BANK OF CANADA
BANQUE DU CANADA

Working Paper/Document de travail
2014-18

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Bank of Canada Working Paper 2014-18

May 2014

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Giovanni Giusti,[1] Janet Hua Jiang[2] and Yiping Xu[3]

[1]Universitat Pompeu Fabra
giovanni.giusti@upf.edu

[2]Funds Management and Banking Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
jjiang@bankofcanada.ca

[3]University of International Business and Economics
xuyiping@uibe.edu.cn

ISSN 1701-9397

Acknowledgements

This paper was previously circulated under the title "Eliminating laboratory asset bubbles by paying interest on cash." For their comments and suggestions, we thank Sermin Gungor, Jianjian Jin, Vadym Lepetyuk, and participants at the 2012 Southern Europe Experimentalists Meeting, the 2012 International Meeting on Experimental & Behavioral Economics, the 2012 CEA conference in Calgary, the 2012 LeeX Workshop on Theoretical and Experimental Macroeconomics, the 2012 ESA Conference in New York, the 2012 SAET Conference in Paris, and the seminars at the University of California – Irvine and the University of International Business and Economics. Janet Hua Jiang acknowledges the financial support from the Social Sciences and Humanities Research Council of Canada during her affiliation with the University of Manitoba.

Abstract

We study the formation of price bubbles on experimental asset markets where cash earns interest. There are two main conclusions. The first is that paying positive interest on cash is ineffective in diminishing bubbles through the reducing-active-participation channel. The second is that the fundamental value generating process plays a critical role in the formation of asset bubbles in the laboratory. In particular, bubbles tend to occur whenever there is a conflict between the sign of the time trend of the fundamental value and the sign of the expected dividend payment. This explanation is consistent with all existing studies that analyze the role of fundamental value processes in inducing bubbles on experimental asset markets.

JEL classification: C90, G10
Bank classification: Asset pricing; Financial markets; Financial stability

Résumé

Nous étudions la formation des bulles de prix sur des marchés d'actifs expérimentaux au sein desquels les liquidités permettent de toucher un intérêt. Nous parvenons à deux conclusions principales. Premièrement, le fait d'appliquer un taux d'intérêt positif aux liquidités n'aide pas à diminuer les bulles par la réduction de la participation active aux marchés. Deuxièmement, dans le cadre expérimental, le processus de création de la valeur fondamentale joue un rôle essentiel dans la formation des bulles d'actifs. En particulier, les bulles ont tendance à surgir lorsque la tendance temporelle de la valeur fondamentale et le paiement de dividendes attendu sont de sens contraire. Cette explication est corroborée par toutes les études existantes qui analysent l'incidence du processus de création de la valeur fondamentale sur l'apparition de bulles dans les marchés d'actifs expérimentaux.

Classification JEL : C90, G10
Classification de la Banque : Évaluation des actifs; Marchés financiers; Stabilité financière

1 Introduction

Bubbles refer to the phenomena associated with dramatic increases in asset prices exceeding the asset's fundamental value. Bubbles occur when asset owners believe that they can resell the asset at an even higher price in the future. There are, broadly speaking, two approaches to modelling bubbles (see Brunnermeier 2009, and Scherbina 2013, for two surveys of the literature on asset bubbles). The first approach assumes full rationality. One result of this approach is that if all information is common knowledge, bubbles must be infinitely-lived and grow at the same rate as the discount rate.[1] The second approach deviates from perfect rationality and assumes that at least some traders are behavioral.

There is a large literature of experimental studies on asset bubbles following the seminal paper by Smith, Suchanek and Williams (1988, hereafter SSW). The experimental approach constitutes a good complement to research using field data. The advantages include cleaner control of trading environments and clearer definition of the fundamental value. In SSW, subjects trade a single asset in a simple experimental asset market environment. The asset has a finite lifetime and pays a random dividend in each period. The dividend payment and a fixed terminal buyout value are the only sources of intrinsic value of the asset. The distribution of the dividend process is common knowledge to all traders. Theory assuming full rationality predicts that bubbles should not occur in the SSW setting. However, SSW find that the trading price frequently exceeds the fundamental value, which provides strong evidence against full rationality.[2]

SSW conjecture that bubbles on the experimental asset market are caused by the lack of common knowledge of rationality leading to speculation. Lei, Noussair and Plott (2001) reject the conjecture after observing bubbles even when resale opportunities are removed, and suggest real irrationality as the source of bubbles. In addition, Lei, Noussair and Plott (2001) find that removing speculative opportunities and simultaneously adding a commodity market greatly reduce trading volumes and price bubbles on the asset market. As a result, they raise the active-participation hypothesis that much of the trading activity that accompanies bubble formation is due to the lack of an alternative activity during the experiment. More generally, Lei, Noussair and Plott (2001) suggest that bubble formation in experimental asset markets could have origins in aspects of the methodology of the experiment.

In this paper, we respond to Lei, Noussair and Plott's (2001) call to explore the aspects

[1] The result that bubbles cannot occur in a finite horizon model is derived by backward induction. Since a bubble cannot grow from the last trading period, there cannot be a bubble of this size in the second-last period, and so on.

[2] In the experimental literature, the fundamental value is usually calculated under the assumption of risk neutrality. If agents are risk averse, the fundamental value should be lower than that implied by risk neutrality, which makes the observation of pricing bubbles (relative to risk-neutral fundamental values) even more striking.

of the SSW design that may have contributed to irrational trading on experimental asset markets. The framework that we choose deviates from the SSW design by the introduction of interest on cash: interest payments interpreted as interest earnings of a savings account, or interest charges interpreted as banking fees.[3] The design allows us to investigate two possible factors contributing to irrational trading in the SSW experimental asset markets. First, the absence of interest payments on cash implies a low opportunity cost of speculation on the asset market, which may have boosted active trading and bubble formation. This is related to the point raised in Lei, Noussair and Plott (2001), that subjects tend to trade (irrationally) due to boredom and the lack of alternative activities during the experiment. We study the case where cash earns positive interest. Although it does not provide alternative trading activities as in Lei, Noussair and Plott (2001), it raises the opportunity cost of speculation on the asset market and may induce more prudent trading and a lower trading volume.

Second, researchers have suspected that the fundamental value generating process featured in the SSW design is inducive to confusion and irrational trading. The introduction of interest on cash allows us to alter the fundamental value process in more flexible ways. Exploring a richer set of fundamental value processes helps us to identify the source of confusion in the SSW design. Note that, without interest payments, two aspects of the fundamental value generating process – the sign of the expected dividend payment and the time trend of the fundamental value – are tied together: positive, zero, or negative expected dividend payments give rise to decreasing, flat, or increasing fundamental values, respectively. The introduction of interest breaks the connection and allows for greater flexibility in terms of more possible combinations of the sign of the dividend payment and the sign of the time slope of the fundamental value.

To investigate how the two aspects of the SSW design – low opportunity cost of speculation and confusion about the fundamental value – may have contributed to irrational trading on experimental asset markets, we design three treatments with interest on cash characterized by different combinations of the sign of dividend payments and the sign of the time slope of the fundamental value. In the first two treatments (treatments F and R), cash earns positive interest, and stocks pay positive expected dividends. The difference lies in the dynamics of the fundamental value: the fundamental value decreases in treatment F and increases in treatment R. In the third treatment (treatment N), banking fees are charged on cash holdings, the expected dividend is negative (interpreted as carrying costs), and the fundamental value decreases over time. There is substantial overpricing in treatment F, very weak mispricing in treatment R, and, on average, slight underpricing in treatment N. There is no significant

[3]Bostian and Holt (2009) and Fischbacher, Hens and Zeisberger (2013) also feature interest on cash. We will discuss the differences between their work and ours in section 2, where we review related literature.

difference in terms of trading volume among the three treatments.

Treatment F shares similarities with a standard SSW design in that both designs have positive dividend payments and decreasing fundamental values; the main difference is that cash earns positive (no) interest in treatment F (SSW). Since treatment F involves significant overpricing, as with the SSW design, we can conclude that paying interest on cash is not sufficient to suppress price bubbles through the reducing-active-participation channel. In addition, a comparison between treatments F and R suggests that active participation is not the reason why bubbles appear in treatment F, because the two treatments share similar levels of trading intensity. A more likely reason for bubble formation is confusion about the fundamental value of the asset. In particular, the results from our study, together with those from other papers (which we will discuss in more detail in the next section), suggest that mispricing tends to occur whenever there is a conflict between the sign of dividend payments and the sign of the time slope of the fundamental value: overpricing tends to occur with positive dividend payments and decreasing fundamental values, and underpricing with negative dividends and increasing fundamental values.

The rest of the paper is organized as follows. We discuss related literature in section 2, describe the experimental design in section 3, analyze the experimental results in section 4, and conclude in section 5.

2 Related Literature

Following the seminal paper by SSW, the experimental literature on asset bubbles has largely followed two directions (see Palan 2013 for a detailed survey of the literature). The first keeps the same fundamental value specification as in SSW and tries to find measures to reduce bubbles. King et al. (1993) examine the effect of allowing for short sales, using non-student subjects, transaction fees, equal endowment and price-change limits; these measures are ineffective in eliminating bubbles.[4] Fisher and Kelly (2000) introduce two simultaneous asset markets and find that bubbles exist in both markets. Fischbacher, Hens and Zeisberger (2013) and our paper study the case with interest payments on cash; both studies suggest that paying interest on cash in itself is ineffective in eliminating bubbles. Rigid measures to curb trading are more effective in reducing or eliminating bubbles; such measures include removing speculative opportunities and diverting subjects' attention from the asset market to a commodity market (Lei, Noussair and Plott 2001), reducing liquidity or controlling for the cash/asset ratio (Caginalp, Porter and Smith 1998, 2001; Fischbacher, Hens and Zeisberger

[4] Ackert et al. (2006) and Haruvy and Noussair (2006) also study the effect of short sales.

2013; Kirchler, Huber and Stöckl 2012), and imposing holding caps (Lugovskyy et al. 2012). Different trading mechanisms have also been studied. Van Boening, Williams and LaMaster (1993) find that bubbles continue to occur in call markets. Lugovskyy, Puzello and Tucker (2011) show that the Tâtonnement mechanism is effective in reducing bubbles. Cheung and Palan (2012) find that trading teams reduce the bubble phenomenon compared to individual traders.

The second direction of the experimental research on asset bubbles contends that the fundamental value generating process in the SSW is conducive to misunderstanding and bubble formation. Except for our study, the existing literature focuses on the effect of the time trend of the fundamental value. Most studies use a framework without interest on cash. Smith, van Boening and Wellford (2000), Noussair, Robin and Ruffieux (2001), Huber, Kirchler and Stöckl (2012), and Kirchler, Huber and Stöckl (2012) study the case with flat fundamental values assuming a zero expected dividend payment, and find that overpricing is greatly reduced. Huber, Kirchler and Stöckl (2012) also study the case with increasing fundamental values by assuming negative dividend payments and find underpricing in this situation.[5] Bostian and Holt (2009) conduct a classroom experiment using a framework with interest payments on cash. They study a single regime which features a flat fundamental value induced by equating the buyout value to the ratio of the expected dividend payment over the interest rate, and observe frequent occurrences of bubbles. Our study exploits the flexibility created by the introduction of interest on cash and includes three different fundamental value processes.[6]

There are two explanations of how the fundamental value process affects trading behavior, both focusing on the effect of the time trend of the fundamental value. First, as pointed out by Smith (2010) and Oechssler (2010), subjects may find it hard to comprehend the decreasing fundamental value in the SSW design, because asset prices tend to increase or stay constant in the long run in real life. Huber, Kirchler and Stöckl (2012) provide a second explanation, proposing that anchoring on information generated by the trading process drives underreaction and, in turn, mispricing on the experimental asset market. According to this

[5]Noussair and Powell (2010) and Breaban and Noussair (2014) examine environments where the fundamental values experience different time trends during the trading game. Noussair and Powell (2010) conduct two sets of experiments. In the "peak" treatment, fundamentals first rise and then fall, while in the "valley" treatment fundamentals first fall and then recover. They find that bubbles still occur in both treatments, but in smaller magnitudes in the peak treatment. Breaban and Noussair (2014) study markets in which a trend in fundamentals sets in after an interval of constant value. They find that prices tend to track fundamentals more closely when the trend is decreasing than when it is increasing. Breaban and Noussair (2014) conclude that the contrast between their results and those from previous studies indicate that the timing of the onset of a trend in fundamentals is an important feature influencing how the trend affects the price discovery process.

[6]Fischbacher, Hens and Zeisberger (2013) also have interest on cash. In their design, the interest rate changes in response to prices, making it difficult to define the fundamental value. They do not focus on the effect of fundamental value dynamics.

explanation, decreasing fundamental values would give rise to overpricing, increasing fundamentals would lead to underpricing, and flat fundamentals would involve little mispricing. Neither of the two explanations is fully compatible with the existing studies. In particular, the results in the two studies with interest on cash – Bostian and Holt (2009) and our study – provide evidence against either explanation. According to Smith (2010) and Oechssler (2010), there should be great overpricing in our treatment N with decreasing fundamentals and no mispricing in Bostian and Holt (2009) with a flat fundamental. However, there is, on average, slight underpricing in our treatment N and frequent bubbles in Bostian and Holt (2009). According to the explanation suggested by Huber, Kirchler and Stöckl (2012), there should be underpricing or negative bubbles in our treatment R with increasing fundamentals, positive bubbles in our third treatment with decreasing fundamentals and no mispricing in Bostian and Holt (2009) with a constant fundamental value; the prediction is inconsistent with the experimental results.

We propose a third explanation that suggests both the time trend of the fundamental value and the sign of the expected dividend payment affect mispricing. In particular, mispricing tends to occur whenever there is a conflict between the sign of dividend payments and the sign of the time slope of the fundamental value: overpricing tends to occur with positive dividend payments and decreasing fundamental values, and underpricing tends to occur with negative dividends and increasing fundamental values. This new explanation is consistent with all existing studies, including our own.

There is also a strand of studies that keeps the same fundamental value generating process as in SSW, but adopts various measures to help subjects understand the process. One measure is to allow subjects to repeat the experiment. Many studies, including SSW, King et al. (1993), Van Boening, Williams and LaMaster (1993), Dufwenberg, Lindqvist and Moore (2005), and Hussam, Porter and Smith (2008), find that past experience with the same game significantly reduces the magnitude of bubbles.[7] Lei and Vesely (2009) include a pre-trading phase where subjects hold the asset and experience dividend flows. Kirchler, Huber and Stöckl (2012) change the context from "stocks" to "stocks of a depletable gold mine." Huber, Kirchler and Stöckl (2012) display the fundamental value on the trading screen. These salient measures are found to be effective in eradicating bubbles. Porter and Smith (1995) find that the existence of a futures market, in which contracts are realized at the halfway point of the trading horizon, helps to reduce but does not remove asset bubbles. A follow-up study by Noussair and Tucker (2006) finds that the futures markets can eliminate bubbles if the contracts are such that there is one maturing in each period of the life of the asset.

[7]The effect of experience only applies if subjects repeat the same game. The effect will disappear if there is a large shock to the environment, such as liquidity and dividend uncertainty as in Hussam, Porter and Smith (2008), and reshuffling of subjects and admission of new subjects as in Xie and Zhang (2012).

Finally, there are also a few papers that study asset bubbles with indefinite horizons. For example, Camerer and Weigelt (1993) study asset markets where subjects trade stochastically lived assets that pay a dividend each period and live from period to period with a known probability; they find that asset prices converge slowly to the fundamental value. On the other hand, in a classroom experiment, in which an asset with a constant fundamental value was traded in an indefinite horizon, Ball and Holt (1998) find systematic overpricing. In Hens and Steude (2009), the dividend process follows a random walk with a positive drift, which implies that the fundamental value depends on the dividend realization in the current period (the paper does not investigate the problem of mispricing). Kose (2013) finds that concerns about bankruptcy risk (the asset becomes worthless once the game ends randomly) cause underpricing irrespective of the time trend of the fundamental value. Crockett and Duffy (2013) and Fenig, Mileva and Petersen (2014) consider general-equilibrium economies. Crockett and Duffy (2013) find that in an environment where subjects are induced to adjust share holding in order to smooth consumption, assets trade at a discount relative to the risk-neutral fundamental price. In Fenig, Mileva and Petersen (2014), subjects are induced to maximize their utility from consumption and leisure, and at the same time engage in speculative activities in the asset market; they find that asset prices consistently grow above the fundamental value and do not decline significantly with learning.

3 Experimental Design

The major departure from the SSW design is the introduction of interest payments or charges on cash holdings. Within this framework, we can study whether positive interest payments on cash, which increase the opportunity cost of asset-market speculation, will reduce speculation and bubbles on the asset market. We can also investigate the effect of different fundamental value generating processes, taking advantage of the flexibility created by the introduction of interest on cash.

Shares have a finite life of T periods. Each share pays a random dividend at the end of each period from time 1 to T, plus a fixed buyout value, K, at the end of period T. The distribution of the dividend is iid over time. The expected value of the dividend is fixed at d. If $d < 0$, we interpret it as carrying costs. In each period, cash earns interest or bears charges at the net rate of r. When $r > 0$, we interpret it to mean that cash is parked in an interest-bearing savings account. When $r < 0$, we interpret it to mean that cash is placed in a banking account that charges proportional banking fees. Subjects can use money from their savings/banking account to purchase shares. Revenues from share sales, the carrying costs of shares and banking fees are automatically deposited into or deducted from the savings/banking account.

Following the usual practice in the literature, we define the fundamental value as the holding value for a risk-neutral agent (the fundamental value for a risk-averse agent is lower). The fundamental value of the asset at the beginning of period t is calculated as the net present value of all remaining dividend payments and the buyout value at the end of T, i.e.,

$$\begin{aligned} FV_t &= d\left[\sum_{\tau=1}^{T-t+1}(1+r)^{-\tau}\right] + K(1+r)^{-(T-t+1)} \\ &= \begin{cases} d(T-t+1)+K \text{ if } r=0, \\ d/r + (K-d/r)\,(1+r)^{-(T-t+1)} \text{ if } r \neq 0. \end{cases} \end{aligned}$$

The time trend of the fundamental value is given by

$$\frac{d(FV_t)}{dt} = \begin{cases} -d \text{ if } r=0, \\ (K-\frac{d}{r})[\ln(1+r)](1+r)^{-(T-t+1)} \text{ if } r \neq 0. \end{cases}$$

Note that in the absence of interest on cash (i.e., $r=0$), the time trend of the fundamental value is fully determined by the sign of the dividend payment (negative dividend payments can be interpreted as carrying costs). If $d>0$ as in the SSW design, the fundamental value must decrease over time. To generate a flat fundamental value, d must be equal to 0 as in Smith, van Boening and Wellford (2000), Noussair, Robin and Ruffieux (2001), and Kirchler, Huber and Stöckl (2012). To induce an increasing fundamental value, d must be negative as in Huber, Kirchler and Stöckl (2012). The introduction of r allows for more flexibility. In particular, it is possible to have increasing fundamental values with $d>0$ (for example, by setting $r>0$ and $K>d/r$) and decreasing fundamental values with $d<0$ (for example, by setting $r<0$ and $K>d/r$).

Using the above framework, we investigate two possible factors that may contribute to irrational trading. The first is the "active-participation hypothesis" raised by Lei, Noussair and Plott (2001). We would like to study whether paying positive interest on cash holdings, which increases the opportunity cost of speculation on the asset market, will reduce trading and overpricing of the asset. The second is the fundamental value generating process. As discussed earlier, existing studies (except our paper) focus on the effect of the time slope of the fundamental value, but the time slope itself cannot explain the results in all studies. We conjecture that the way to generate the time slope is also important. Taking advantage of the flexibility created by the introduction of interest on cash, we run three treatments with different combinations of the interest rate, dividend payment, the buyout value, and the time slope of the fundamental value. We run a total of 19 sessions. Detailed information for each

session is listed in Table 1.

In the first treatment, cash earns a positive interest payment with $r = 10\%$ or 15%.[8] The dividend payment has four possible realizations, $0, 8, 28$, and 60, with equal probabilities, which implies a positive expected dividend payment with $d = 24$.[9] The buyout value K is set to be less than d/r to induce a decreasing fundamental value. This treatment is labeled "F" to reflect the falling fundamental value. We run six experimental sessions (sessions F1-6) of this treatment. The second treatment is similar to the first treatment in terms of interest and dividend payments, but with $K > d/r$, which implies increasing fundamentals. We label the second treatment "R" to capture the rising fundamental values. We run seven treatment-R sessions (R1-7). The third treatment has interest charges on cash holdings with $r = -10\%$ and negative dividend payments interpreted as carrying costs with $d = -24$ (the dividend is equal to $0, -8, -28$, or -60 with equal probabilities); the buyout value, K, is set at 500; and the fundamental value decreases over time. We label the treatment "N" to reflect the negative dividend and interest payment. There are six sessions (N1-6) of this treatment.

Treatment F differs from a standard SSW design in that cash earns positive interest (both designs have positive dividend payments and decreasing fundamental values). Therefore, we can use the result from treatment F to evaluate whether increasing the opportunity cost of asset trading by paying positive interest on cash is effective in eliminating bubbles through the reducing-active-participation channel. In addition, if bubbles are observed only in treatment F, but not in treatment R, we can infer that the main reason for the different results from the two treatments is due to the different fundamental value process.[10]

To examine the effect of the fundamental value generating process, we compare the results from all three treatments, together with the results from other papers that study the effect of alternative fundamental dynamics, including Smith, van Boening and Wellford (2000), Noussair, Robin and Ruffieux (2001), Bostian and Holt (2009), Huber, Kirchler and Stöckl (2012), and Kirchler, Huber and Stöckl (2012). Our purpose is to reconcile all existing studies on the effect of fundamental value generating processes.

The program used to conduct the experiment is written in z-Tree (Fischbacher, 2007). See the Appendix for the experimental instructions. There are 9 or 10 subjects participating in each session, trading a single asset called "shares." Communication among subjects is prohibited during the experiment. The number of trading periods, T, is 15, except for session

[8]The interest rate of 10% or 15% seems to be unrealistically high. Because subjects play with small stakes in the experiment, we set the interest rate at conspicuously high levels to induce meaningful responses from subjects.

[9]Some treatments in SSW feature the same dividend distribution.

[10]The result that substantial overpricing occurs only in treatment R, but not in treatment F, is unlikely to occur.

R7, which has 12 trading periods. Each trading period lasts for 150 seconds. Subjects are given the opportunity to practice with the trading interface. There is also a training period during which subjects familiarize themselves with the task that they will perform. Each subject starts the first formal trading period with the same endowment of shares and cash. The share endowment for each subject is 4. The amount of cash endowment is chosen to control for the initial cash/asset ratio, which ranges from 1 to 2.5 in treatment F, 1 to 3 in treatment R, and 6.65 to 8.32 in treatment N.[11]

Following the usual practice in the literature, we provide subjects with a table to list the holding value of a share in terms of cash. The trading mechanism is a continuous double auction with open order books. Subjects initiate a transaction by posting offers to buy (bids) and offers to sell (offers). Each offer is for the transaction of one share, but subjects can post multiple offers to buy or sell. Active orders to buy and orders to sell are ranked in two separate columns, with the best available offers at the bottom of the lists. Subjects execute a trade by selecting the best order and press the "buy" or "sell" button located at the bottom of the order book. To facilitate the comparison between our results and those from other papers that study the effect of interest payments and the fundamental value dynamics, we adopt the same design to ban short sales of shares and borrowing money to buy shares. The sessions were conducted from October 2011 to March 2012 at two universities: Universitat Pompeu Fabra (UPF), Barcelona, and University of International Business and Economics (UIBE), Beijing. Each session of experiment lasts for about 90 minutes. The average earning is 13 euros at UPF and 100 renminbi at UIBE.

4 Experimental Results

We document the experimental results in Figures 1-3 and Tables 2-7. Before discussing the experimental results, we first describe the information in these figures and tables.

Figures 1-3 plot the time series of the fundamental value (FV_t), the median trading price (P_t) and the trading volume (N_t) for each session of experiment.[12] The six sessions with treatment F are graphed in Figure 1. Figure 2 reports the seven treatment-R sessions. The six treatment-N sessions are represented in Figure 3. The horizontal axis indicates the trading period running from 1 to 15. Prices are depicted along the left vertical axis: the solid line is the path of P_t, the dashed line represents FV_t, the upper dotted line indicates $(1+30\%)\text{x}FV_t$,

[11] Caginalp, Porter and Smith (1998, 2001) suggest that the effect of the cash/asset ratio is stronger in early periods of the experiment.

[12] We use the median trading price instead of the average trading price because the former is less affected by errors made by subjects while posting offers.

and the lower dotted line represents $(1-30\%)\text{x}FV_t$. The two dashed lines serve as reference lines to visualize the extent of mispricing. The trading volume is graphed against the right vertical axis in circles.

Table 2 provides four statistics to quantify the trading behavior. We provide the statistics for each individual session, and the treatment statistics (in bold face) averaged across sessions of the same treatment. There are three statistics to measure price deviations: relative absolute deviation (RAD), relative deviation (RD) and price amplitude (PA). The fourth statistic, share turnover (ST), measures trading intensity. The four statistics are calculated as follows. Let $\overline{FV} = \left(\sum_{t=1}^{T} FV_t\right)/T$ be the average lifetime fundamental value. Denote the number of outstanding shares as N_0, which is equal to 40 in sessions with 10 subjects and 36 in sessions with 9 subjects. The relative absolute deviation $RAD = \left(\sum_{t=1}^{T} \frac{|P_t - FV_t|}{\overline{FV}}\right)/T$ measures the average level of mispricing relative to the average lifetime fundamental value of the asset. The relative deviation $RD = \left(\sum_{t=1}^{T} \frac{P_t - FV_t}{\overline{FV}}\right)/T$ measures the extent of over or undervaluation. The price amplitude $PA = \max_{1\le t\le T}[(P_t - FV_t)/\overline{FV}] - \min_{1\le t\le T}[(P_t - FV_t)/\overline{FV}]$ measures the overall size of mispricing. The share turnover is calculated as $ST = \sum_{t=1}^{T}(N_t/N_0)$. Note that we use the average lifetime fundamental value, $\overline{FV}$, to calculate the three measures of price deviation. As discussed in Stöckl, Huber and Kirchler (2010), it is more appropriate to use $\overline{FV}$ (than FV_1, as in many studies) for comparison among different experimental settings, especially among treatments with different time paths of the fundamental value.

Table 3 reports the results from two-tailed Mann-Whitney tests that compare the trading patterns of the different treatments. Each session is counted as one observation of the treatment: there are six observations for treatment F, seven observations for treatment R, and six observations for treatment N. The test is performed for each of the four trading statistics and for each pair of the three treatments. A total of 12 tests (four statistics and three pairs) are conducted. For each test, we list the average treatment statistic for the pair of treatments being compared, the Z-statistic, the p-value of the Z-statistic, and the combined sample size of the pair of treatments.

In Table 4, we identify the incidence of bubbles. We use a commonly adopted rule in the literature: we say that a bubble occurs in a session if the median transaction price exceeds the fundamental value by at least $x\%$ for more than five consecutive periods (see, for example, Noussair, Robin and Ruffieux 2001). Table 4 lists the number of bubbly sessions for each of the three treatments for $x = 30$, 40, and 50.

Finally, Tables 5-7 provide information about individual trading behavior. In particular, we check the extent of "fundamental trading" for each subject. We say a transaction or offer is "fundamental" if the price is $\leq (1+30\%)$xFV for share purchases, and $\geq (1-30\%)$ xFV for share sales. We then measure the extent to which an individual is a fundamental trader by the percentage of fundamental transactions and offers that the individual engages in across the session. Table 5 lists the information for each individual subject who participated in each of the 19 sessions. We provide session-level and treatment-level statistics in Table 6. The session statistic is calculated as the median of the individual statistics for subjects who participated in that session. The treatment-level statistic (in bold face) is the average of session statistics for sessions belonging to the same treatment. Table 7 shows the results from the Mann-Whitney test of the three treatments using the session-level statistics as observations.

4.1 Description of Experimental Results

Next we describe the experimental results. It is clear from Figure 1 that the median trading price frequently exceeds the fundamental value (and the $(1+30\%)$xFV line) in sessions with treatment F. In contrast, in sessions with treatment R, the median trading price closely tracks the fundamental value most of the time. For treatment N, except for two sessions N2 and N6, the median trading price does not deviate substantially from the fundamental value: the line for the median trading price lies within the $(1 \pm 30\%)$xFV band most of the time.

From Table 2, which provides the trading statistics, one can see that treatments R and N have, on average, mild underpricing (relative to the risk-neutral fundamental value): the average treatment RD is -0.3% for treatment R and -0.9% for treatment N. In contrast, treatment F exhibits substantial overpricing, with the average treatment RD being high at 72.3%. In terms of general mispricing, treatment R involves the smallest deviation from the fundamental value (the treatment average RAD is 11.1%), followed by treatment N (the treatment average RAD is 20.9%). Treatment F exhibits substantial mispricing: the treatment average RAD is 76.6%. The price amplitude is very high in treatment F averaged at 148.6%, compared with 44.5% for treatment R and 92.0% for treatment N. The three treatments have a comparable trading intensity: the share turnover is 5.171 for treatment F, 5.661 for treatment R and somewhat higher at 7.034 for treatment N.

Table 3 shows the results from Mann-Whitney tests on RAD, RD, PA and ST. The tests suggest that treatment F generates statistically higher mispricing, mainly in the form of overpricing, than the other two treatments. In terms of RAD, which measures overall mispricing, the test between treatments F and R has a Z-value of 3, and the test between treatments F and N gives a Z-value of 2.882. In terms of RD, which measures overpricing, the test between

treatments F and R has a Z-value of 3, and the test between treatments F and N has a Z-value of 2.722. All four tests have a p-value of 0%.[13] The tests on PA suggest that treatment R involves much smaller price fluctuations than the other two treatments. The comparison between treatments F and N is not statistically different, with a p-value of 26%. Finally, in terms of trading intensity, measured by share turnover, the three treatments are not statistically different: the tests between treatments F and R, F and N and R and N, have a p-value of 67%, 75% and 67%, respectively.

In terms of the number of bubbles (see Table 4), we find that all treatment-F sessions have bubbles if we define a bubble as the situation where the median transaction price exceeds the fundamental value by at least 30% or 40% for more than five consecutive periods (i.e., $x = 30\%$ or 40%). Even if we increase x to 50% (which tends to give a low bubble count), there are still five bubbly sessions out of the six treatment-F sessions. There are no bubbles in treatment R using all three rules. For treatment N, two sessions (N2 and N6) have bubbles if we set $x = 30\%$ (which tends to give a high bubble count), one session (N6) has a bubble if $x = 40\%$, and there are no bubbles if $x = 50\%$.

From Tables 5-7, we can see that there are more fundamental traders in treatments R and N than in treatment F. For example, among the 70 subjects who participate in the seven sessions of treatment R, the percentage of fundamental transactions is 80% for 80% of the subjects (remember that in a fundamental transaction, the purchasing price is $\leq (1 + 30\%)$xFV and the sale price is $\geq 30\%)$ xFV). In contrast, among the 59 participants in the six sessions of treatment F, only 14% of subjects have more than 80% of fundamental transactions. For treatment N, among the 57 participants, 72% have more than 80% fundamental transactions, which is much higher than the 14% in treatment F, but somewhat lower than the 80% for treatment R. The treatment average percentage of fundamental transactions is 94% for treatment R, 87% for treatment N and 61% for treatment F. The treatment average percentage of fundamental offers is 99% for treatment R, slightly lower at 95% for treatment N and much lower at 84% for treatment F.[14] The Mann-Whitney test shows that the difference between the three treatments in terms of the percentage of fundamental trading and posting is statistically significant.

To summarize, treatment F involves substantial mispricing in the form of overpricing, while treatments R and N involve, on average, much lower mispricing and very mild underpricing. The three treatments are not significantly different in terms of trading intensity.

[13] Note that the RADs for all seven treatment-R sessions are universally lower than those for all six treatment-F sessions. The same pattern applies to RD (see Table 2).

[14] The data in Tables 5 and 6 show with regularity that posted offers follow the fundamental value more closely than trading prices.

4.2 Effect of Interest Payments on Cash

We first check whether paying positive interest on cash helps to reduce bubbles by increasing the opportunity cost of speculation on the asset market.

Note that treatment F differs from a standard SSW design in that cash earns positive interest (both treatments have positive dividend payments and decreasing fundamental values). Since treatment F involves significant overpricing (as with the SSW design), we can conclude that paying interest on cash is not sufficient to suppress overpricing through the reducing-active-participation channel. The result is consistent with the findings in previous studies that have interest payments on cash. Bostian and Holt (2009) observe that bubbles frequently occur in an environment where cash earns positive interest and the fundamental value is constant. Fischbacher, Hens and Zeisberger (2013) investigate the effect of monetary policy in correcting mispricing by raising (cutting) the interest rate when the trading price is above (below) the fundamental value throughout the whole trading session. They find that raising the interest rate cannot eliminate bubbles.

In addition, a comparison between treatments F and R suggests that active participation is not the reason why bubbles (do not) appear in treatment F (R), because the two treatments share similar trading intensity. A more likely reason for bubble formation is confusion about the fundamental value process.

4.3 Effect of the Fundamental Value Generating Process

Given that the fundamental value generating process plays a critical role in the formation of bubbles, the next step is to identify features of the fundamental generating process that are responsible for the occurrence of bubbles.

One explanation, as formulated in Smith (2010) and Oechssler (2010), is that, since asset prices tend to increase or stay constant in the long run in real life, subjects may find it difficult to comprehend that the fundamental price of the asset could decrease over time. According to this explanation, we should observe little overpricing in treatments with flat or increasing fundamental values. This explanation is consistent with some studies, but conflicts with others. For example, Smith, van Boening and Wellford (2000), Noussair, Robin and Ruffieux (2001), Huber, Kirchler and Stöckl (2012), and Kirchler, Huber and Stöckl (2012) find that bubbles are greatly reduced or disappear with a flat fundamental value, and our treatment R shows that there are no bubbles with increasing fundamental values; these results support the explanation. On the other hand, Bostian and Holt (2009) find positive bubbles with a flat fundamental value, Huber, Kirchler and Stöckl (2012) find underpricing or negative bubbles

with increasing fundamental values, and our treatment N has decreasing fundamental values but no substantial overpricing; these results are inconsistent with the explanation.

Huber, Kirchler and Stöckl (2012) provide another explanation. They conduct an experiment with increasing, decreasing and flat fundamental values (in the absence of interest), induced by a positive, negative and zero expected dividend payment, respectively. They find no bubbles with a flat fundamental value, positive bubbles with decreasing fundamental values and negative bubbles with increasing fundamental values. As a result, Huber, Kirchler and Stöckl (2012) propose that anchoring on information generated by the trading process drives underreaction and, in turn, mispricing on the experimental asset market. Again, this explanation is consistent with some studies, but incompatible with others. According to the explanation, there should be negative bubbles in our treatment R, no bubbles in Bostian and Holt (2009), and positive bubbles in our treatment N. However, there is minimal mispricing in our treatment R, significant overvaluation in Bostian and Holt (2009) and no substantial mispricing in our treatment N.

To identify the source of confusion, we investigate in detail the fundamental value generating process, particularly the way in which each paper controls the time trend of the fundamental value of the traded asset. In papers that feature environments without interest payments on cash, the time trend of the fundamental value is determined by the sign of the expected dividend payment, d. A constant fundamental value requires $d = 0$, as in Smith, van Boening and Wellford (2000), Noussair, Robin and Ruffieux (2001), Huber, Kirchler and Stöckl (2012), and Kirchler, Huber and Stöckl (2012). More specifically, in Smith, van Boening and Wellford (2000), shares do not pay dividends. In Noussair, Robin and Ruffieux (2001), the positive dividend is offset by a carrying cost, which implies a zero net expected dividend. In Huber, Kirchler and Stöckl (2012) and Kirchler, Huber and Stöckl (2012), the dividend follows a random process with a zero expected value. To achieve increasing fundamental values, d has to be negative as in Huber, Kirchler and Stöckl (2012), who find undervaluation in this treatment. If $d > 0$, as in a standard SSW design, the time series of the fundamental value has a decreasing trend, and bubbles frequently appear in this setting. Bostian and Holt (2009) and our paper study the formation of bubbles in environments where cash earns interest. The time trend of the fundamental value is determined by three parameters: K, d and r. Bostian and Holt (2009) achieve a flat fundamental value by setting $K = d/r$ with $K, d, r > 0$. The fundamental value increases over time in our treatment R with $K, d, r > 0$ and $K > d/r$. In treatment F, we have $K, d, r > 0$ and $K < d/r$. In treatment N, we have $K > d/r > 0$ with $d < 0$ and $r < 0$.

Based on the above observations, we propose a third explanation: mispricing tends to occur whenever there is a conflict between the sign of the time trend of the fundamental value

and the sign of the expected dividend. Subjects are more likely to perceive that the value of the share should increase if it pays a positive dividend, decrease if the dividend is negative and remain flat if the dividend is zero. The hypothesis is compatible with the results from all existing studies. In Smith, van Boening and Wellford (2000), Noussair, Robin and Ruffieux (2001), Huber, Kirchler and Stöckl (2012), and Kirchler, Huber and Stöckl (2012), the fundamental value is flat and $d = 0$; the trading price tends to follow the fundamental value well. In the SSW design, Bostian and Holt (2009) and our treatment F, the time slope of the fundamental value is negative or zero, but the dividend is positive; this conflict induces overvaluation or positive bubbles. In our treatment R (N), both the time slope of the fundamental value and the expected dividend payment are positive (negative); the extent of overpricing is, in general, small. In the increasing treatment in Huber, Kirchler and Stöckl (2012), the fundamental value increases over time but the dividend is negative, a conflict that results in undervaluation or negative bubbles.

5 Conclusion

In this paper, we investigate the formation of price bubbles in an experimental asset market with interest payments or charges on cash holdings. We investigate two aspects of SSW design that may have contributed to irrational trading on experimental asset markets: low opportunity cost of speculation and confusion about the fundamental value.

We have run three treatments. In the first two treatments (treatments F and R), cash earns a positive interest payment, and stocks pay positive expected dividends. The difference lies in the dynamics of the fundamental value: the fundamental value decreases over time in treatment F and increases in treatment R. In the third treatment (treatment N), banking fees are charged on cash holdings, the expected dividend is negative (interpreted as carrying costs), and the fundamental value decreases over time. We find little mispricing in treatment R, substantial overpricing in treatment F and mild underpricing in treatment N. There is no significant difference in terms of trading volume among all three treatments.

The results suggest that paying interest on cash is not likely to reduce asset bubbles through the reducing-active-participation channel, and the occurrence of bubbles is mainly due to confusion about the fundamental value of the asset. In order to identify the source of confusion, we investigate in detail the designs of existing studies, including our own three treatments, with a particular focus on how each study controls the time trend of the fundamental value. We offer a new explanation that bubbles tend to occur whenever there is a conflict between the sign of the time trend of the fundamental value and the sign of expected dividend payments. This new explanation is consistent with all existing studies.

References

Ackert, L., Charupat, N., Church, B. and Deaves, R. (2006) Margin, short selling, and lotteries in experimental asset markets, *Southern Economic Journal* 73(2), 419-436.

Ball, S.B. and Holt, C.A. (1998) Classroom games: speculation and bubbles in an asset market, *Journal of Economic Perspectives* 12(1), 207-218.

Bostian, A.J. and Holt, C.A. (2009) Price bubbles with discounting: a web-based classroom experiment, *Journal of Economic Education* 40, 27-37.

Breaban, A. and Noussair, C. (2014) Fundamental value trajectories and trader characteristics in an asset market experiment, CentER Discussion Paper Series No. 2014-010.

Brunnermeier, M. (2009) Bubbles, in S. Durlauf and L. Blume (eds), *The New Palgrave Dictionary of Economics* (2nd edition), Palgrave Macmillan.

Caginalp, G., Porter, D. and Smith, V. (1998) Initial cash/asset ratio and asset prices: an experimental study. *Proceedings of the National Academy of Sciences of the United States of America* 95, 756–761.

Caginalp, G., Porter, D. and Smith, V. (2001) Financial bubbles: excess cash, momentum, and incomplete information. *Journal of Psychology and Financial Markets* 2(2), 80-99.

Camerer, C.F. and Weigelt, K. (1993) Convergence in experimental double auctions for stochastically lived assets, in: *The Double Auction Market: Institutions, Theories, and Evidence, Proceedings Volume in the Santa Fe Institute Studies in the Sciences of Complexity* (14). Addison-Wesley, Reading, MA, pp. 355-396.

Cheung, S. and Palan, S. (2012) Two heads are less bubbly than one: team decision-making in an experimental asset market, *Experimental Economics* 15(3), 373–397.

Crockett, S. and Duffy, J. (2013) An experimental test of the Lucas asset pricing model, working paper, University of Pittsburgh.

Dufwenberg, M., Lindqvist, T. and Moore, E. (2005) Bubbles and experience: an experiment, *American Economic Review* 95, 1731-1737.

Fenig, G., Mileva, M. and Petersen, L. (2014) Asset trading and monetary policy in production economies, working paper, Simon Fraser University.

Fischbacher, U. (2007) Z-Tree: Zurich toolbox for ready-made economic experiments, *Experimental Economics* 10(2), 171-178.

Fischbacher, U., Hens, T. and Zeisberger, S. (2013) The impact of monetary policy on stock market bubbles and trading behavior: evidence from the lab, *Journal of Economic Dynamics and Control* 37(10), 2104-2122.

Fisher, E. and Kelly, F. (2000) Experimental foreign exchange markets, *Pacific Economic Review* 5, 365-387.

Haruvy, E. and Noussair, C. (2006) The effect of short selling on bubbles and crashes in experimental spot asset markets, *Journal of Finance* 61(3), 1119-1157.

Hens, T. and Steude, S.C. (2009) The leverage effect without leverage, *Finance Research Letters* 6, 83-94.

Huber, J., Kirchler, M. and Stöckl, T. (2012) Underreaction and anchoring in experimental asset markets with distinct fundamental value regimes, working paper, University of Innsbruck.

Hussam, R., Porter, D. and Smith, V. (2008) Thar she blows: can bubbles be rekindled with experienced subjects?, *American Economic Review* 98, 924-937.

King, R., Smith, V., Williams, A. and Van Boening, M. (1993) The robustness of bubbles and crashes in experimental stock markets, in: I. Prigogine, R. Day, and P. Chen (eds). *Nonlinear Dynamics and Evolutionary Economics*, Oxford University Press, Oxford.

Kirchler, M., Huber, J. and Stöckl, T. (2012) Thar she bursts – reducing confusion reduces bubbles, *American Economic Review* 102, 865-83.

Kose, T. (2013) Price convergence and fundamentals in asset markets with bankruptcy risk: an experiment, working paper, University of Pittsburgh.

Lei, V., Noussair, C. and Plott, C. (2001) Nonspeculative bubbles in experimental asset markets: lack of common knowledge of rationality vs. actual irrationality, *Econometrica* 69, 831-859.

Lei, V. and Vesely, F. (2009) Market efficiency, evidence from a no-bubble asset market experiment, *Pacific Economic Review* 14, 246-258.

Lugovskyy, V., Puzzelo, D. and Tucker, S. (2011) An experimental study of bubble formation in asset markets using the Tâtonnement trading institution, working paper, Indiana University.

Lugovskyy, V., Puzzelo, D., Tucker, S. and Williams, A. (2012) Can concentration control policies eliminate bubbles?, working paper, Indiana University.

Noussair, C. and Powell, O. (2010) Peaks and valleys: price discovery in experimental asset markets with non-monotonic fundamentals, *Journal of Economic Studies* 37(2), 152-180.

Noussair, C., Robin, S. and Ruffieux, B. (2001) Price bubbles in laboratory asset markets with constant fundamental values, *Experimental Economics* 4, 87-105.

Noussair, C. and Tucker, S. (2006) Futures markets and bubble formation in experimental

asset markets, *Pacific Economic Review* 11, 167-184.

Oechssler, J. (2010) Searching beyond the lamppost: let's focus on economically relevant questions, *Journal of Economic Behavior and Organization* 73, 65-67.

Palan, S. (2013) A review of bubbles and crashes in experimental asset markets, *Journal of Economic Surveys* 27, 570-588.

Porter, D. and Smith, V. (1995) Futures contracting and dividend uncertainty in experimental asset markets, *Journal of Business* 68, 509-541.

Scherbina, A. (2013) Asset price bubbles: a selective survey, working paper, IMF Working Paper WP/13/45.

Smith, V. (2010) Theory and experiment: what are the questions?, *Journal of Economic Behavior and Organization* 73, 3-15.

Smith, V., Suchanek, G. and Williams, A. (1988) Bubbles, crashes and endogenous expectations in experimental spot asset markets, *Econometrica* 56, 1119-1151.

Smith, V., van Boening, M. and Wellford, C. (2000) Dividend timing and behavior in laboratory asset markets, *Economic Theory* 16, 567-583.

Stöckl, T., Huber, J. and Kirchler, M. (2010) Bubble measures in experimental asset markets, *Experimental Economics* 13, 284-298.

Van Boening, M., Williams, A. and LaMaster, M. (1993) Price bubbles and crashes in experimental call markets, *Economics Letters* 41, 179-185.

Xie, H. and Zhang, J. (2012) Bubbles and experience: an experiment with a steady inflow of new traders, CIRANO Scientific Series, CIRANO, Montreal.

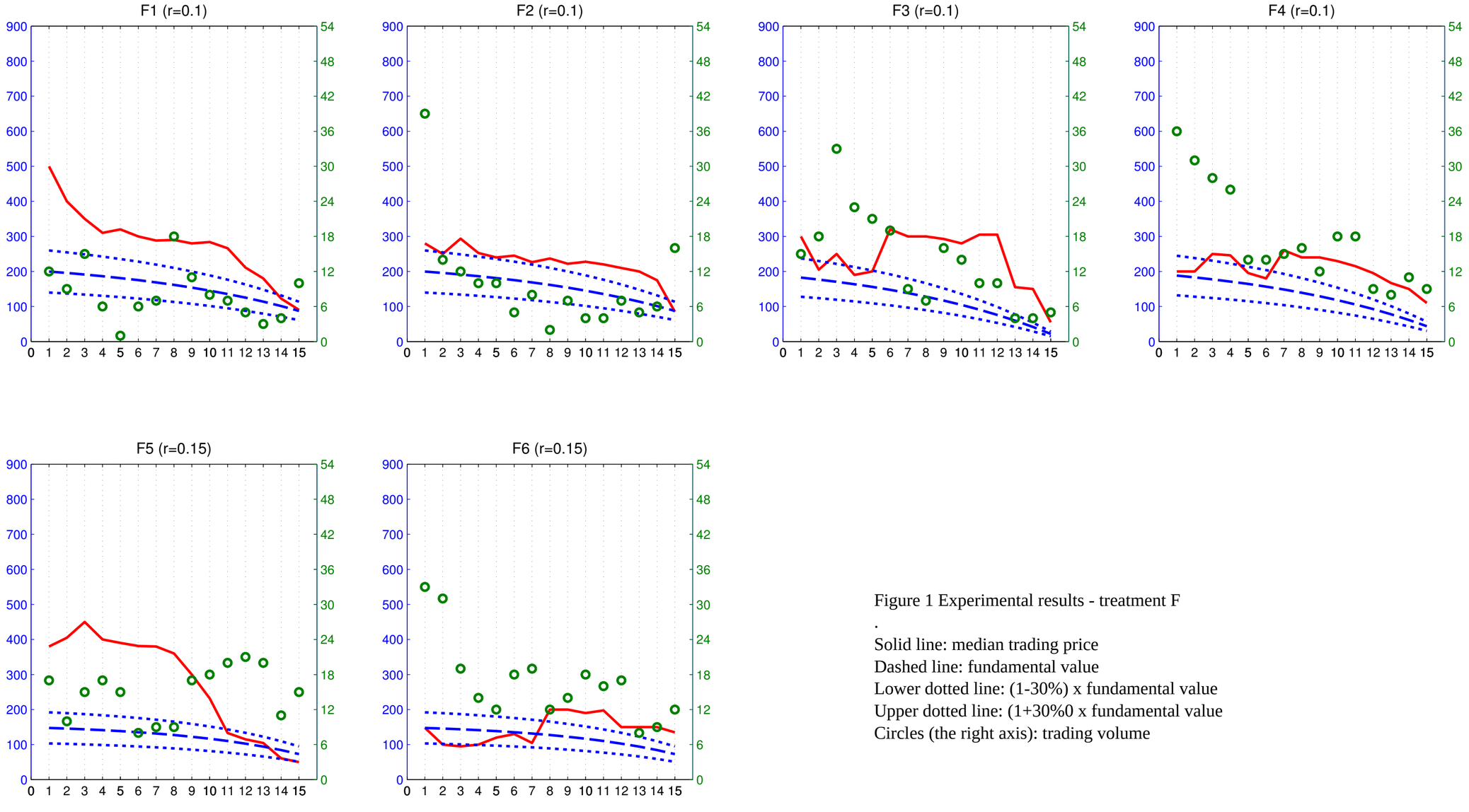


Figure 1 Experimental results - treatment F

.

Solid line: median trading price
Dashed line: fundamental value
Lower dotted line: (1-30%) x fundamental value
Upper dotted line: (1+30%0 x fundamental value
Circles (the right axis): trading volume

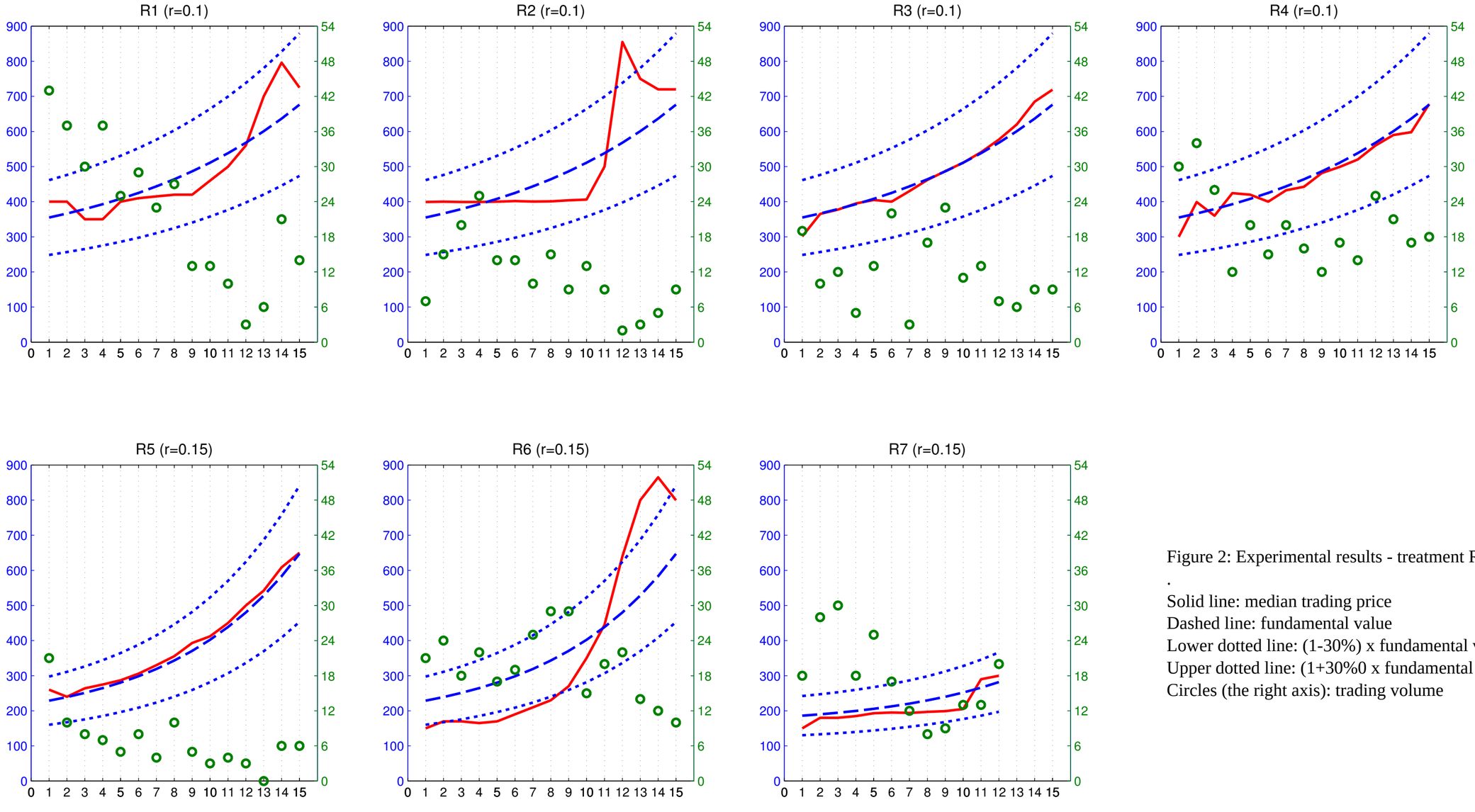


Figure 2: Experimental results - treatment R

.

Solid line: median trading price
Dashed line: fundamental value
Lower dotted line: (1-30%) x fundamental value
Upper dotted line: (1+30%0 x fundamental value
Circles (the right axis): trading volume

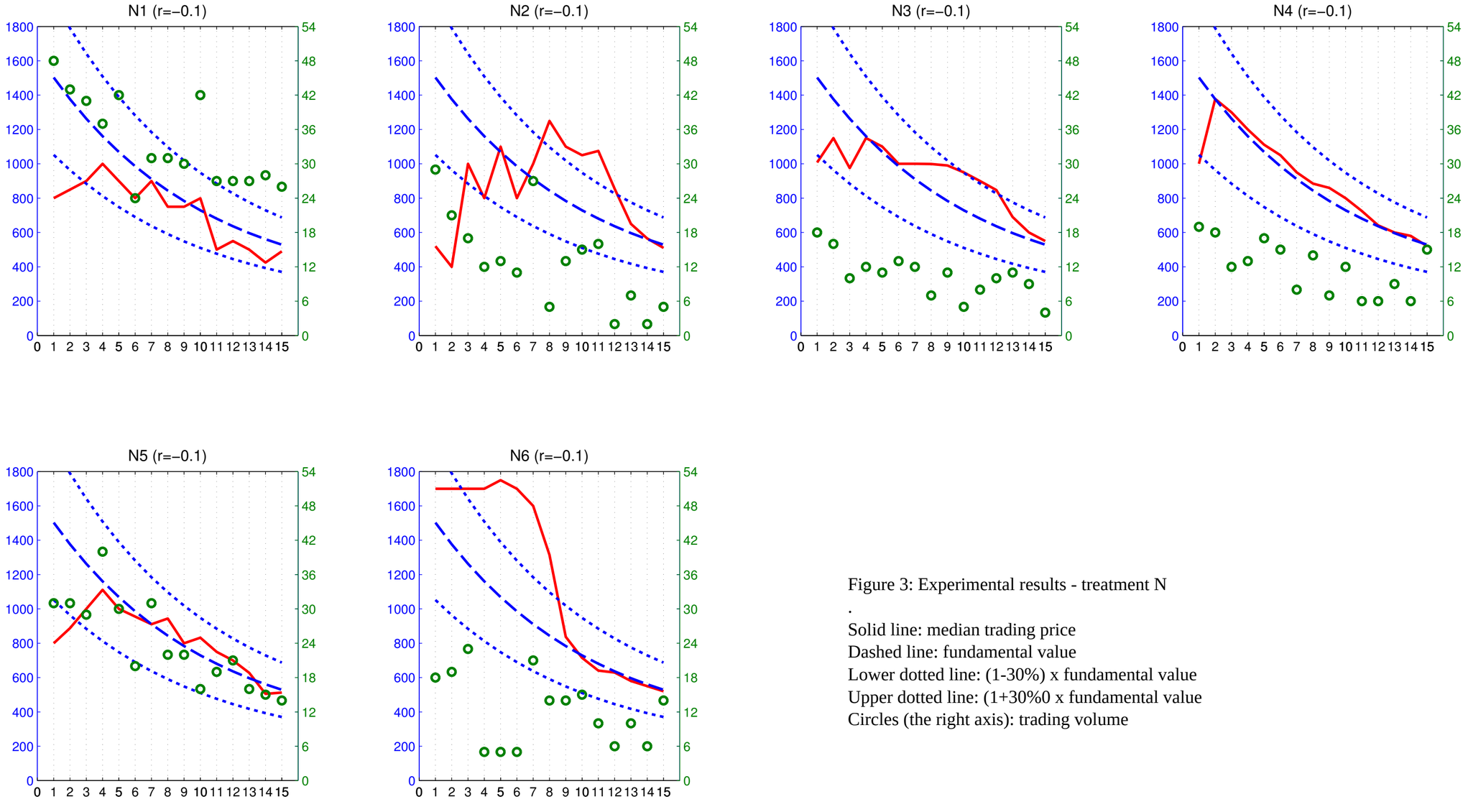


Figure 3: Experimental results - treatment N

.

Solid line: median trading price
Dashed line: fundamental value
Lower dotted line: (1-30%) x fundamental value
Upper dotted line: (1+30%0 x fundamental value
Circles (the right axis): trading volume

Table 1
Parameters used in the experiment

Treatment	Session	Date	Location	Subjects	Trading periods	Dividend	Initial shares	Initial cash	Interest rate *(r)*	Buyout *(K)*	FV_1	FV_{15}	FV_{15}/FV_1	CA_1
F	F1	12/16/11	UIBE	10	15	(0,8,28,60)	4	2000	0.1	72	200	87	0.44	2.50
	F2	12/23/11	UIBE	10	15	(0,8,28,60)	4	2000	0.1	72	200	87	0.44	2.50
	F3	02/10/12	UPF	9	15	(0,8,28,60)	4	1022	0.1	0	183	22	0.12	1.40
	F4	02/16/12	UPF	10	15	(0,8,28,60)	4	1054	0.1	24	188	44	0.23	1.40
	F5	03/12/12	UPF	10	15	(0,8,28,60)	4	827	0.15	60	148	73	0.49	1.40
	F6	03/20/12	UPF	10	15	(0,8,28,60)	4	591	0.15	60	148	73	0.49	1.00
R	R1	10/28/11	UPF	10	15	(0,8,28,60)	4	2000	0.1	720	355	676	1.91	1.41
	R2	11/07/11	UPF	10	15	(0,8,28,60)	4	2000	0.1	720	355	676	1.91	1.41
	R3	11/07/11	UPF	10	15	(0,8,28,60)	4	2000	0.1	720	355	676	1.91	1.41
	R4	03/30/12	UPF	10	15	(0,8,28,60)	4	4259	0.1	720	355	676	1.91	3.00
	R5	11/04/11	UIBE	10	15	(0,8,28,60)	4	2000	0.15	720	229	647	2.83	2.19
	R6	01/27/12	UPF	10	15	(0,8,28,60)	4	2000	0.15	720	229	647	2.83	2.19
	R7	01/23/12	UPF	10	12	(0,8,28,60)	4	745	0.15	300	186	282	1.52	1.00
N	N1	07/17/12	UPF	9	15	(0,-8,-28,-60)	4	50000	- 0.1	500	1503	529	0.35	8.32
	N2	09/10/12	UPF	10	15	(0,-8,-28,-60)	4	50000	- 0.1	500	1503	529	0.35	8.32
	N3	09/12/12	UPF	9	15	(0,-8,-28,-60)	4	50000	- 0.1	500	1503	529	0.35	8.32
	N4	09/19/12	UPF	10	15	(0,-8,-28,-60)	4	40000	- 0.1	500	1503	529	0.35	6.65
	N5	10/15/12	UPF	9	15	(0,-8,-28,-60)	4	40000	- 0.1	500	1503	529	0.35	6.65
	N6	10/23/12	UPF	10	15	(0,-8,-28,-60)	4	40000	- 0.1	500	1503	529	0.35	6.65

Note:
CA_1 stands for initial cash/asset ratio

Table 2
Statistics based on the median trading price

Session	RAD	RD	PA	ST
F1	0.805	0.805	1.918	3.050
F2	0.451	0.449	0.675	3.725
F3	1.033	1.033	1.711	5.778
F4	0.573	0.573	0.766	6.625
F5	1.333	1.282	2.724	5.550
F6	0.401	0.196	1.124	6.300
Treatment F Average	**0.766**	**0.723**	**1.486**	**5.171**
R1	0.099	0.008	0.467	8.275
R2	0.142	0.042	0.811	4.250
R3	0.031	0.003	0.211	4.475
R4	0.042	-0.020	0.181	7.425
R5	0.035	0.035	0.080	2.500
R6	0.316	-0.009	1.043	7.425
R7	0.110	-0.079	0.319	5.275
Treatment R Average	**0.111**	**-0.003**	**0.445**	**5.661**
N1	0.209	-0.199	0.850	14.000
N2	0.339	-0.070	1.529	4.875
N3	0.170	0.021	0.788	4.361
N4	0.073	-0.002	0.638	4.425
N5	0.151	-0.095	0.887	9.917
N6	0.308	0.294	0.830	4.625
Treatment N Average	**0.209**	**-0.009**	**0.920**	**7.034**

Table 3
Mann-Whitney tests of RAD, RD, PA and ST

		RAD	RD	PA	ST
F		0.766	0.723	1.486	5.171
R		0.111	-0.003	0.445	5.661
	Z-value	3.000	3.000	2.429	-0.429
	p -value	0%	0%	1%	67%
	Sample size	13	13	13	13
F		0.776	0.723	1.486	5.171
N		0.209	-0.009	0.920	7.034
	Z-value	2.882	2.722	1.121	-0.320
	p -value	0%	0%	26%	75%
	Sample size	12	12	12	12
R		0.111	-0.003	0.445	5.661
N		0.209	-0.009	0.920	7.034
	Z-value	-1.857	0.714	-2.000	-0.429
	p -value	6%	48%	5%	67%
	Sample size	13	13	13	13

Table 4

Incidences of bubbles

Treatment	Number of Sessions	Number of Sessions with Bubbles		
		30% rule	40% rule	50% rule
F	6	6	6	5
R	7	0	0	0
N	6	2	1	0

Table 5

Percentage of fundamental trading and posting -- individual subjects

Session	Player	% Fundamental transactions	% Fundamental offers	Session	Player	% Fundamental transactions	% Fundamental offers	Session	Player	% Fundamental transactions	% Fundamental offers
	1	50	52		1	78	95		1	70	83
	2	100	100		2	93	100		2	81	82
	3	56	92		3	92	100		3	86	92
	4	64	75		4	96	99		4	72	100
F1	5	50	74	R1	5	88	100	N1	5	85	88
	6	58	88		6	92	100		6	93	96
	7	31	84		7	100	100		7	71	80
	8	50	63		8	99	100		8	86	94
	9	78	71		9	72	100		9	97	98
	10	64	66		10	77	99				
	1	53	79		1	100	100		1	59	95
	2	68	66		2	100	100		2	50	100
	3	95	100		3	100	100		3	87	99
	4	56	87		4	100	98		4	79	100
F2	5	42	97	R2	5	100	100	N2	5	57	94
	6	100	100		6	100	100		6	63	93
	7	57	88		7	100	99		7	100	100
	8	64	85		8	100	100		8	36	78
	9	83	92		9	89	93		9	95	98
	10	93	100		10	100	100		10	81	100
	1	69	73		1	100	100		1	92	98
	2	75	66		2	100	100		2	91	100
	3	62	83		3	100	100		3	83	98
	4	59	56		4	100	100		4	91	95
F3	5	58	82	R3	5	64	94	N3	5	90	99
	6	55	92		6	100	100		6	92	99
	7	57	77		7	100	100		7	74	96
	8	100	88		8	100	100		8	91	97
	9	71	97		9	100	100		9	88	96
					10	99	100				
	1	28	96		1	93	100		1	94	93
	2	40	89		2	99	100		2	91	100
	3	53	77		3	100	100		3	98	100
	4	52	71		4	95	100		4	78	94
F4	5	53	67	R4	5	100	100	N4	5	100	100
	6	55	82		6	100	100		6	100	100
	7	27	100		7	100	100		7	100	100
	8	79	77		8	83	98		8	100	100
	9	50	86		9	86	n/a		9	98	98
	10	76	92		10	100	100		10	94	98

continued …

Table 5 (continued)

Percentage of fundamental trading and posting -- individual subjects

Session	Player	% Fundamental transactions	% Fundamental offers	Session	Player	% Fundamental transactions	% Fundamental offers	Session	Player	% Fundamental transactions	% Fundamental offers
	1	82	90		1	100	100		1	65	64
	2	58	52		2	100	100		2	91	98
	3	67	76		3	100	100		3	86	95
	4	56	85		4	94	100		4	95	100
F5	5	64	61	R5	5	78	100	N5	5	81	94
	6	70	47		6	96	100		6	88	89
	7	60	92		7	100	100		7	87	92
	8	71	84		8	100	100		8	100	100
	9	69	100		9	100	100		9	100	100
	10	63	72		10	89	97				
	1	48	100		1	70	94		1	78	50
	2	59	98		2	65	99		2	88	83
	3	74	86		3	77	n/a		3	75	71
	4	47	90		4	73	87		4	96	91
F6	5	79	94	R6	5	90	100	N6	5	92	95
	6	64	94		6	74	91		6	64	100
	7	54	90		7	71	79		7	89	100
	8	73	100		8	64	100		8	84	94
	9	63	75		9	69	97		9	78	80
	10	87	100		10	83	86		10	90	73
					1	99	99				
					2	75	95				
					3	96	97				
					4	100	100				
				R7	5	88	100				
					6	97	100				
					7	100	100				
					8	97	99				
					9	100	100				
					10	100	100				

Table 6

Percentage of fundamental transactions and offers -- session and treatment

Session	Transactions	Offers
F1	57	74
F2	66	90
F3	62	82
F4	52	84
F5	66	80
F6	64	94
Treatment F average	**61**	**84**
R1	92	100
R1	92	100
R2	100	100
R3	100	100
R4	100	100
R5	100	100
R6	72	94
R7	98	100
Treatment R average	**94**	**99**
N1	85	92
N2	71	98
N3	91	98
N4	98	100
N5	88	95
N6	86	87
Treatment N average	**87**	**95**

Table 7
Mann-Whitney test of fundamental transactions and offers

		Median (% fundamental transactions)	Median (% fundamental offers)
F		61	84
R		94	99
	Z-value	-3.046	-3.085
	p -value	0%	0%
	Sample size	13	13
F		61	84
N		87	95
	Z-value	-2.887	-2.406
	p -value	0%	2%
	Sample size	12	12
R		94	99
N		87	95
	Z-value	2.103	2.178
	p -value	4%	3%
	Sample size	13	13

Appendix: Experimental Instructions (Treatment R)

Part A: General Instructions

You are taking part in an experiment on investment behavior. If you follow the instructions carefully and make the right decisions, you can earn some money, which will be paid to you at the end of the experiment.

The experiment consists of a sequence of trading periods, each one lasting for 150 seconds. During each period, you will make decisions to invest your money between two forms of investment: shares of stocks of a fictitious company, and a savings account. The currency used in the market is called EURUX, which will be converted into euros at the end of the experiment. The conversion rate is 1000 EURUX for 1 euro.

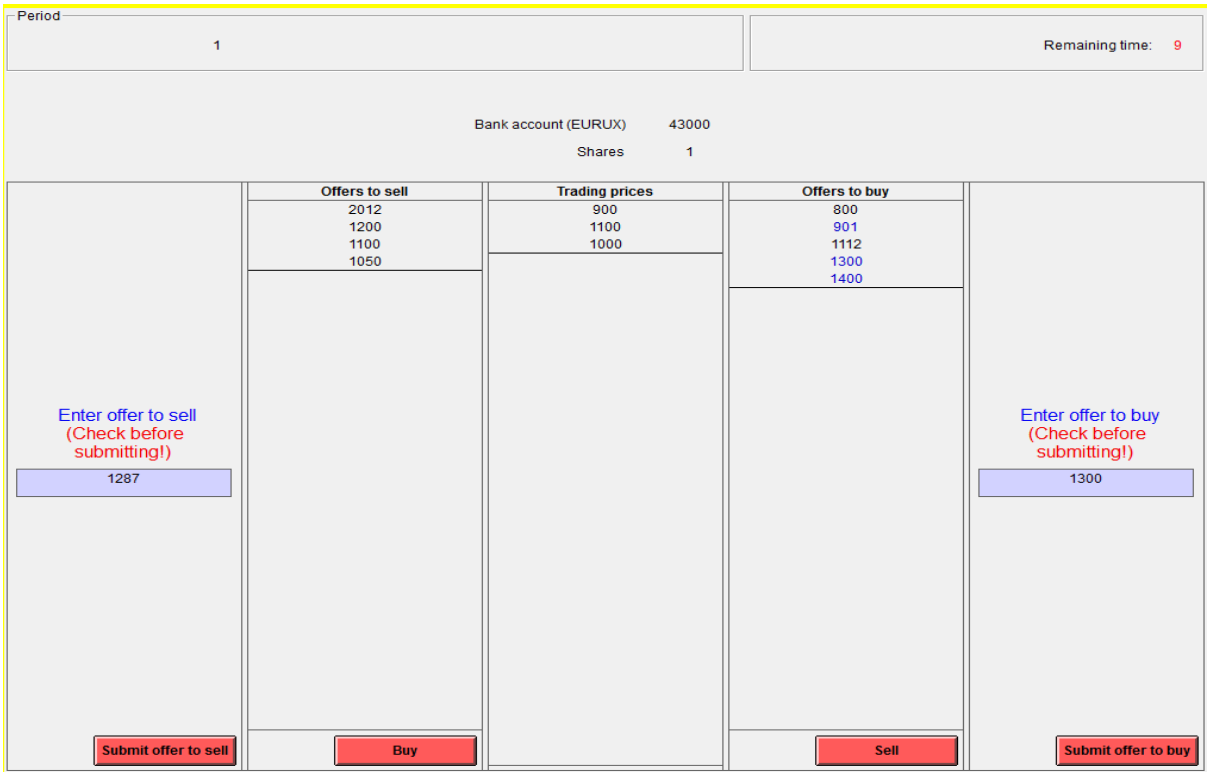
The experiment will proceed in the following sequence. First, we will show you the trading interface you will use (you will practice with it as we explain), and then we will discuss the features of the two forms of investments. After that, you will have the opportunity to practice trading for one period. We will then give you further instructions and information to help you make trading decisions. If anything is unclear during the instructions or practice, you can raise your hand and ask the administrator whatever question you may have.

Before the experiment formally starts, you will be required to complete a quiz to demonstrate that you have a complete and accurate understanding of these instructions. After you have completed the quiz, the administrator will check your answers and discuss with you any question that has been answered incorrectly.

TRADING INTERFACE

In each trading period, you start with some money invested in two forms of investment: savings account and shares. Money in the savings account earns interest and shares earn dividends (interest and dividend will be described later).

During each trading period, you make investment decisions to allocate money between the two forms of investment: you can use money in the savings account to buy shares, or sell shares and deposit the revenue in your savings account. Here is a sample trading screen.



The top left corner shows the current trading period, and the top right corner shows how much time (in seconds) is left in the current period. Your investment portfolio – money in your savings account and the number of shares you own – are shown in the middle of the screen. On this screen you can buy or sell shares in **four** ways.

First, you can **initiate a sale** of shares by **submitting** an **offer to sell.**

If you have shares, you may choose to sell them. You can initiate a sale in the text area below "Enter offer to sell" in the first column. Here you can enter the price at which you are offering to sell a share. To send the offer, you have to click the "Submit offer to sell" button. After that, your offer to sell will appear in the second column labelled "Offers to sell". Each offer introduced corresponds to **one single** share. If you want to sell more shares, repeat this process.

Note that by submitting an offer to sell, you initiate a sale, but the sale will not be executed until someone accepts it.

Try offering to sell a share now. Write a number (integer) in the text area labelled "Enter offer to sell" and then click on the button "Submit offer to sell". You can see that a set of numbers will appear in the column labelled "Offers to sell". Each number corresponds to an offer from one of the participants. Your own offers are shown in blue; others' offers are shown in black. The offers to sell are ranked from high to low, so that the **cheapest (best)** price is displayed at the **bottom** of the list.

Second, you can **realize a purchase** of shares by **accepting** an **offer to sell.**

If you have enough money in your savings account, you can buy a share at one of the prices in the "Offers to sell" column (which also contains your previously submitted offer to sell). You buy a share by selecting one of the **others'** offers (shown in black) and then clicking on the red button "Buy". Note that you are not allowed to accept your own offers, which are shown in blue. Remember that the **cheapest (best)** price is displayed at the **bottom** of the list.

It may happen that when you select the best price and press the "Buy" button, someone else is doing the same thing but acting slightly faster than you. In that case, a message "someone has been faster than you" will show up.

Try buying a share now. Choose a price in the column "Offer to sell" and then click on the "Buy" button; or directly click on the "Buy" button and buy at the cheapest price listed in the column "Offers to sell".

Whenever an offer is accepted, a transaction is executed. Immediately when you **accept** an offer to sell, you realize a purchase and the number of EURUX in your savings account goes down by the trading price; at the same time, your trading partner realizes a sale and the balance in his/her savings account increases by the trading price. In contrast, when your offer to sell **is accepted**, you realize a sale, your trading partner realizes a purchase, and money is transferred from your trading partner's savings account to your savings account by the amount of the trading price.

Given that you all submitted one offer to sell and accepted one offer to sell, you all realized one purchase and one sale so you have the same number of shares as you started out with.

Third, you can **initiate a purchase** of a share by **submitting** an **offer to buy**.

If you have money in your savings account and would like to buy a share, you can initiate the purchase by submitting an offer to buy. Enter a number in the text box under "Enter offer to buy" situated on the right side of the screen and then click on the "Submit offer to buy" button.

Try submitting an offer to buy a share now. Write a number in the text area "Enter offer to buy." Then press the red button labelled "Submit offer to buy". Immediately in the column labelled "Offers to buy" you will see a list of numbers ranked from low to high, so that the **highest (best)** price is displayed at the **bottom** of the list. If you want to sell more shares, repeat this process. Again, your own offers are shown in blue; others' offers are shown in black.

Fourth, you can **realize a sale** of a share by **accepting** an **offer to buy.**

You can sell a share at one of the prices offered in the "Offers to buy" column (which also contains your previously submitted offer to buy). Select one of the offers and then click on the red button "Sell". Again, note you are not allowed to accept your own offers (shown in blue). Remember that the **highest (best)** price is displayed at the **bottom** of the list.

Try selling a share now. Choose a price in the column "Offer to buy" and then click on the "Sell" button.

Again, a transaction is executed whenever an offer to buy is accepted. If you accept an offer to buy posted by others, you realize a sale and as a result, the amount of EURUX in your savings account increases by the trading price. In contrast, when your offer to buy is accepted by someone else, you realize a purchase and the number of EURUX in your savings account decreases by the trading price. The reverse happens to your trading partner.

You can see that these four trading methods are complementary: you can **initiate** a trade by **offering** a price to sell or buy and wait for the offer to be accepted by others; you can **execute/realize** a trade by **accepting** an offer to buy or sell submitted by other participants.

In the column situated in the middle of the screen and labelled "Trading price", you can see the prices at which shares have been traded during the trading period by all participants present in the market.

The above is the trading interface you will use during the experiment. In the following, we will give more instructions about the two forms of investment. After that, you will have time to practice a full trading period. ***Do not press the "continue" button until the instructor tells you so.***

DIVIDEND AND INTEREST

At the end of the trading period, you receive dividends for the shares you hold, and interest on money in your savings account. Both dividends and interest are automatically added to your savings account.

Dividend. The amount of dividend **per share** is determined by a random device (the company's business may go well or bad, which will affect how much dividend you get) and takes one of four values with the same probability:

1/4 probability you get 0 EURUX per share,

1/4 probability you get 8 EURUX per share,

1/4 probability you get 28 EURUX per share, and

1/4 probability you get 60 EURUX per share

Each participant gets the same dividend per share. There is a new random dividend draw for each new trading period.

Since all four outcomes are equally likely, we can calculate the average dividend as (0 + 8 + 28 + 60)/4=24 EURUX.

Interest. The money in your savings account earns interest rate at 10% per period.

Here is an example to illustrate how dividends and interest are paid. Suppose that after trading, you have 2 shares and 1000 EURUX in your savings account. The random device shows that each share receives a dividend of 28 EURUX. At the end of the period, you will receive 28x2=56 EURUX of dividend and 1000x10%=100 EURUX of interest. As a result, the balance in your savings account at the end of the period will be 1000+56+100=1156.

END-OF-PERIOD INFORMATION SCREEN

At the end of the trading period, after dividends and interest are paid and deposited in your savings account, you will be shown an "information screen" which includes the information about dividends and interest payments. The screen also includes the information about your end-of-period inventory of shares and the balance in your savings account.

The "information screen" contains the following information:

1. *Period*: the period just finished
2. *Your shares*: number of shares you own after trading in the period
3. *Savings account balance before dividend and interest*: amount of *EURUX* you have in your savings account right after trading and before dividends and interest payments
4. *Dividend per share:* the amount of dividend in *EURUX* you receive for each share you own.
5. *Total dividend:* calculated as *Your shares* x *dividend per share*.
6. *Interest:* net amount of interest you receive in the period for money in your savings account, which is calculated as *Savings account balance before dividend and interest* x *10%.*
7. *Savings account balance after dividend and interest:* money in your savings account after dividend and interest have been paid and deposited, which is calculated as *Savings account balance before dividend and interest + Total dividend + Interest*

TRIAL

In the next 3-4 minutes you will practice trading in this market for one period. Your actions in this period will not count toward your earning in this experiment and do not influence your position in the real experiment.

Next, please click on the "Continue" button on your screen and we will start the trial.

Now that you know how to trade shares and how dividends and interest are paid, before the experiment formally starts, let us go through some instructions to help you maximize your earnings in the experiment.

The experiment consists of 15 consecutive trading periods. Each period will last for 150 seconds. You start period 1 with a certain investment portfolio of shares and money in your savings account. In each of the 15 trading periods, you trade among yourselves using the interface you just practiced with. At the end of each trading period, you see the "information screen" which shows your end-of-period portfolio position after dividend and interest payments.

Your inventory of shares and savings account balance carry over from one period to the next. For example, if at the end of period 4 you have 2 shares and 1000 EURUX, you start period 5 with the same portfolio of 2 shares and 1000 EURUX before trading.

The game ends after 15 periods. If you own some shares at the end of period 15, the company will purchase your shares at a **buyout value** of 720 EURUX per share.

For example, suppose after trading in period 15 that you own 3 shares and 2000 EURUX. At the end of period 15, after dividends and interest payments, you can sell your shares to the company at the buyout value. If the dividend payment is 8 EURUX per share, you receive 3x8=24 EURUX as dividends. The interest payment is 2000x10%=200 EURUX. Your 3 shares are sold to the company for 3x720=2160 EURUX. Your total earnings in this game are calculated to be 2160+24+200+2000=4384 EURUX, which will be converted into euros.

B

Part B: HOLDING VALUE TABLE

The objective of your investment decisions is to maximize your end-of-game total earnings. In each trading period, you decide how to allocate your money between the two forms of investment: shares and savings account.

To facilitate your decision-making, we provide you a table called "Holding Value Table" (see next page), which can be used throughout the entire experiment. The table calculates the average value of a share **if** you buy it in the current period and **hold it until the end of the game**. Of course, you may choose **not** to hold the share until the end of the game, if, for example, you can sell it at a good price before the end of the game. The holding value table is just for reference.

The table has 6 columns, which we will go through one-by-one.

1. *Current period*: The current trading period.
2. *Average dividend*: The average amount of dividend per share per period. This, as explained earlier, is equal to 24 EURUX.
3. *Average remaining dividends*: If you hold 1 share of stock until the end of the game, you will be entitled to a dividend payment at the end of each of the remaining periods. The remaining dividend is calculated as the total amount of money you will accumulate **at the end of the game** if you deposit all dividend payments into your savings account, which earns 10% interest per period. For example, for each share you hold in period 14, there are two remaining dividend payments: one at the end of period 14, and one at the end of period 15. You deposit the period 14 dividends in your savings account, which will increase your money balance at the end of the game by 24x1.1=26.4 EURUX. The period 15 dividend is paid at the end of the game (so will not earn interest) and will increase your end-of-game money balance by 24 EURUX. The average remaining dividends are calculated as the sum of the two amounts = 26.4+24=50.4 EURUX.
4. *Buyout value.* **At the end of game**, each share you own will be purchased by the company at 720 EURUX.
5. *End average holding value*. The average amount of EURUX you will receive **at the end of the game** if you hold one share for the remainder of the experiment. It is calculated as the sum of the *average remaining dividend* (column 3) and the *buyout value* (column 4). For example, the average holding value I for a share in period 14 is calculated as 50.4+720=770.4 EURUX.
6. *Current average holding value*. To buy a share in the **current** period, you have to use money **currently** in your savings account. When you make the buying decision, you may want to know the average holding value of a share measured in terms of **money in the current savings account.** Call this the *current average holding value*. Let us illustrate how to calculate the value by an example. Suppose you are trading in period 14. One EURUX in the current savings account will generate 1.1^2 (there are two remaining interest payments) units of EURUX at the end of the game. Holding one share generates (on average) 770.40 EURUX at the end of the game. Holding one share is thus (on average) equivalent to holding 770.40/1.21=637 EURUX in the **current** savings account.

Holding Value Table

1 Current period	2 Average dividend	3 Average remaining dividends	4 Buyout value	5 End average holding value	6 Current average holding value
1	24	762.54		1482.54	355
2	24	671.40		1391.40	366
3	24	588.55		1308.55	379
4	24	513.22		1233.22	393
5	24	444.75		1164.75	408
6	24	382.50		1102.50	425
7	24	325.91		1045.91	444
8	24	274.46		994.46	464
9	24	227.69		947.69	486
10	24	185.17		905.17	511
11	24	146.52		866.52	538
12	24	111.38		831.38	568
13	24	79.44		799.44	601
14	24	**50.40**		**770.40**	**637**
15	24	24.00	720	744.00	676

C

Part C: Quiz

Please read carefully the Holding Value Table and make sure that you understand it. Raise your hand if you have any questions. When you think you understand the table, please answer the following questions:

1. Suppose you are in period 5. How much is the *average dividend* you should expect at the end of this period? _____
2. Which is the maximum and minimum dividend you can get in any period? _____
3. Suppose you are in period 5 and a share pays the average dividend in each of the remaining periods. The *current holding value of* one share in terms of money in the current savings account is _____.
4. Please explain in one sentence or two what the *current holding value* is.