Liquidity Shocks in Experimental Asset Markets

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August 2014

Abstract: We explore the impact of an unusual trade on behavior in experimental bubbles markets. After several rounds of trading the market receives a large quantity order at an extreme price, i.e., a price distant from fundamental value. In the base treatment there is no liquidity shock and we observe the typical bubble and crash pattern. With aberrant orders at both high and low prices, the bubble is dissipated. Our results are consistent with the notion that an unusual order serves as a synchronizing mechanism for traders who rationally understand that the asset is trading a price that deviates from fundamentals.

* Corresponding author. The authors acknowledge the financial support from Agnes Scott College, the Humanities and Social Sciences Revitalization Fund (2012WKYB010, Tsinghua University), Research Grant for Returned Overseas Chinese Scholars (110000204 and 553406001, Tsinghua University), Tsinghua University Research Funds (LF20114649), and the National Science Foundation of China (71273150). The authors thank Bryan Church, Jie Zheng, Yingzi Zhu, and an anonymous referee for helpful comments and Yuyuan Cui, Jie Liu, Jinyu Liu, Patricia Schneider, Jinming Wang, and Yunzhe Zhu for research assistance.

Liquidity Shocks in Experimental Asset Markets

The robustness of asset price bubbles in the laboratory is extraordinary. Since first reported by Smith, Suchanek, and Williams (1988), experimental asset markets in which prices rise above fundamental value and subsequently crash have received significant attention by researchers. Policymakers are interested in these finding because extreme valuations that seem to defy any reasonable economic explanation are also observed outside the laboratory. Recent examples include Internet stocks in the late 1990's, the housing price bubble peaking in 2006, and Chinese warrants in 2005-8 (Xiong and Yu (2011)).

To add to concerns about the functioning of markets, price swings in recent decades have been quite dramatic.[1] Ambiguity about the role of computer trading in generating volatility has exacerbated the alarm, with regulators calling on exchanges to better manage technological problems.[2] Trader errors and computer glitches have led to chaos, and left many questioning the operational efficiency of markets. For example, on September 17, 2012 several U.S. oil stocks experienced price swings likely due to a "fat finger" trade or data entry error (Jarzemsky (2012)). In another newsworthy case, a large Chinese broker experienced a systems glitch that is blamed for a sudden 6% increase in the Shanghai Composite Index (Yan (2013)). Of course the U.S. market disruption on May 6, 2010 is etched in the memory of most market participants. Markets and regulators were in disbelief as they watched a sudden drop in stock prices and subsequent recovery all within a short 20-minute time period (Report of the Staffs of the CFTC and SEC (2010)). It appeared that this "flash crash" was not caused by a shift in underlying fundamentals,

[1] The experience of the Standard and Poor's 500 Stock Index provides glaring evidence. In December 1999 the index level was 1,428.68, a peak at that time. The market fell 35% in the next few years, to a relative low of 935.96 in March 2003. As it recovered, the market peaked in 2007 with a gain of 65% from the previous low. The recent financial crisis left the index at 757.13 in March 2009, a loss of 51%. Since then, the index has risen a whopping 128%, reaching 1725.52 in September 2013.
[2] See, for example, Patterson and Bunge (2013).

but rather by an extreme, temporary loss in liquidity. Since then, media reports of human and computer errors seem to be even more frequent.

As the flash crash and other market disruptions have taught us, liquidity lapses due to errors can have powerful, even if short-lived, influence in a market. In this article we explore the impact of an unusual trade on behavior in an experimental bubbles market. After several rounds of trading in our markets the experimenter enters a large quantity order at an extreme price, i.e., a price quite distant from the underlying fundamental value. We then observe how the market responds to the aberrant order. While practitioners and policymakers are concerned about trader and computer errors, little systematic evidence has been presented on this issue. We use the experimental method, which allows control over the asset's fundamental value, the timing and size of the unusual order, and other aspects of the environment so that we can focus on the impact of an aberrant order on market outcomes.

Though the method permits control over the experimental environment, we cannot control the expectations traders bring to the market, only their knowledge of the parameters. Smith, Suchanek, and Williams (1988) argue that they observe asset price bubbles because traders do not come to the market with common expectations. In their design an asset with finite life is traded and all participants know the dividend-generating process. With this knowledge, fundamental value is easily computed as the expected dividend per period times the number of remaining trading periods. Yet, uncertainty about the behavior of others remains. Smith, Suchanek, and Williams argue that, with experience, traders form common expectations, allowing price to converge to equilibrium.

Abreu and Brunnermeier (2003) present a model with price bubbles that persist even when there are rational arbitrageurs in the market. Bubbles do not dissipate because the wellinformed traders lack a synchronization mechanism. Rational traders clearly understand that the market will crash back to fundamental value at some point. The problem is that they do not know the timing of the crash. The rational traders have common expectations about fundamentals, but they have different opinions on exit timing and need a coordination device. In their model, Abreu and Brunnermeier note that, relative to its information content, a news event can have a disproportionately large impact on the market because it serves as a synchronizing event. In our experimental markets, we examine whether a liquidity shock, in the form of an abnormally large order at an extreme price, serves as a coordinating device that promotes efficient pricing relative to fundamental valuations. In this paper we explore pricing behavior in experimental bubbles markets in which mispricing is often observed. We do not aim to guide policy on how to avoid the generation of mispricing. Rather, our goal is to provide insight into how traders coordinate exit from a bubble.

The experiment by Hussam, Porter, and Smith (2008) is of particular importance to our study because they also impose a liquidity shock in their bubbles markets. Their goal was to examine the resiliency of mispricing. In their design, the liquidity shock was implemented by actually changing the experimental environment and parameters. Importantly, Hussam, Porter, and Smith conclude that price bubbles dissipate with experience but *only under stable conditions*. Earlier research has shown that bubbles dissipate with trader experience (Ackert and Church (2001); Dufwenberg, Lindqvist, and Moore (2005)). Hussam, Porter, and Smith report that, even with experience, bubbles can be rekindled with a large liquidity shock in a new environment. Our goal differs in that we examine whether a large price shock allows traders to coordinate their exit strategies in a stable environment.

The evidence on behavior in bubbles markets is voluminous and Palan (2013) provides a recent review and synthesis. In our investigation we use a bubble market design because there is compelling evidence of mispricing in this market structure. Researchers have replicated mispricing in a large variety of treatment conditions (e.g., King, Smith, Williams, and van Boening (1993); Ackert, Charupat, Church, Deaves (2006); Haruvy and Noussair (2006)). Some have devoted attention to discovering why bubbles are generated in this particular design (e.g., Ackert, Charupat, Deaves, and Kluger (2009); Kirchler, Huber, and Stöckl (2012)) or how they can be dissipated (e.g., Porter and Smith (1995); Lei, Noussair, and Plott (2001)). In contrast, we specifically chose this design because our goal is to provide insight into the impact of a liquidity shock in a market prone to mispricing.

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

I. Experimental Design

The asset market experiments were conducted at Tsinghua University in Bejing, China. Seventeen market sessions were conducted (in addition to one pre-test).[3] The experimental design, summarized in Panel A of Table 1, includes a base-line treatment (No Shock), markets with positive and negative liquidity shocks (Positive and Negative Shock), and markets with fundamental value uncertainty (FV Uncertainty).

Ten traders participated in each session. The 170 participants were university students and all were inexperienced in that none had participated in an earlier session. Traders earned from 50.28¥ to 220.45¥ for participating, with an average (median) payout of 113.94¥ (109.56¥). This level of compensation is quite motivating for students who earn approximately 6.20¥ per hour working as student assistants at the university. The sessions generally required 1½ hours to complete.

Each market session consisted of 12 three-minute periods, organized as a computerized double auction market using the *Z-tree* (Zurich Toolbox for Readymade Economic Experiments) software (Fischbacher, 2007).[4] With *Z-tree* traders can transact in real time over a number of market periods. Participants can post bids and asks and also act as price-takers. Multiple-unit transactions were permitted. Traders were not permitted to short sell or borrow additional capital.

On arrival traders received a set of instructions and were given 20 minutes to read through them.[5] Thereafter one of the experimenters did an extensive recap while addressing all procedural and technical questions. Participants were endowed with shares of a stock as well as the experimental currency, referred to as "francs." In the first three treatments the stock paid a dividend of 0 or 10 francs at the end of each period. The dividend payouts were equally likely, randomly determined, and cross-sectionally and intertemporally independent. Following Smith, Suchanek, and Williams (1988), the asset traded in our markets had a known dividend generating process and finite lifespan. After the final dividends were paid at the end of period 12, shares ceased to exist and had zero value. Thus, fundamental value (FV) was readily computed using backward induction as the expected dividend (5 francs) times the number of remaining periods. With 12 periods, the stock had an initial fundamental value of 12 x 5 = 60 francs. As

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[3] The typical bubble and crash pattern has been replicated around the world, even with experienced business people and professional traders (e.g., King, Smith, Williams, and van Boening (1993)). Our baseline sessions confirm the usual price path with our Chinese subject pool.

[4] This software is provided to experimental researchers by the University of Zurich, Institute for Empirical Research in Economics. See http://www.iew.unizh.ch/ztree/index.php.

[5] The instructions are included in Appendix 1.

summarized in Panel A of Table 1, each market included two trader types with different endowments of shares and cash. Though endowments varied, all traders had a total expected portfolio value of 4,600 francs.

The experimental environment in the first three treatments was held constant across all 12 trading periods. However, during period 6 a positive or negative liquidity shock occurred. In the Positive Shock treatment an order was placed at the beginning of period 6 to buy 100 shares at a price of 100 francs per share, whereas the Negative Shock treatment received an order to sell 100 shares at 17 francs. The fundamental value in period 6 was 30 francs. In designing the experimental parameters, we wanted price shocks that would be extreme and looked to the price experience reported in the existing literature, as well as our baseline treatment, for guidance. We chose these order price shocks because they were likely to lie far from trading prices in period 6, regardless of whether a bubble had generated or not. All traders could see the large, extreme order on the trading screen but in no case did an order reveal a trader number. While the extreme order was placed by the experimenter, participants would have no reason to expect that the order was not entered by another trader. Of course, they could not immediately discern whether the trade was (or was not) information based. Each market received a single price shock and all aspects of the market setting were unchanged.

We included a fourth treatment to investigate whether behavior changes in a more uncertain environment. In the FV Uncertainty treatment, traders faced additional uncertainty regarding dividend payoffs. With higher uncertainty traders may search in earnest for a coordinating device. The impact of an aberrant order may be heightened, as traders time their exit of the bubble using the synchronization devise. In the last four markets there was a 2% probability that the observed state would be "bad." If the "bad" state was drawn, the equally likely dividends were 0 and 5 francs with an expected payout per period of 2.5 francs. All subsequent periods were “bad” if the “bad” state was drawn. The fundamental value each period was now conditional on prior state draws with expected payouts reported in Panel B of Table 1. Though endowments varied across the two trader types, all traders had a total expected portfolio value of 4,382.33 francs in the final treatment. As in the Negative Shock Treatment, a negative price shock was received in period 6 when an order to sell 100 shares at 17 francs was received.

At the conclusion of each session, the final cash balance was (privately) displayed on a trader’s computer screen. The experimental currency was converted to Yuan using a conversion rate of 0.025, so that 1,000 francs was equal to ¥25.00. Participants completed a post-experiment questionnaire that elicited subject attributes including sex, educational background, economic status, and reactions to the experiment. Each participant was called forward (privately) to check and receive cash earnings before filling out a receipt and leaving the room.

II. Market Behavior

In this section, we begin with descriptive data to assess price behavior in the experimental markets, followed by formal statistical tests.

A. *Observed Price Paths*

Figures 1-4 show the mean transaction price per period for each session, along with the asset’s fundamental value.[6] Consistent with earlier research, prices clearly exhibit large deviations from fundamental value. In addition, the figures indicate that there is substantial

[6] Figures illustrating the experience based on median transactions prices give a similar view of the markets.

variability across markets in the evolution of prices over time, with important differences across treatments.

Figure 1 shows that the price of the asset does not settle close to the fundamental value until the final periods of trading for three of four markets in treatment 1, the baseline design with no liquidity shock. The price paths exhibit large run-ups from (declining) fundamental value and do not crash back to the risk-neutral valuation until period 12 in the second session, and are consistent with persistent misvaluation even in the final trading period in the first and fourth sessions. Session 3 begins with some underpricing, with price tracking fundamental value beginning in period 4. Taken together, three of four sessions in the treatment 1 exhibit price bubbles. This is consistent with the findings of others. For example, Smith, Suchanek, and Williams (1988) report that 14 of their 22 markets are characterized by price bubbles.

Figure 2 indicates significant variability across the five sessions in the Positive Shock Treatment with large deviations in prices from fundamental value in some sessions. Sessions 1, 2, and 4 display the typical bubbles pattern with a large price run-up followed by a crash to fundamental values in the final periods of trading. Session 5 is characterized by a negative price bubble, where price begins low and converges to fundamental value near the end of trading. Yet, in session 3 price tracks the underlying quite closely throughout.[7] For the Positive Shock treatment, we observe clear, positive price bubbles in three of five market sessions. It is noteworthy when comparing Figures 1 and 2 that the positive order shock in period 6 does not seem to have a large, clearly visible effect on pricing in the second treatment.

[7] While behavior in some sessions may seem curious, it is quite common to have a session or two without the typical bubble pattern. Recall that Smith, Suchenek, and Williams (1988) reported that bubbles were common, but not universal. They report that 37% of their markets did not exhibit the typical bubble pattern. See also Ackert, Charupat, Deaves, and Kluger (2009) who report that about half of their markets exhibit the usual bubble pattern.

In contrast, Figure 3 indicates that prices more closely follow fundamental value after the negative price shock in the third treatment. In sessions 1, 3, and 4, prices begin to bubble up, but when the negative shock hits the market in period 6, the market evolves toward the underlying valuations. In session 2, the market begins below fundamental value and after the large, unusual order in period 6, prices remain flat and do not converge to fundamental value until late in trading.

As in Treatment 3, the observed price path for the FV Uncertainty treatment begins with a typical looking pattern. While price appears to begin to bubble above fundamental value in the first half of trading, after the negative liquidity shock prices in all four market sessions fall below the underlying value in the latter half of the trading periods. Note that the fundamental value does not shift in treatment 4 based on state realizations. The Bad state was never observed due to its low probability of occurrence.

Overall, the figures indicate some consistencies in behavior. The No Shock, baseline treatment reveals the typical mispricing pattern. It is not clear whether the extreme order has an effect on market participants in treatment 2, while the price shocks in treatments 3 and 4 appear to have strong effects on trader behavior, moving price toward fundamental value. In the next section we formally test for differences across treatments.

B. *Descriptive Statistics*

Table 2 reports summary statistics on the deviations in price from fundamental value. The empirical measures assume risk neutrality and are designed to gauge the bubble in asset price (if one is observed). A large number of bubble measures have been reported in experimental studies which complicates the comparison of findings (Palan (2009); Stöckl, Huber, and Kirchler (2010)). We chose five bubble measures to summarize the experience in our markets. Table 2 reports the average value of each measure across sessions in each treatment.[8]

The first three measures are commonly reported in experimental bubbles studies.[9] First we compute the average number of periods for which the median price (P_t) is greater than the fundamental value (FV_t). Second, we report positive duration which is computed as the average number of consecutive periods with price increases relative to fundamental value when the increase produces a price that exceeds fundamental value. The third bubbles measure is the peak deviation, a measure the magnitude of the bubble using the normalized peak deviation in price from fundamental value (maximum observed $(P_t - FV_t)/FV_t$).

Table 2 reports two additional bubbles measures following Stöckl, Huber, and Kirchler, (2010). Stöckl, Huber, and Kirchler argue that these measures are superior to many used in prior studies because they promote comparability and satisfy desirable criteria, such as being independent of the number of trading periods. The fourth bubble measure we report is the relative absolute deviation (RAD) which measures the absolute level of mispricing and is calculated as

$$RAD = \frac{1}{N}\sum_{i=1}^{N}\left|\overline{P_i} - FV_i\right| / \left|\overline{FV}\right| \qquad (1)$$

where i is the trading period, N is the total number of periods, P is the trading price, and FV is the underlying risk-neutral fundamental value. RAD is easily interpreted. For example, when RAD = 0.20 the average mean price per period is 20 percent from the average fundamental value

[8] Inferences are similar using median values.
[9] See, for example, Ackert, Charupat, Church, and Deaves (2006).

(above or below). The final bubble measure we report is the relative deviation (RD) which measures overvaluation and is computed as

$$RD = \frac{1}{N}\sum_{i=1}^{N}\left(\overline{P_i} - FV_i\right)/\left|\overline{FV}\right|. \quad (2)$$

Unlike RAD, RD is calculated based on signed price deviations from fundamental value. The asset is overvalued when RD is positive, whereas negative RD indicates undervaluation.

The results are presented in Table 2 with Panel A reporting on periods before the liquidity shock and Panel B after. In the five periods prior to the liquidity shock, outcomes in the treatments appear to be somewhat similar, as would be expected. Recall that the first three treatments are actually identical prior to the liquidity shock. In the FV Uncertainty treatment additional uncertainty regarding the fundamental value exists, but as Panel B of Table 1 indicates the fundamental values are quite close. In fact, due to the low probability of occurrence, no "bad" draws are actually observed at any time in these markets. The summary statistics are consistent with the development of mispricing in the bubbles markets, as frequently reported by others. It is typical that bubbles generate slowly at the beginning of a market, as traders become accustomed to the environment, particularly if traders are risk averse. Periods with prices exceeding FV, positive duration, and peak deviation, do not provide strong evidence of large positive deviations in price. Across the treatments RAD varies from 19% to 34% suggesting mispricing but RD indicates that three of four markets are actually underpricing on average. Thus, overall, the summary statistics for the first five periods of trading are not striking.

The picture changes substantially in later trading periods. In the No Shock treatment on average 5 of 7 trading periods have average prices exceeding FV, there are over 5 periods with consecutive price increases, and the price deviation above fundamental value is over four times the level of the FV. RAD indicates that the price is 51% from FV with sizable overpricing (RD = 50%). Interestingly, as we move across columns from treatment 1 to 4, we observe an almost perfectly monotonic decline in the size of the observed bubbles. In the FV Uncertainty treatment the summary statistics provide very little evidence of bubbles. Additional support is provided by our examination of trades at prices exceeding the maximum possible dividend. These trades indicate extreme behavior because they indicate a willingness to pay more than the trader could get even in the very best scenario. The percentage of extremely irrational trades declines across treatments 1 through 4, with averages of 23%, 12%, 1% and 0%, respectively.

C. *Comparisons across Treatments*

To test for differences in the bubble measures across treatments we use permutation tests which give a simple way to compute the sampling distribution for a test statistic, without making an assumption regarding the form of the underlying distribution of the variable (Siegel and Castellan (1988)). Table 3 reports comparisons of the average value of each bubble measure reported in Table 2 across treatment pairs. The No Shock treatment serves as the baseline.

First, in Panel A the table reports tests of the null hypothesis of no treatment effect for periods before the liquidity shock. For each paired comparison, the table reports the difference in mean values across the two treatments and p-values below in parentheses. In Panel A, p-values are from a test of the null hypothesis of no difference in mean (two-sided) because there is no basis to predict a difference across treatments in the initial periods of trading. Recall that sessions in treatments 1-3 are identical in the first 5 periods of trading, though treatment 4 differs in terms of additional state uncertainty. Not surprisingly, none of the pairwise permutation tests indicates a significant difference in a bubble measure across treatments.

Panel B of Table 3 reports tests for trading periods 6-12, after the liquidity shock. If the shock serves as a synchronization mechanism, we expect to find a dampening of bubbles in treatments 2-4, compared to the baseline treatment. In Panel B, p-values are one-sided because the alternative hypothesis is that the mean for the baseline treatment is higher. The null hypothesis of no treatment effect is not supported by the data. For Positive Duration, Peak Deviation, RAD, and RD there is strong evidence that the rise of a bubble is checked by an aberrant order as the null is rejected for most comparisons. Though casual consideration of Figure 2 seems to indicate that the price shock had minimal effect in the Positive Shock treatment, formal tests indicate that three of the five bubbles measures (i.e., Positive Duration, Peak Deviation, and RD) are significantly smaller and indicate more efficient pricing in comparison to the baseline treatment.

III. Discussion and Concluding Remarks

This paper reports the results of experimental asset markets in which market participants trade a finitely-lived asset with public knowledge of the fundamental generating process. In the base treatment we observe the often-reported bubble and crash pattern. In other treatments, a price liquidity shock hits the market after several periods of trading. The shock takes the form of a large order at an extreme price. Even with an aberrant order at a high offering price, the evidence indicates that the bubble is dampened. With negative price shocks, the bubble dissolves, even in markets with increased uncertainty about fundamental valuations.

Our results are consistent with the notion that an unusual order serves as a synchronizing mechanism for traders who rationally understand that the asset is trading a price that deviates from underlying fundamentals. The theory of Abreu and Brunnermeier (2003) predicts that bubbles persist even when traders are rational if they lack a coordination device. In our markets, traders come to the market with diverse views regarding exit strategy and a liquidity shock moves the market toward prices that reflect common expectations. An unexpected benefit of extreme price shock is its role as a coordinating device that promotes efficient pricing.

Somewhat surprisingly, our results provide strong support for our expectations despite the fact that in some cases the price shock is accompanied by an increase in funding liquidity. In the positive shock treatment, the experimenter submits a large order to buy shares at a high price. In effect, we inject cash into the markets. Previous research indicates that price bubbles are inflated in markets with greater availability of cash (Caginalp, Porter, and Smith (1998), (2000a), (2000b), (2001)). Price bubbles even farther above underlying economic values when the ratio of available cash to available shares increases. Our evidence supports the conclusion that the uninformative price shock has a strong force on the market as it serves as a coordinating mechanism even in a frothy market when traders are flush with cash.

Abreu and Brunnermeier note that an event can have a disproportionately large impact on the market relative to its information content. The Everbright (Guang Da) fiasco on August 16, 2013 provides stark evidence of the potential impact of a faulty trade on markets. Due to a software error, a large number of buy orders were sent to the market within a 2-second time frame. This error is blamed for swings of more than 6 percent in the Shanghai Composite Index, though the market returns to calm that same day.

Future research into the relative impacts of market and funding liquidity could provide additional interesting insight. Brunnermeier and Pederson (2009) present a model in which the ease of trading (market liquidity) is linked to the ease of obtaining funding (funding liquidity). While trading increases market liquidity, traders’ ability to fund trades depends on the liquidity of the market. In most experiments including our own, traders are endowed with sufficient capital to fund trade. If traders face greater constraints, Brunnermeier and Pederson argue that the market may become unstable. While researchers have examined the impact of buying on margin in experimental bubbles markets (King, Smith, Williams, and van Boening (1993); Ackert, Charupat, Church, Deaves (2006)), other aspects of liquidity have not been investigated. Future empirical investigation of the interactive effects of market and funding liquidity could add insight into the fragility of liquidity.

FIGURE 1. Time Series of Mean Transaction Prices for the No Shock Treatment

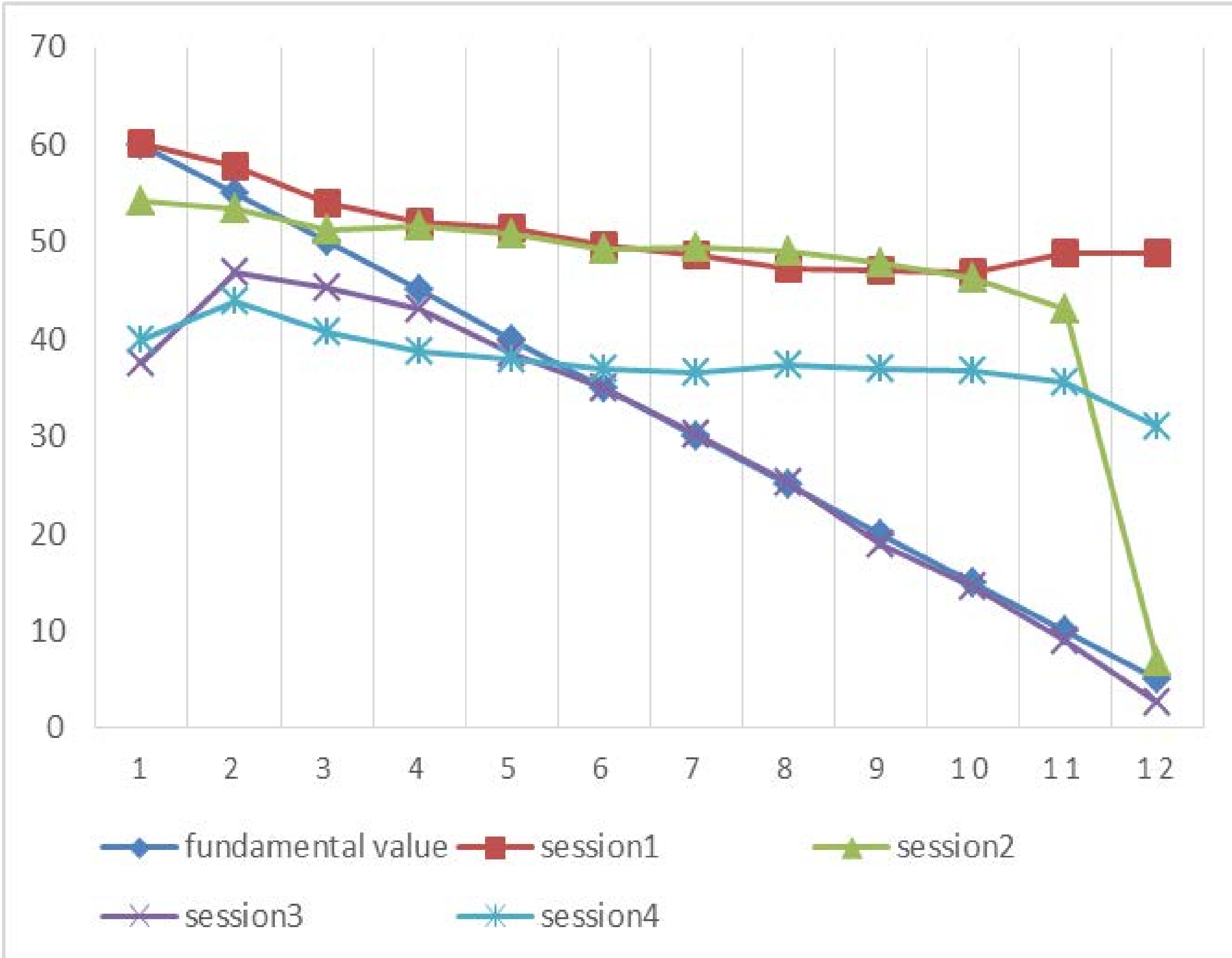

FIGURE 2. Time Series of Mean Transaction Prices for the Positive Shock Treatment

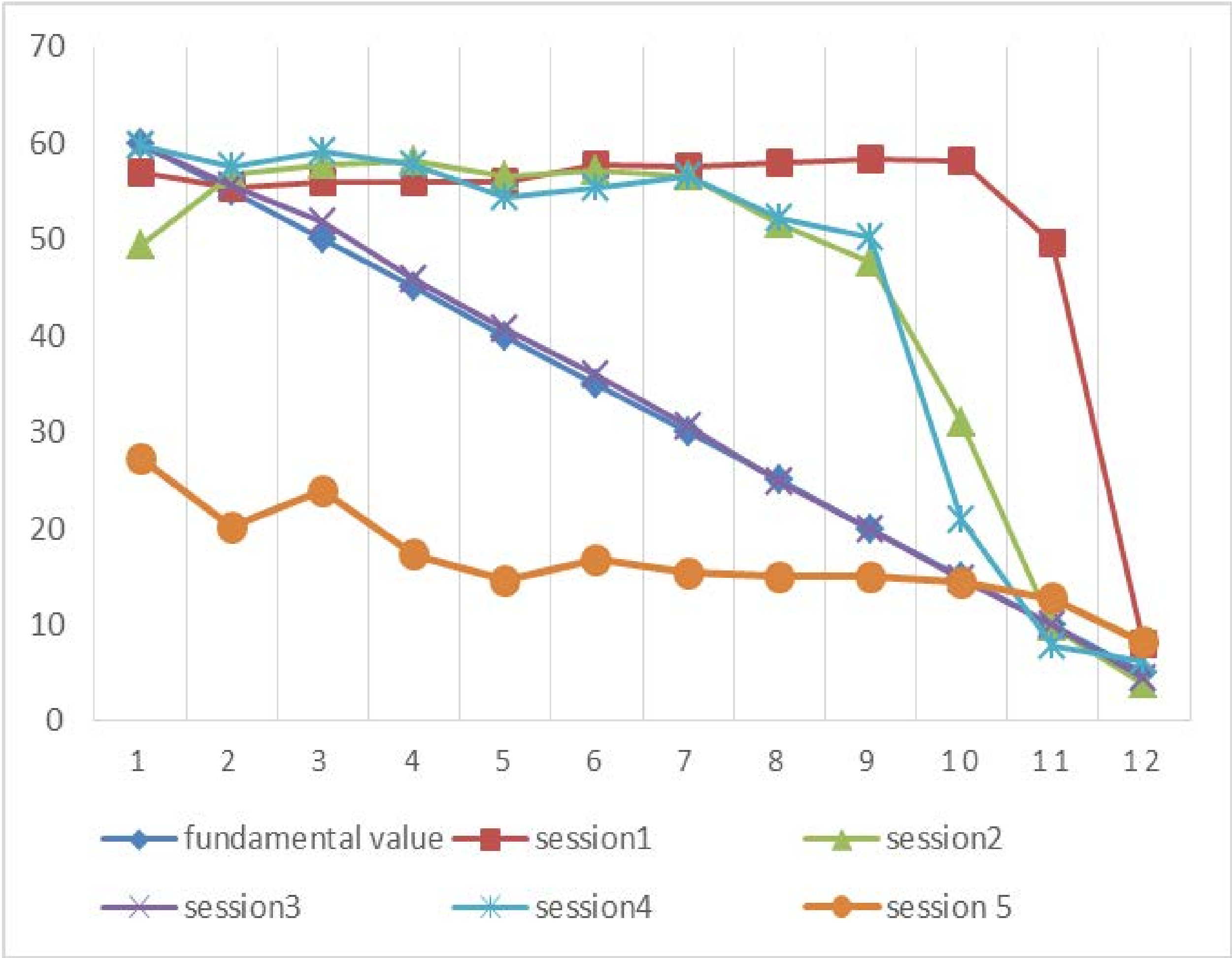

FIGURE 3. Time Series of Mean Transaction Prices for the Negative Shock Treatment

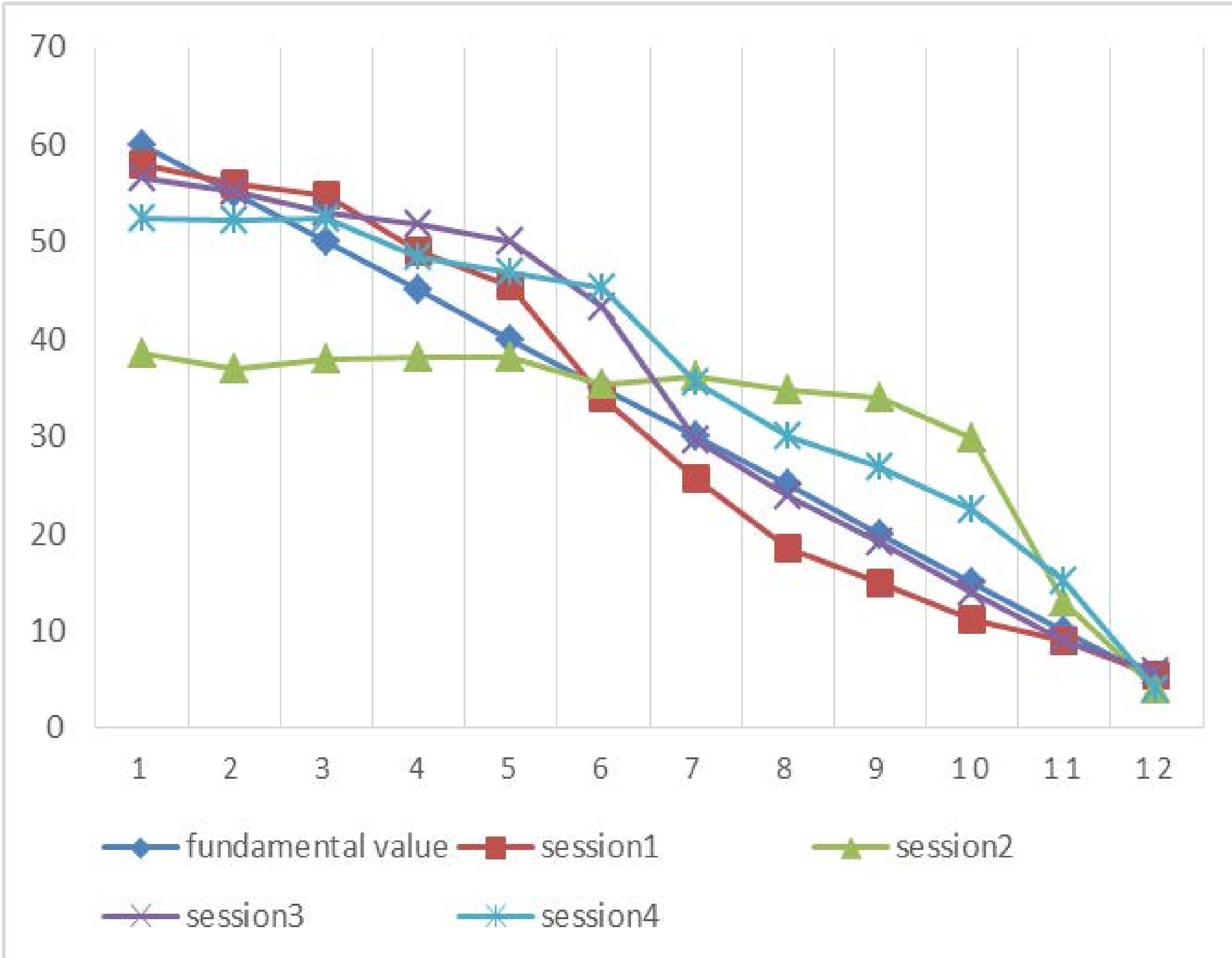

FIGURE 4. Time Series of Mean Transaction Prices for the FV Uncertainty Treatment

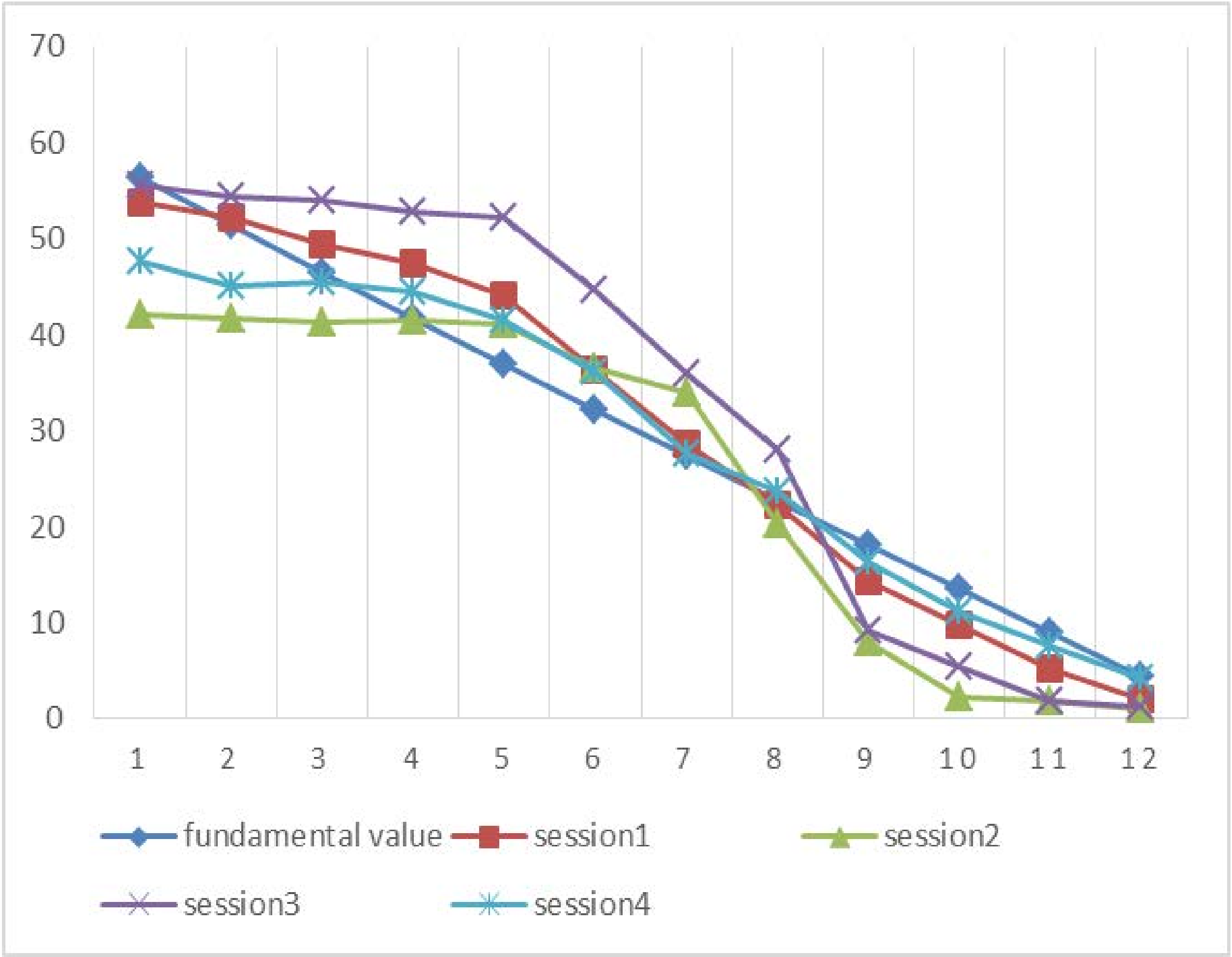

TABLE 1
Experimental Set Up

The asset has an equal probability of paying 0 and 10 francs in each of 12 periods in the first three treatments. In the last treatment (FV Uncertainty), the payouts of 0 and 10 francs are also equally likely in the "Normal State." However, there is a 2% chance that the state is "Bad," in which case the dividends are 0 and 5 francs with equal probability. If the "Bad" state is drawn, it is observed for all remaining periods.

Panel A: Experimental design

Session	Treatment	Trader Type	Endowments		Liquidity Shock	FV Uncertainty
			Shares	Cash		
1	No Shock	X	60	1,000	No	No
2						
3		Y	20	3,400		
4						
5	Positive Shock	X	60	1,000	Positive	No
6						
7		Y	20	3,400		
8						
9						
10	Negative Shock	X	60	1,000	Negative	No
11						
12		Y	20	3,400		
13						
14	FV Uncertainty	X	60	1,000	Negative	Yes
15						
16		Y	20	3,255		
17						

Panel B: Fundamental Values

Periods Remaining	Treatments 1, 2, and 3	Treatment 4 No "bad" draws
12	60	56.3722
11	55	51.4222
10	50	46.5212
9	45	41.66822
8	40	36.8623
7	35	32.1025
6	30	27.38789
5	25	22.71758
4	20	18.09067
3	15	13.5063
2	10	8.9636
1	5	4.4618

TABLE 2
Summary Statistics

Panel A: Before the Liquidity Shock (Periods 1-5)

	Treatment			
	No Shock	Positive Shock	Negative Shock	FV Uncertainty
Periods when median $P_t > FV_t$	1.7500	3.0000	2.2500	3.0000
Positive Duration	1.7500	2.8000	2.2500	2.7500
Peak Deviation	0.1173	0.1377	0.1295	0.2142
Relative Absolute Deviation	0.2134	0.3399	0.1907	0.1904
Relative Deviation	-0.0777	-0.0555	-0.0419	0.0280

Panel B: After the Liquidity Shock (Periods 6-12)

	Treatment			
	No Shock	Positive Shock	Negative Shock	FV Uncertainty
Periods when median $P_t > FV_t$	5.0000	4.0000	3.7500	2.2500
Positive Duration	5.5000	2.8000	2.2500	0.7500
Peak Deviation	4.3296	1.5023	0.4578	0.2241
Relative Absolute Deviation	0.5118	0.4384	0.1385	0.1541
Relative Deviation	0.5009	0.3450	0.0769	-0.0389

Notes: The table reports the average value of each measure across sessions in the four treatments. First the table reports the average number of periods for which the median price (P_t) is greater than the fundamental value (FV_t). Positive duration is the average number of consecutive periods with price increases relative to fundamental value when the increase produces a price that exceeds fundamental value. Peak deviation is a measure of the magnitude of the bubble using the normalized peak deviation in price from fundamental value (maximum observed $(P_t - FV_t)/FV_t$). The relative absolute deviation (RAD) measures mispricing and is calculated using equation (1). The relative deviation (RD) measures overvaluation and is computed using equation (2).

TABLE 3
Tests

Panel A: Before the Liquidity Shock (Periods 1-5)

	Pairwise Permutation Tests		
	No vs. Positive Shock	No vs. Negative Shock	No vs. FV Uncertainty
Periods when median $P_t > FV_t$	-1.2500 (0.23)	-0.5000 (0.12)	-1.2500 (0.24)
Positive Duration	-1.0500 (0.18)	-0.5000 (0.27)	-1.0000 (0.22)
Peak Deviation	-0.0204 (0.38)	-0.0122 (0.38)	-0.0969 (0.29)
Relative Absolute Deviation	-0.1265 (0.42)	0.0227 (0.41)	0.0231 (0.48)
Relative Deviation	-0.0222 (0.69)	-0.0358 (0.82)	-0.1057 (0.67)

Panel B: After the Liquidity Shock (Periods 6-12)

	Pairwise Permutation Tests		
	No vs. Positive Shock	No vs. Negative Shock	No vs. FV Uncertainty
Periods when median $P_t > FV_t$	1.0000 (0.13)	1.2500 (0.20)	2.7500 (0.12)
Positive Duration	2.7000*** (0.00)	3.2500*** (0.00)	4.7500*** (0.01)
Peak Deviation	2.8273*** (0.00)	3.8718*** (0.00)	4.1055** (0.02)
Relative Absolute Deviation	0.0734 (0.11)	0.3733* (0.07)	0.3577* (0.06)
Relative Deviation	0.1559** (0.04)	0.4240** (0.03)	0.5398* (0.06)

Notes: The table compares the average value of each bubble measure reported in Table 2 across treatment pairs with the No Shock treatment serving as the baseline. Panel A includes periods before the liquidity shock and Panel B those after a shock. For each paired comparison, the table reports the difference in mean values across the two treatments and p-values below in parentheses. In Panel A, p-values are from a test of the null hypothesis of no difference in mean (two-sided), whereas in Panel B p-values are from a test of the null hypothesis that the mean for the baseline treatment is higher (one-sided). One asterisk indicates significance at $p < 0.10$, two asterisks at $p < 0.05$, and three asterisks at $p < 0.01$.

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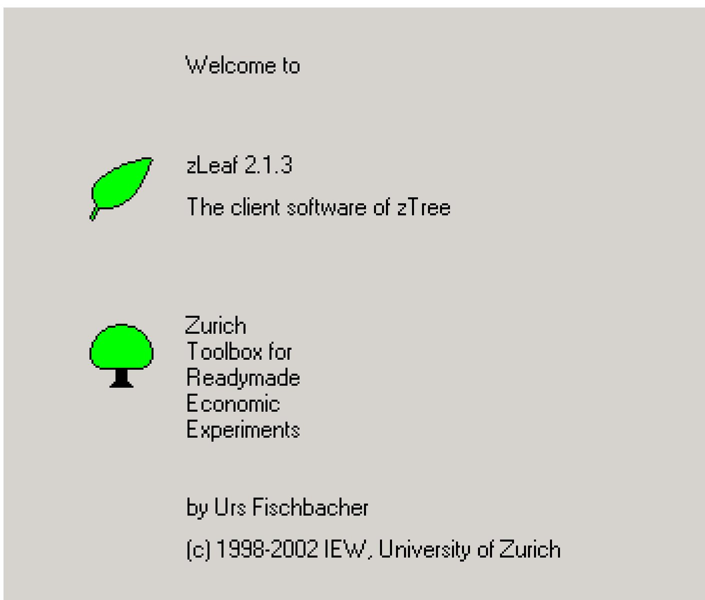
APPENDIX 1
EXPERIMENTAL INSTRUCTIONS

The computerized double asset markets were conducted using Z-tree, though participants were given the following written instructions. Instructions for the first three treatments are identical and follow. Instructions for the FV Uncertainty treatment are similar and differ only in terms of the description of the possible states and resulting dividend payouts.

We are about to begin an asset market experiment in which you can purchase and sell shares of stock. The experiment is conducted in a computerized electronic market. We will describe to you how this experiment works and your interface with it. Based on your decisions you will be able to generate profits. These profits will be paid to you in cash at the conclusion of the experimental session today.

Please raise your hand and let the experimenter know if you don't see the following screen on your computer:



Please follow along as the experimenter reads these instructions aloud. Feel free to ask questions at any time. We will practice trading on the computer before the actual markets begin.

General Instructions

This experiment is concerned with the economics of market decision-making. You are going to participate in a market in which you will buy and sell shares of a stock in a sequence of 12 periods, with each period lasting 3 minutes. Based on your trading decisions, you will be able to generate profits. You can keep track of your position on the record sheets that are in front of you. **Your profits will be paid to you in cash at the conclusion of the experiment today.**

General Trading Instructions

Each period you will trade shares of a stock. All ten participants in this room today will participate in the same market for this stock. At the beginning of the first period, every trader will be provided with an endowment of the trading currency, francs, and shares of stock. Half of the traders in this room will receive an endowment of 1,000 francs and 60 shares of stock and the other half will receive an endowment of 3,400 francs and 20 shares of stock. Your endowment will be shown on your trading screen before trading commences.

When trading begins in each period, you can sell part or all of your holdings of the stock. Alternatively, you can use your cash endowment to purchase more shares. You may also decide not to trade and hold on to the shares that you have at the start of the period. Sales of your share holdings increase your cash balance by the amount of the sale price. Similarly, purchases reduce your cash balance by the amount of the purchase price.

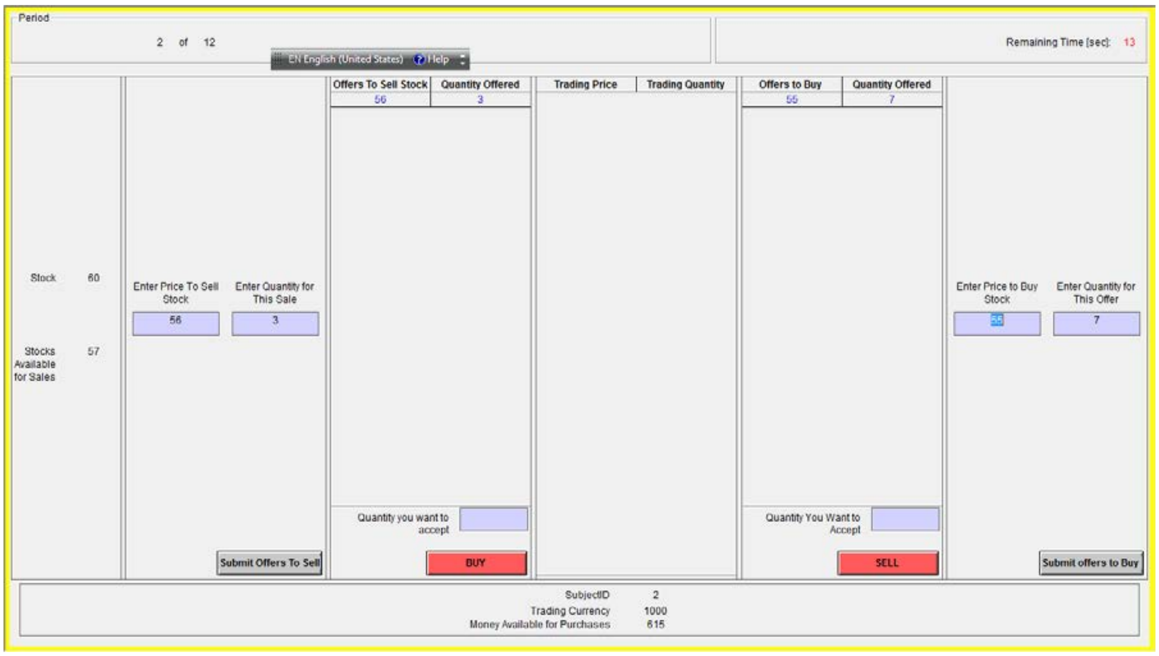
The trading system will automatically update your cash balance and share holdings to reflect your purchases and/or sales of shares. Your cash and shares of the stock at the end of a period carry over to the next trading period.

Shares of stock earn dividends at the end of each trading period, as will be described shortly. At the end of the 12 trading periods, the stock will cease to exist and will be worthless at that time.

Trading Screen

The left upper corner of the screen shows you the current trading period and the total number of trading periods in the session today. The right upper corner shows the remaining *seconds* of the *current* trading period. In today's experiment, each trading period is 3 minutes and the session includes a sequence of 12 periods.

The screen displays the cash you hold at the beginning of the period on the left hand side. The rest of the screen is divided into two boxes for offers to sell and offers to buy.



On the trading screen above you see the number of shares you hold. The above window indicates that you have 60 shares of the stock. You submit offers to sell in the column to the right and next to it is the column of existing offers submitted to the market to sell. The middle column indicates the trading prices for the stock. The next column on the right shows existing offers submitted to the market to buy. You submit offers to buy in last column on the very right of the screen.

Trading a Stock

To place an offer to sell stock, type the price and quantity (*in francs*) at which you want to sell in the boxes under the labels “Enter Price to Sell Stock” and “Enter Quantity for this Sale.” Click the button “Submit offer to Sell Stock” to send your offer. Your offer will be posted in the column of “Offers to Sell,” which is to the right of the column where you submitted your offer. Once you submit an offer either to buy or sell, *you are committed to that offer until someone accepts the offer, or if no one accepts your offer, until the end of the trading period*.

Follow the same steps to place an offer to buy stock. The column to submit offers to buy and the column showing the current submitted offers to buy are laid symmetrically to the right of the box for each stock. The offers are displayed in descending order using submitted prices. As with offers to sell, enter the quantity you want to buy and your offering price. Remember, prices are in francs, the trading currency.

Accepting an offer results in a trade. If you would like to accept any of the offers (either to buy or sell a share of the asset) submitted to the market, click on the offer you would like to accept, enter the number of units you would like to buy or sell, and click the “BUY” or “SELL” button.

Note that accepting an offer from the column of “Offers to Sell” means that you are buying that stock from the subject who submitted the offer, while accepting an offer from the column of “Offers to Buy” means that you are selling that stock to the subject who submitted the offer at the specified price. After the transaction, the corresponding shares of the stock you traded and the cash remaining will be updated. In addition, the trading price and units transacted will be posted in the middle column labeled “Trading Price.”

You can place offers to buy or sell for multiple shares and accept to buy or sell portions of posted offers. For example, if another trader submits an offer to buy 3 shares and you would like to sell only 1 share at the offered price, enter “1” in the quantity box (“Q you want to sell”) and then click “SELL.”

Because some trades may involve only a portion of an offer, the balance of the offer will remain open. For example, suppose a trader made on offer for 6 shares. If the offer is accepted for fewer than 6 shares, the balance of the offer will still appear in the column of existing offers. If four units were bought or sold in this transaction, an offer for the remaining two shares will appear. If the offer is accepted for all 6 shares, the original offer will be eliminated from the column of existing offers.

Please refer again to the trading screen on the previous page. Notice that this trader has 60 shares of stock. Because the trader has posted an offer to sell 3 units at a price of 56, the screen shows that the trader has 57 units left for sale. This means the trader has 57 shares on which new offers to sell can be posted. The trader can also sell up to 57 shares by accepting other traders’ offers to buy. Similarly, if the trader has posted offers to buy, additional offers are limited by the cash available.

Best offers

Note that the best offers to sell or buy the stock will appear in the final row of the "Offers to Sell" and "Offers to Buy" columns.

The trading screen above provides an example of how orders are cued by the computer. If you want to buy stock, the best offer will be the lowest purchase price. Notice that the computer automatically orders the incoming offers so that the best offer to sell is the last offer in the "Offers to Sell" column. Similarly, the computer orders the buy offers so that the highest offer to buy appears in the last row of the "Offers to Buy" column. If you want to sell stock, the highest price is most favorable to you so you will want to choose the offer appearing in the last row.

When you accept an offer to sell or buy, you must click on the offer you are accepting. It is important to remember that the offer appearing in the last row will be most favorable to you if you are buying (lowest price) or selling (highest price).

Make sure the quantity and price you type are correct before you hit the submit button.

Once an offer is accepted, a trade cannot be reversed.

Trading Restrictions

There are a few restrictions regarding submitting and accepting offers when trading. They are summarized as follows:

1. You are not allowed to trade with yourself, meaning that you cannot accept offers submitted by yourself.

2. No short-selling is allowed, which means that if you don't have a share of a stock, you can't send out an offer to sell that stock.

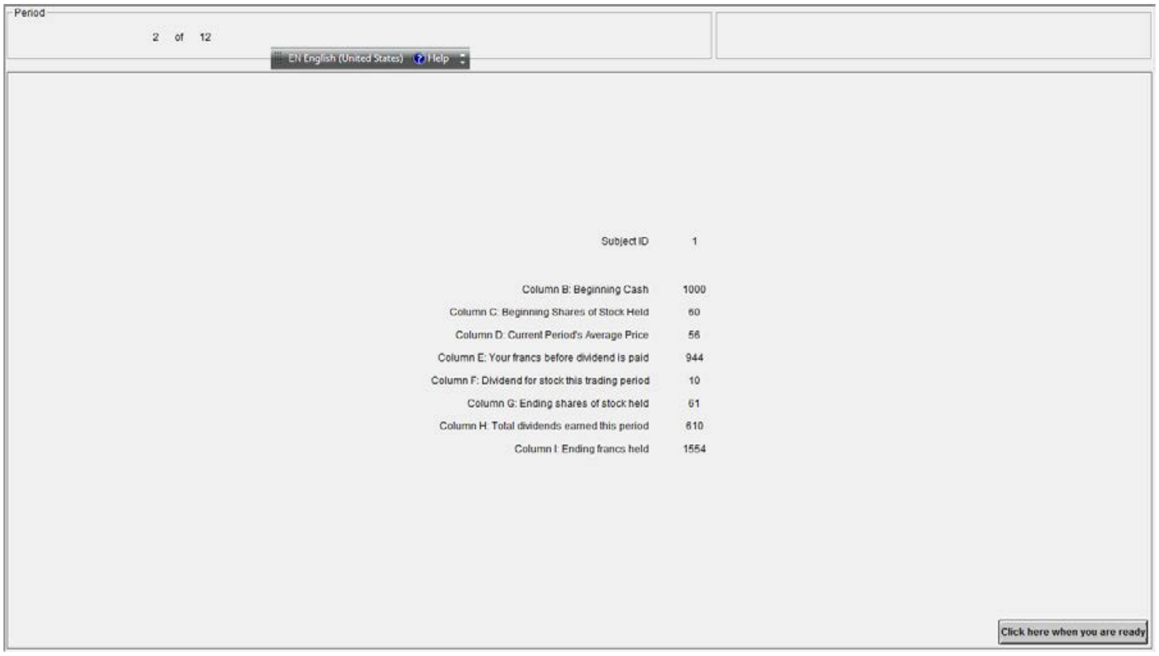
3. You are not permitted to place offers or accept the offers of others if you do not have enough shares to cover all the outstanding offers you have submitted. Suppose, for example, that you currently hold 7 shares. You have posted an offer to sell 4 of your shares and another trader then posts an offer to buy 6 shares. You cannot accept to sell 6 shares to this trader because you have 4 committed in an open offer to sell. You could, however, accept to sell the 3 shares you hold that are not already committed.

4. You can't place a buy order if you don't have enough money left in your account.

An error message will inform you of the situation in any of these cases.

Summary Screen

At the end of each trading period, a summary screen will pop up.



On this screen, you will see summary information for the trading period. The "Column" refers to the column on the Record Sheet. You will record trading information on the Record Sheet each period. The information included is:

A. The trading period (and your subject ID)
B. Beginning cash
C. Beginning shares of stock held
D. Current (and previous) period's average price
E. Your francs held before dividend is paid
F. Dividend paid on the stock this trading period
G. Ending shares of stock held
H. Total dividends you earned this period
I. Ending francs held

When you are finished, please click the "Please Wait" button to wait until other participants are ready to continue to the next trading period.

Dividends

At the end of each period, the actual dividend paid for each share of stock will be indicated on your summary screen. The dividend each period is randomly determined by the computer program and there are two equally likely dividend amounts. The dividend per share in each period is either 0 or 10 francs. A random number draw determines whether the dividend is 0 or 10.

The total dividends you receive are computed by multiplying the dividend per share by the number of shares you hold at the end of the period. Suppose, for example, that you hold 10 shares of stock at the end of period 1. If the dividend per share for that period is 10 francs, then your total dividends for the stock in period 1 are (10 shares x 10 francs) = 100 francs. If, on the other hand, the dividend per share for that period is 0 francs, then your total dividends for the stock in period 1 are (10 shares x 0 francs) = 0 francs.

Notice that the expected payoff for a share of stock is 5 francs because half of the time you will earn 0 francs and the other half of the time you earn 10 francs. You can easily calculate that the expected value of dividends per period is 5 francs.

At the end of the experiment, we will convert your earnings into yuan. We will add the dividends you earn in the final trading period (period 12) to your francs before the dividend is paid. Then we take the ending francs held and multiply by 0.025. This is your compensation for participating today. Notice that 1,000 francs in total would be equal to ¥25.00.

In period 1, the expected value of a share of stock is 5 francs*12 periods = 60 francs. If you buy a share of stock in period 1 and hold it until the end of the experiment, you will earn the dividends paid over all 12 periods and the total expected value is 60 francs. Similarly, if you buy a share of stock in period 2 and hold it until the end of the experiment, you will earn the dividends paid over the 11 remaining periods and the total expected value is 55 francs

Dividend Independence

The dividend paid each period is determined by the program independently of past payments and the two dividends (0 and 10) are equally likely.

Carry Forward

The cash balance and shares that you have at the end of one period will be carried forward to the next period. Notice that even if you do not trade, the shares you hold will earn the randomly determined dividend.

The expected value per period for the stock is 5 francs. Notice that the expected value the stock in any period is exactly 5 times the number of periods remaining. So, for example, in period 1, the expected value of the stock is 60 francs. In period 2, the expected value is 5*11 = 55 francs, and so forth.

Your Earnings

Your trading profit is each period comes from two sources. First, you earn dividends on shares held at the end of the period. Second, you can generate trading profits and losses when you purchase and sell shares of stock.

The Final Trading Period

At the end of the last period, the shares will pay a final dividend and cease to exist. Your trading screen will then display the final cash balance. You will be paid this amount in cash at the end of the session today. If your final profit is negative, you will be paid a small attendance fee.

Now let's practice trading!

At this time we will conduct two practice trading periods so that you can become familiar with the computer interface. The practice periods are 3 minutes, the same time as later periods, and we encourage you to take advantage of this practice by making and accepting offers.