NI, E, I*E, E}^N\text{, I*E}^N)$$

Model	Intercept	NI	I*E	I*E^N	R^2
			Panel A Experiments 15–18 (n = 20)		
6	NOINT[b]	45.0 (0.37)	400.6*** (4.67)	−201.3** (−2.34)	.55
			Panel B Experiments 19–22 (n = 40)		
7	NOINT[b]	−22.8(−1.60)	22.5** (2.36)	−92.9*** (−6.89)	.57
			Panel C Experiments 23–26 (n = 20)		
8	−130.0** (−3.61)		174.5*** (3.95)	−208.0*** (−4.08)	.80

[a] t-values in parentheses. Variables defined as follows:

P^L-PFE	represents the deviation from equilibrium for Period A of each trading year where P^L is the last trade of the period and PFE is the Perfect Foresight Equilibrium price.
I	is a dummy variable representing the shortened Investment horizon according to Table 9.1. I = 1 for shortened horizon, and 0 otherwise.
E	is a dummy variable representing the Endowment effect according to Table 9.1. E = 1 when 2 securities are issued, and 0 otherwise.
I*E	is an interaction dummy variable representing both a shortened investment horizon and two security endowment.
E^N	is a dummy variable representing the sell side of the Endowment effect hypothesized to lead **N**egative bubbles. E = 1 when 10 securities are issued and 0 otherwise.
I*E^N	is an interaction dummy variable representing both a shortened investment horizon and a ten security environment.

[b] NOINT means the regression was run by suppressing the intercept.
*, **, *** signify statistical significance levels at .10, .05, and .01, respectively.

markets (11 and 12) and the interaction of shortened horizon with a speculative market (12). In addition, a restricted endowment effect (E = 1) is imposed for experiments 11–14 since experiments 7–10 clearly established their necessity in creating bubbles. Model 4 results highlight the significant positive effect of the combined shortened horizon/restricted endowment effect (t = 6.98 for I). More importantly, the speculative group statistically differs from conservatives with an additional mean price difference of 89.9 (t = 4.92). Model 5 supports the results of experiments 1–10 in that: (1) a shortened investment horizon with restricted endowments leads to price bubbles (t = 2.71) for I, (2) a heightened tournament incentive will heighten short-term horizons and lead to positive price effects (t = 2.83 for I*T), and (3) speculators contribute to positive price bubbles in restricted endowment environments (t = 3.17 for S).[26]

The visual analysis of experiments 15–18 (negative bubble experiments) is confirmed by the regression results reported in Table 9.5. The variables are as defined earlier under equation 5 albeit the EN representing a dummy variable for the negative endowment effect. EN = 1 when the initial endowment equals 10 securities and 1,000 firms and 0 otherwise. In addition, since the shortened horizon variable I occurs for all years except 1A of each experiment, I and E are highly correlated. The design is therefore set to only measure the interaction effects of a shortened horizon and endowment. The four periods (1A of each experiment) are the control periods where a shortened horizon is not present (dummy NI = 1 for not I).

The parameter estimates of Model 6 show significant positive results for both positive and negative bubbles. The joint presence of a shortened horizon induced by a tournament payoff along with a buy side endowment (2 securities, 10,000 firms); that is, I*E = 1, leads to an average increase of 400.6 francs in price levels. The single alteration of the endowment to sell side (10 securities, 1,000 francs) in the presence of a tournament leads to an average decrease in price of 201.3 francs. The estimate for NI reflects the insignificant impact of the control periods where the endowment effect is present but without the tournament payoff inducing a shortened horizon. So as in the earlier results, the combined effect of the incentive (i.e., the tournament) and the ability (i.e., the endowment) work to create both positive and negative price bubbles.

9.4.7 Further Tests

To check the robustness of our results we conducted eight final experiments in a unique and different setting, the former communist country of Albania. Of its many unique

[26] Furthermore, although insignificant, the p-value for $I*S$ is equal to 14 suggesting that the speculative difference may be even greater under a shortened investment horizon.

characteristics, one of the most important is its history of being the most isolated (politically and economically) country in Europe since World War II. Since democratic reforms began in 1991, a new business school was opened in the second largest city of Albania, Shkodra, where the third year students served as traders. Would the students whose country didn't have a securities market or a history of free market trade show the same results as we had found at U.S. universities? While our previous experiments had the most experienced traders ever used in a study, these Albanian students may indeed represent the least experienced traders examined to date, which may be regarded as an extreme test of the validity of our results.

Because of the newness of the trading experience for these students, a single period design was used in the first four experiments. For each experiment's ten trading years (no period B), asset payoffs were for a single dividend payoff. The amounts used were the same as those of Table 9.2 so that equilibrium levels remained at 230 for each year. As shown in Table 9.1, Design 7 (experiment 19) consists of a single period security without a tournament effect. Design 8 (experiments 20 and 21) introduces the tournament payoff of Table 9.3 (Schedule Two) within the single period environment. This allows us to test for the presence of bubbles in the simpler pricing environment while also easing the learning experience of the Albanian students toward two-period tournament pricing.

The pricing results for these three experiments can be seen in Figs. 9.19–9.21. Without the tournament in experiment 19, pricing is rational and typical showing a discount (risk premium) of about 30 francs from the equilibrium level of 230. Near the end of experiment 20, the tournament effect appears to have created some price movement above equilibrium. This pressure continues into experiment 21 where prices trade at an average premium of 30 francs. Although these premiums do not constitute a bubble, it is clear they had a significant positive impact on pricing levels. Would this effect be eliminated (reversed) by changing the buy/sell pressure as was done earlier under Design 6 where negative bubbles were induced? Design 9 tests this proposition by changing the endowment from 2 securities and 5,000 francs to 20 securities and 500 francs. The results, reported in Fig. 9.22, show that even in these simple markets the endowment effect combined with tournament payoff leads to pricing away from equilibrium. These observations are confirmed by the regression results of Model 7 in Table 9.5 where buy side preference ($I^*E = 1$) leads to significant increase in prices while sell side preference ($I^*EN = 1$) leads to lower prices. The absence of a tournament payoff ($NI = 1$) leads to insignificant price effects as investment horizon cannot be altered in a single period market.

The Albanian students had now participated in four single period experiments and were ready to attempt two-period pricing. Experiment 23 was a simple two period pricing environment without any tournament payoff as in Design 1 (control). The plot of prices in Fig. 9.23 shows that the students initially struggled with two-period pricing since period A prices (two payoffs) differed little from period B prices (single payoff), although by the end of the experiment enough learning had developed.

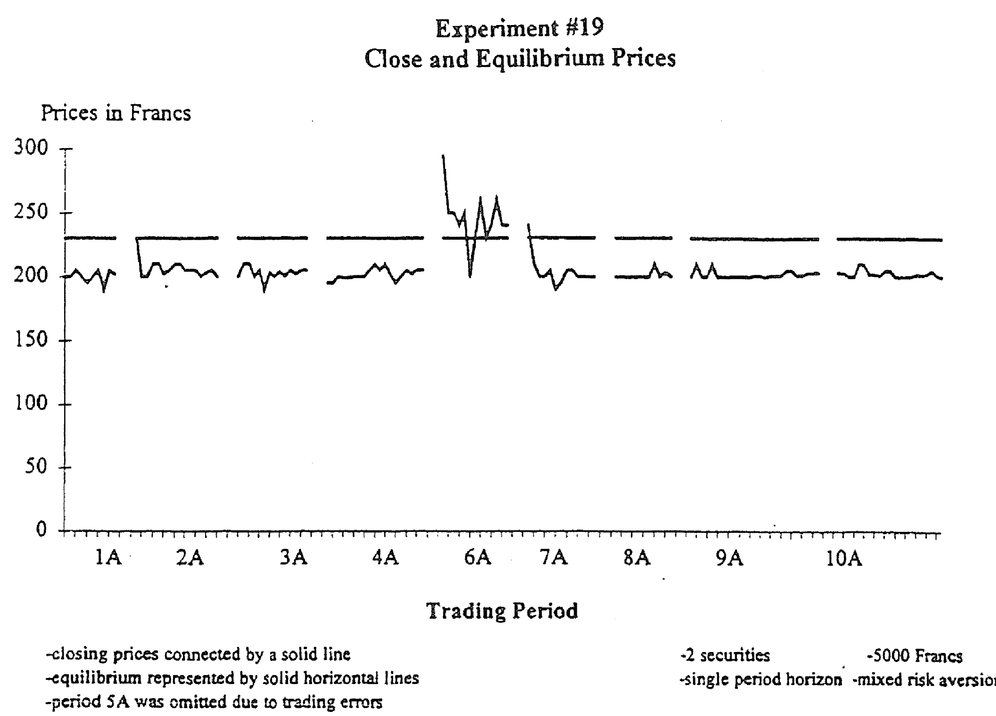


Fig. 9.19 Experiment #19

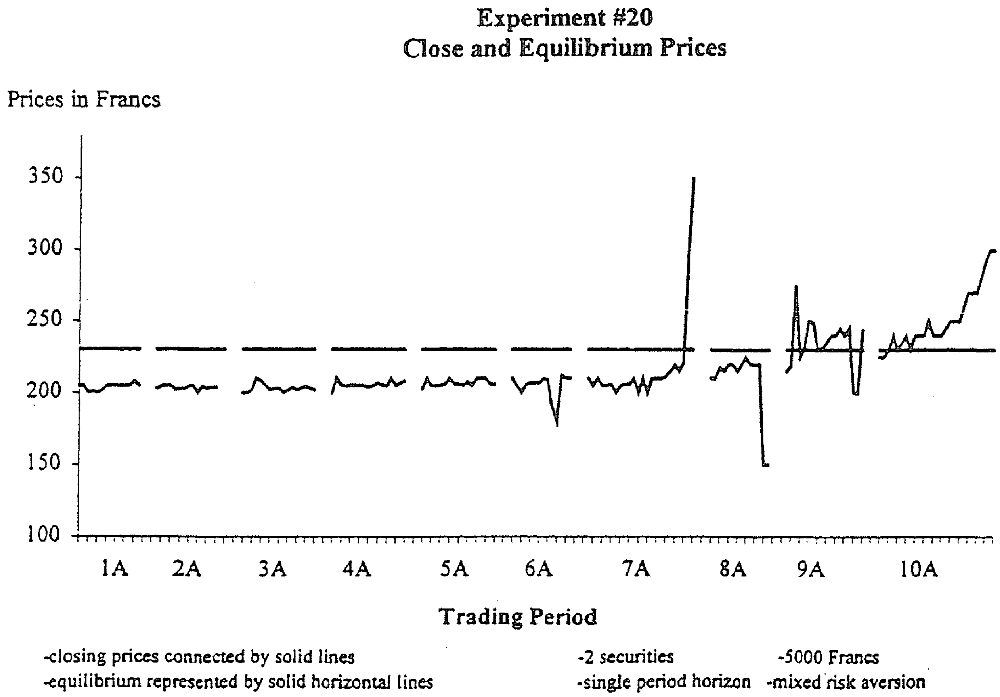


Fig. 9.20 Experiment #20

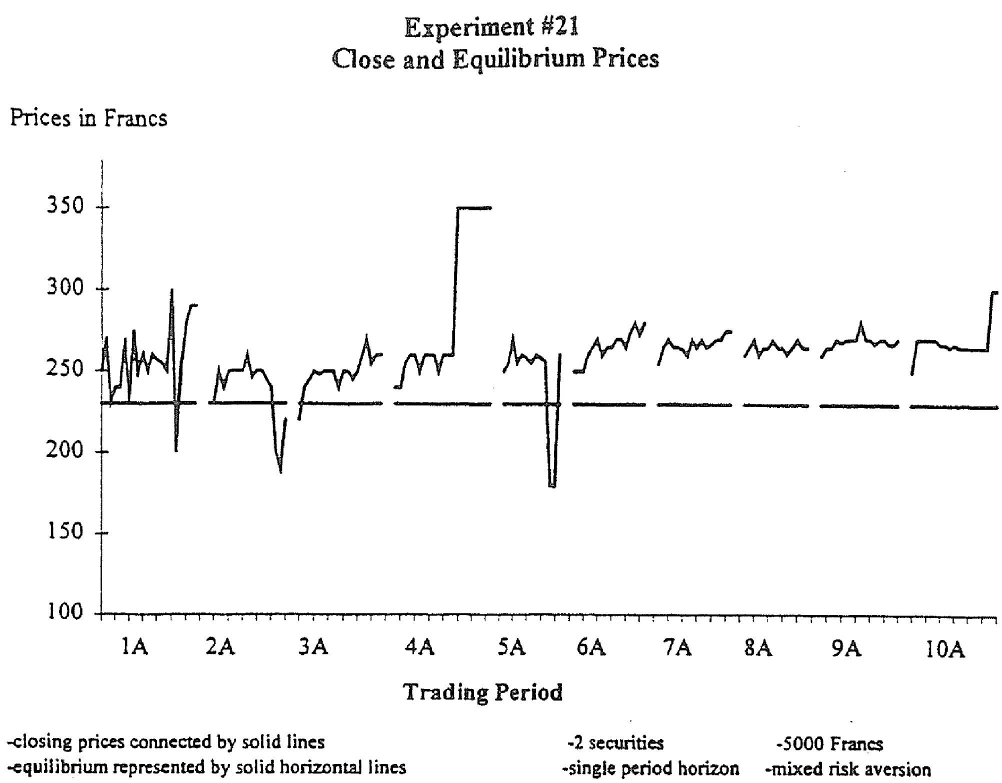


Fig. 9.21 Experiment #21

Experiments 24 and 25 introduce the shortened investment horizon (tournament effect) within the two-period framework as in Design 2 earlier. The price patterns in Figs. 9.24 and 9.25 show the creation of positive price bubbles to levels approaching 650 francs. Despite the historical background of this country and these students, they responded to market pressures in the same bubble-like manner. The last experiment, 26, alters the endowment to the sell side as before to see if negative bubbles can also be obtained. Price paths in Fig. 9.26 show a general downward trend of

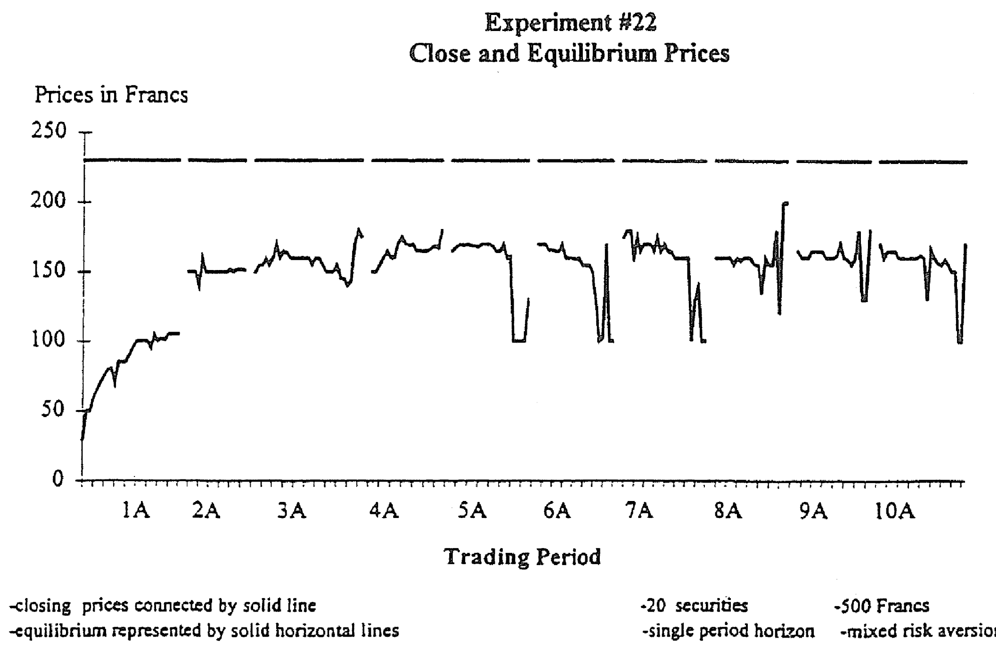


Fig. 9.22 Experiment #22

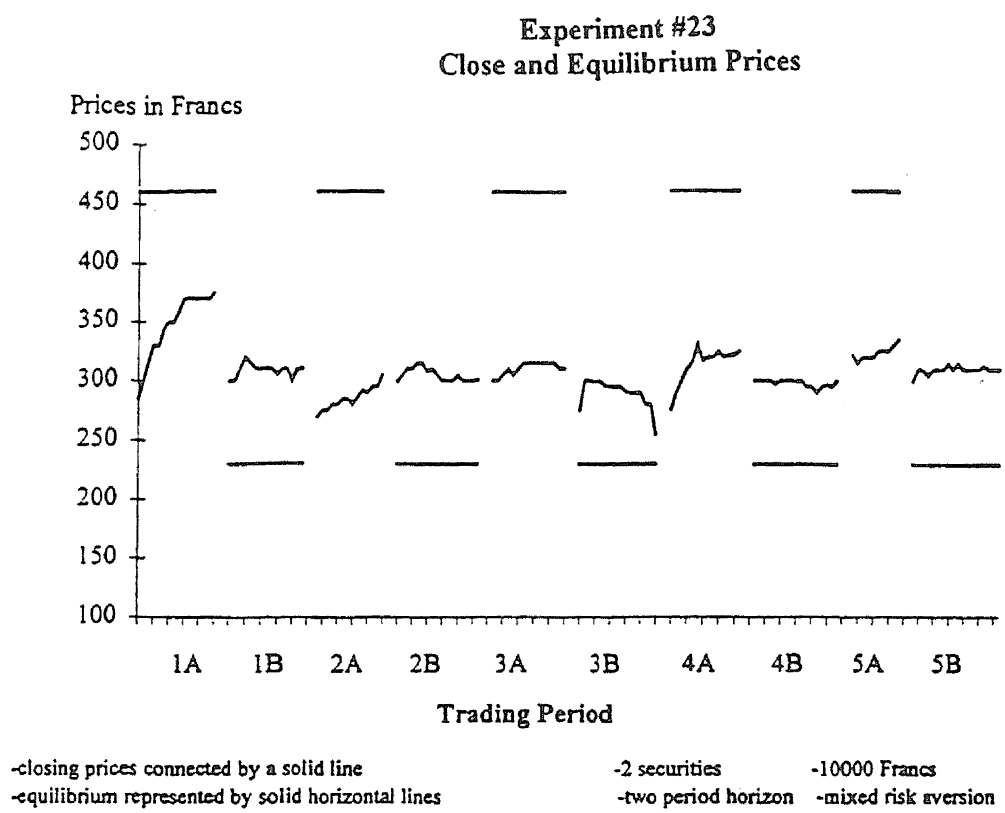


Fig. 9.23 Experiment #23

prices. The prices in period A show significant and growing discounts from the equilibrium levels of 460. These observations are confirmed by the regression results reported in Panel C of Table 9.5 with buy side endowment contributing 174.5 francs and sell side endowment reducing levels by 208.0 francs.

9.5 Conclusions

The results of this study have a number of implications for real world markets. Experiments 1–6 seem to imply that within an environment that restricts selling pressures,

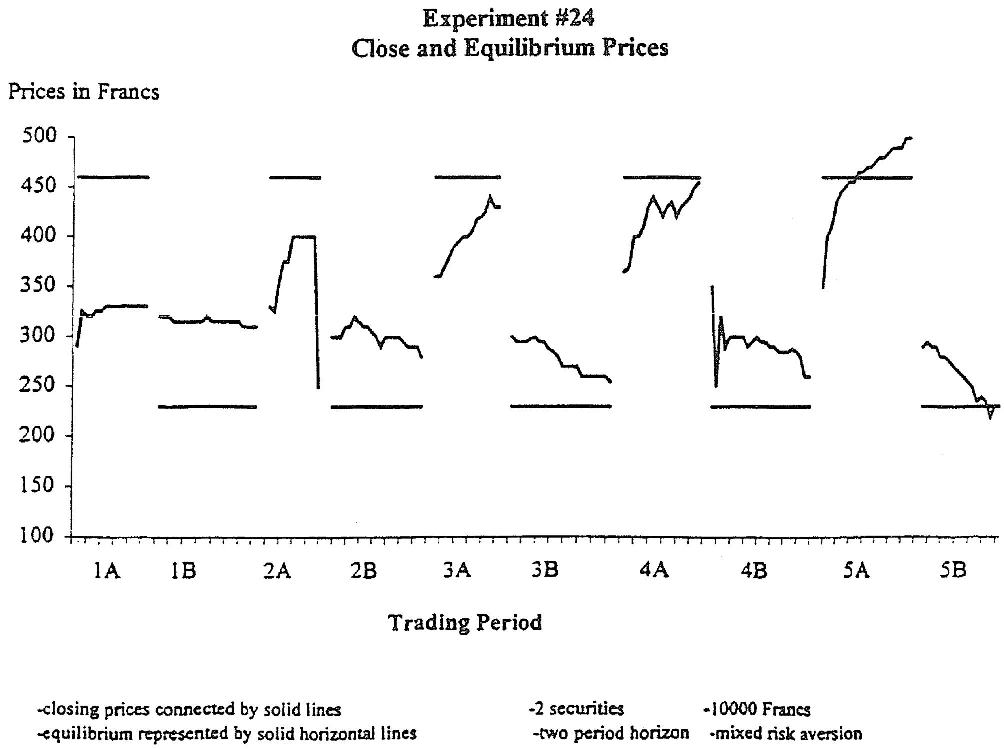


Fig. 9.24 Experiment #24

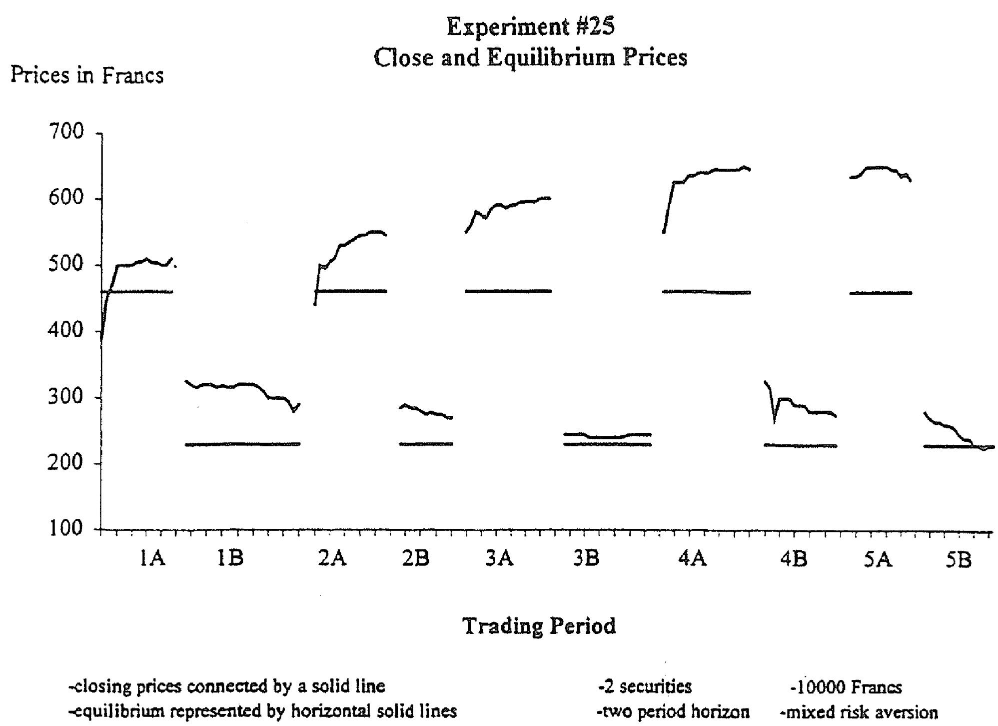
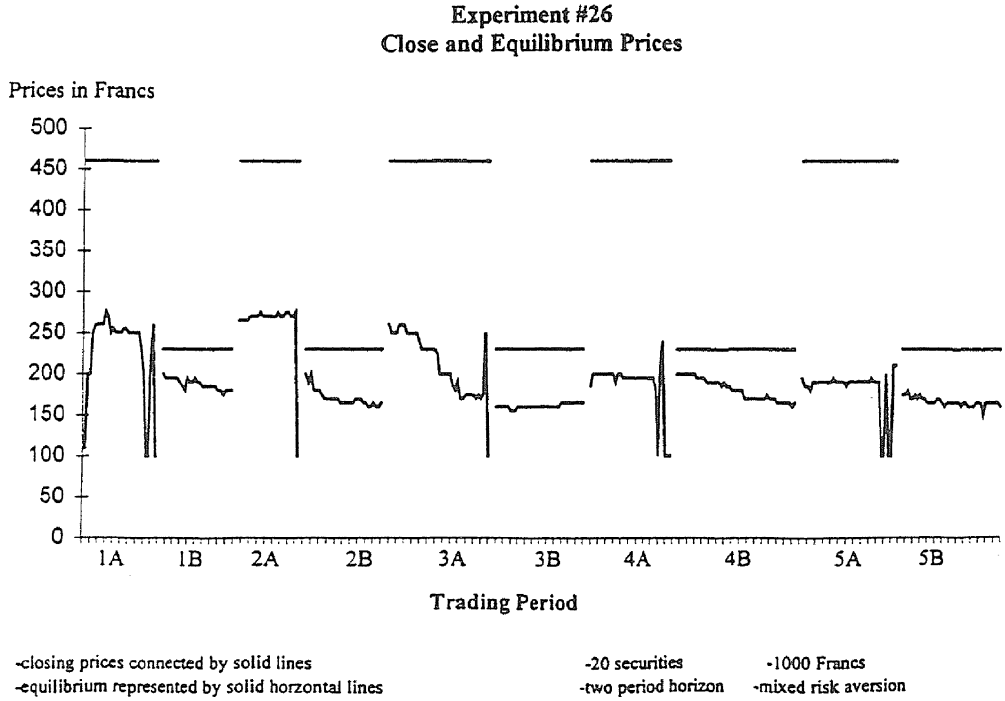


Fig. 9.25 Experiment #25

a shortened investment horizon is sufficient to create asset bubbles. In application to the real world, short-term performance of traders, portfolio managers, and so forth could create pressures leading to price bubbles. Experiments 7–10 provide restrictions to the previous conclusion in that a shortened investment horizon creates bubble pressure only when the market environment favors buyers over sellers. Unfortunately, most of our real world securities markets do have such a bias via restricted short sales, asymmetric leverage for longs versus shorts, restricted options and futures, and the like. Experiments 11–14 add to the puzzle by demonstrating the role of speculators within bubble formation. As a whole,

Fig. 9.26 Experiment #26



the study suggests that necessary and sufficient conditions for the formation of asset bubbles are a shortened investment horizon, restricted selling activity relative to buyers, and the presence of speculators. We have also shown that repeated replication of these experiments under different settings still produce robust results.

The first and third variables are a matter of fact within U.S. securities markets while restricted selling activity relative to buyers can take many forms. Either enhancing the buyer's position or restricting the seller's position is sufficient. Examples include increasing purchasing (speculative) ability through reduced stock margin levels, introduction of high leverage stock index futures, and in macroeconomic terms, a growing money supply or savings level. This latter variable may help explain the previous high levels of the Japanese equity market. The high level of Japanese savings creates very large endowments available for investment purchase. Given a limited supply of securities, our experimental markets show that these conditions will lead to a bubble. They also suggest that the bubble will burst when there is greater equating between the supply and demand. Recent changes in the Japanese institutional framework may, as predicted by this study, have lead to the bursting of that bubble.

The primary prescription put forth for regulatory authorities to eliminate unnecessary market volatility resulting from asset bubbles is to create an institutional environment that does not restrict the transfer of information to the market. Structure the variables so that both bulls and bears have equal costs in executing their trades.

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