

No. 2008–49

**PEAKS AND VALLEYS: EXPERIMENTAL ASSET MARKETS  
WITH NON-MONOTONIC FUNDAMENTALS**

By Charles N. Noussair, Owen Powell

April 2008

ISSN 0924-7815

# Peaks and Valleys: Experimental asset markets with non-monotonic fundamentals

Charles N. Noussair and Owen Powell\*

April 2008

We report the results of an experiment designed to measure how well asset market prices track fundamentals when the latter experience peaks and troughs. We observe greater price efficiency in markets in which fundamentals rise to a peak and then decline, than in markets in which fundamentals decline to a trough and undergo a subsequent increase. The findings demonstrate that the characteristics of the time path of the fundamental value can influence the degree of market efficiency.

Keywords: Bubble, Peak, Experiment

JEL Codes: C9, G10

## I. INTRODUCTION

When market prices of assets reflect their underlying fundamentals, markets provide accurate information to investors about the value of the assets. This price information aligns investors' incentives to allocate their capital profitably with those decisions that increase overall efficiency in the allocation of capital. Thus, the extent to which prices deviate from fundamentals can affect the efficiency of an economy's allocation of resources. It has long been argued that such deviations are commonplace and substantial, and that asset prices readily become decoupled from fundamental values (see Shiller, 2003, for a review) and form market bubbles (Shiller, 1981; Froot and Obstfeld, 1991). Interest in such episodes of mispricing is heightened by spectacular historical incidents of price booms<sup>1</sup>, followed by subsequent rapid declines or crashes, which

---

\* Department of Economics, Tilburg University, P.O.Box 90153, 5000 LE Tilburg, The Netherlands. Email addresses, Noussair: [C.N.Noussair@uvt.nl](mailto:C.N.Noussair@uvt.nl), Powell: [O.R.Powell@uvt.nl](mailto:O.R.Powell@uvt.nl). We thank John Duffy, Wieland Muller, and Marta Serra Garcia, as well as seminar participants at the University of Pittsburgh, GATE-Lyon, Tilburg University, the University of Innsbruck, and the 2008 ENTER Jamboree in Madrid, Spain, for helpful comments.

<sup>1</sup> Some well-known and well-documented historical examples of bubbles and crashes include the Dutch tulip mania of the 1600s, in which the prices of tulip bulbs increased by 5000% in three years (1634-1637),

have had dramatic effects on the payoffs of market participants. On the other hand, the suggestion that price bubbles and crashes are pervasive is unappealing to many economists because such mispricing is at odds with classical economic and financial theory<sup>2</sup>. Thus, there is an ongoing debate about whether asset prices have a tendency to deviate from fundamentals as a matter of course, or whether deviations from fundamentals are a rare, unbiased, or rather inconsequential phenomenon (Fama, 1998; Malkiel, 2003). The conjecture that we investigate in this paper is that the tendency for an asset to track its fundamental value depends on properties of the time-profile of the fundamental, and we consider the validity of this conjecture for a particular class of experimental market.

A feature of many economic time series is that they are cyclical or seasonal, and thus experience periods of rising value followed by periods of decline, often followed again by episodes of increasing value. Despite the fact that such a structure is common, and that peaks and troughs are often optimal times to trade, markets with these properties have not to date been investigated with experimental methods. This paper reports the results of an experiment designed to directly compare, in a controlled manner, the efficiency of (i) markets for assets that experience a period of increasing, and then a period of falling, fundamentals, versus (ii) markets in which fundamentals first decline and then rise. We call the first type of market a *Peak* market, and the second type a *Valley* market. The *Peak* and *Valley* markets that we create are symmetric in the sense that the assets are traded over an equal time horizon, experience a peak or trough in fundamental values of equal magnitude compared to initial and final values, and experience their extreme fundamental value at the same time. Thus, the experiment is designed so that there is an opportunity for asymmetries in the reaction of prices to peaks and troughs in fundamentals to appear and to be identified. The existence of a pricing asymmetry would be consistent with an intuition that has been expressed by some policymakers with regard to the behavior of

---

and then rapidly lost over 90% of their value (Garber, 1990). Other examples include shares in the South Sea Company in the 1700s, which gained 843% between 1719 and 1721, only to lose the entire gain and more, declining by 88%, in 1721 (Temin and Voth, 2004). After sustained price booms, the Dow Jones Industrial Average decreased by 91% between October 1929 and June 1932, the Nikkei index declined by 39% in 1990 (French and Poterba, 1991), and the NASDAQ index lost 78% of its value between March, 2000 and October, 2002 (Pastor and Veronesi, 2006).

<sup>2</sup> Temin and Voth (2004) have argued that during the South Sea bubble episode at least one major investor was aware that the market was in a speculative bubble. On the other hand, Pastor and Veronesi (2006) find that the runup and decline in the NASDAQ index was not indicative of a bubble. French and Poterba (1991) argue that the Japanese stock market bubble of the late 1980's cannot be explained by changes in fundamentals. Booms and crashes have been modeled both as originating from the presence of irrational trader types such as feedback traders (see for example DeLong et al., 1990) or overconfident traders (Scheinkman and Wong, 2003) as well as rational phenomena (Tirole, 1982; Abreu and Brunnermeier, 2003).

macroeconomic variables.<sup>3</sup>

The use of experimental methods, as with any choice of research methodology, involves a tradeoff. The use of experimental methods restricts us to studying markets that are small in scale, in terms of time, number of traders, and monetary stakes, as well as different in trader characteristics than typical non-laboratory markets. However, experimental methods do allow the fundamental value of an asset to be unambiguously specified, observed, controlled, and compared to transaction prices. Non-experimental empirical tests of market efficiency typically involve postulating a hypothesis about the fundamental value of an asset and measuring how well prices track fundamentals under the assumption that the hypothesis governing fundamentals is correct. Thus, tests of market efficiency in the field are in fact joint tests of price efficiency and the assumptions made on the process guiding fundamentals (Fama, 1970).<sup>4</sup>

In our study, market efficiency is measured with three different indicators: (a) the magnitude of the differences between price levels in the asset markets and the underlying fundamental values, (b) the consistency with which price trends reflect trends in underlying fundamentals, and (c) the difference between the timing of peaks and troughs of prices and those of fundamentals. Our design, in which the same individuals participate in four sequential markets, also allows us to study how differences between treatments, with regard to the market efficiency measures above, evolve with repeated interaction in a sequence of markets.

We find that markets that experience a peak are more efficient than markets that experience a trough. Peak markets have a stronger and more rapid tendency to converge toward fundamental pricing as traders gain more experience. Thus, in the markets we study, the likelihood that an asset market tracks fundamental value depends on the process that fundamentals follow. In other words, one environment is more conducive to pricing at fundamentals than the other, simply because of the interaction between the behavior that appears

---

<sup>3</sup> This intuition has been voiced, for example, by former US Federal Reserve Chairman Alan Greenspan who in a recent interview indicated “What strikes me about the current period is it’s wholly consistent with my generalized view of how important innate human characteristics are in sustaining the business cycle. I’ve always been concerned that in setting up an econometric model you take history irrespective of whether it’s up or down, and there’s an implicit judgment that the coefficients work symmetrically on the upside and downside. There is a general belief, for example, that capital gains on homes has a buoyant effect on consumption going up and precisely the same on the other side. I’m beginning to question whether that premise is true” (Alan Greenspan, Sept. 17, 2007).

<sup>4</sup> Summers (1986) observes that many tests of the observable implications of market efficiency have low power to reject the null hypothesis of no mispricing. He writes “...certain types of inefficiency in market valuations are not likely to be detected using standard methods. This means the evidence found in many studies, that the hypothesis of efficiency cannot be rejected, should not lead us to conclude that market prices represent rational assessments of fundamental valuations. Rather, we must face the fact that most of our tests have relatively little power against certain types of market inefficiency. In particular, the hypothesis that market valuations include large persistent errors is as consistent with the available empirical evidence as is the hypothesis of market efficiency.”

in asset markets and the particular process guiding the time path of fundamentals. The degree of market efficiency depends not only on previously identified factors such as the market institutions in place, the regulatory framework, and the number, experience level, and sophistication of traders, which are controlled for in our markets, but also on the time path of the fundamental values.

Our work builds on a substantial body of experimental work, beginning with Smith et al. (1988), which has investigated the behavior of experimental markets for long-lived assets. The assets studied in this literature are almost exclusively finitely-lived, pay dividends at regular intervals, and are created in settings where no alternative interest-bearing investments exist. This means that the assets have fundamental values that decrease monotonically over time.<sup>5</sup> For this special case of declining fundamentals, the literature has yielded consistent results about the behavior of prices for assets with this particular structure. A consistent pattern of price booms, episodes of pricing at greater than fundamentals, and crashes, rapid decreases in prices, reminiscent of those believed to occur in field markets, is generally observed. As individuals accumulate experience in an identical environment, prices move closer to fundamental values (Smith et al., 1988; Dufwenberg et al., 2005; Haruvy et al., 2007), but bubbles may re-emerge if the dividend parameters are changed (Hussam et al., 2007) in a manner that preserves the declining fundamental value property. The current study is the first experimental study, to our knowledge, in which the behavioral properties of markets experiencing a peak or trough in fundamentals are investigated.

The paper is organized as follows. Section 2 presents our hypotheses, while section 3 describes the experimental design and procedures. Section 4 reports the results and section 5 briefly summarizes the main points of the study and provides some concluding remarks.

## II. HYPOTHESES

The hypotheses in this paper concern the differences between two different experimental treatments, *Peak* and *Valley*, with regard to various criteria of market efficiency. As described in more detail in section three, each treatment is in effect for five experimental sessions, and in each session the market is repeated four times. Denote the lifetime of the asset in each market repetition as  $T$  periods and let  $f_t^V$  and  $f_t^P$  denote the fundamental value of the asset in period  $t$  ( $t$

---

<sup>5</sup> Experimental studies of long-lived asset markets have focused almost exclusively on the case of monotonically decreasing fundamental values, with a few exceptions (Camerer and Weigelt, 1993; Noussair et al., 2001; Ball and Holt, 2005) that study assets with constant fundamental values.

$= 1, \dots, T$ ) in the Valley and Peak treatments, respectively. Let  $p_{mt}^{Vi}$  denote the observed median transaction price in period  $t$  of market  $m$  ( $m = 1, \dots, 4$ ) in session  $i$  ( $i = 1, \dots, 5$ ) of the *Valley* treatment, and define  $p_{mt}^{Pi}$  analogously for the *Peak* treatment. Since the same traders participate in consecutive markets, the index  $m$  can be interpreted as a measure of the experience of traders. Furthermore, let  $p_m^{ji} = (p_{m1}^{ji}, \dots, p_{mT}^{ji})$  be the  $1 \times T$  vector indicating the  $T$ -period price trajectory in market  $m$  of session  $i$  of treatment  $j$ , and define  $f^j$  as the  $1 \times T$  vector of fundamental values in each market of treatment  $j$ , so that  $f^j = (f_1^j, \dots, f_T^j)$ .

Our market efficiency criteria measure the degree of consistency between the two series  $p_m^{ji}$  and  $f^j$  in terms of three measures: (1) levels, (2) trends, and (3) timing of changes in trend. We first compare the treatments with regard to *price level inefficiency*: the difference between price level and fundamentals over the life of the asset. To measure price level inefficiency, we use two measures of mispricing introduced by Haruvy and Noussair (2006)<sup>6</sup>. These measures are *Total Dispersion* and *Total Bias*. They are defined as follows.

$$\text{Total Dispersion} = D(p_m^{ji}, f^j) = \sum_t |p_{mt}^{ji} - f_t^j|. \quad (1)$$

$$\text{Total Bias} = B(p_m^{ji}, f^j) = \sum_t (p_{mt}^{ji} - f_t^j). \quad (2)$$

Total Dispersion is a measure of overall discrepancy between prices and fundamentals, where larger values indicate larger absolute differences between prices and fundamentals. Total Bias is a measure of systematic over- or under-pricing, where higher values indicate higher prices, and where a value of zero reflects equal prices and fundamentals on average. The most basic question to consider is whether price levels track fundamental value to the same extent across treatments. Hypothesis 1 is that the distribution of price level inefficiency, as measured by Total Dispersion and Total Bias, for a given experience level and taking each session as an observation, does not differ significantly between treatments.

**Hypothesis 1:** Price levels track fundamentals equally closely in the two treatments.

While Hypothesis 1 is concerned with price level inefficiency, Hypothesis 2 addresses a

---

<sup>6</sup> Haruvy and Noussair (2006) used a measure called *Average Bias*, rather than Total Bias, which is used here. Average Bias for a market is calculated as the Total Bias of the market divided by the number of periods in the market. Thus, for the experiments reported here, the Total Bias is simply 15 times the Average Bias. Table A2 in Appendix A contains the results from an analysis of treatment differences using several other measures of price deviation from fundamental value that have appeared in the experimental literature (see King et al., 1993), Van Boening et al., 1993), or Porter and Smith, 1995).

similar question about the relationship between *trends* in prices and fundamentals. In an efficient market, price trends send accurate signals to investors and observers about whether the intrinsic value of an asset is currently increasing or decreasing. We consider here whether prices are equally likely to move in the same direction as fundamentals in the two treatments. Let  $\Delta p_{mt}^{ji} = p_{mt}^{ji} - p_{m,t-1}^{ji}$  and  $\Delta f_t^j = f_t^j - f_{t-1}^j$ . Let  $S_{mt}^{ji} = 1$  if  $\text{sign}(\Delta p_{mt}^{ji}) = \text{sign}(\Delta f_t^j)$  and 0 otherwise, and define the *trend inefficiency* of a market as  $TE(p_m^{ji}, f^j) = 1 - \sum_t S_{mt}^{ji} / T$ . The trend inefficiency indicates the percentage of periods in which current price changes fail to be in the same direction as current fundamental value changes in market  $m$  of session  $i$  of treatment  $j$ . Hypothesis 2 is that trend inefficiency is equal in the two treatments. To test this hypothesis, we compute the trend inefficiency in each session, and test whether the distribution of trend inefficiency differs between treatments for given experience levels.

**Hypothesis 2:** Price trends are equally consistent with trends in fundamentals in the two treatments.

We also consider the timing of the period, within each market, when prices attain their extreme value (maximum in *Peak*, minimum in *Valley*). We refer to this period as the turning point of prices and compare it to the turning point in fundamentals, which is the analogous period for the fundamental value process<sup>7</sup>. We define the *turning point inefficiency* of a Valley market as  $TP(p_m^{Vi}, f^V) = |t_m^{i*} - t'|$ , where  $t_m^{i*}$  solves  $\min_t p_{mt}^{Vi}$  and  $t'$  solves  $\min_t f_t^V$ . For Peak market  $TP(p_m^{Pi}, f^P) = |t_m^{i**} - t''|$ , where  $t_m^{i**}$  solves  $\max_t p_{mt}^{Pi}$  and  $t''$  solves  $\max_t f_t^P$ . The periods  $t_m^{i*}$  and  $t_m^{i**}$  denote the turning points in prices in market  $m$  of session  $i$  in the Valley and Peak treatments, respectively. The periods  $t'$  and  $t''$  are the turning point of fundamentals in the Valley and Peak treatments, respectively. Larger values of  $TP$  indicate greater inefficiency. Hypothesis 3 is that the distribution of turning point inefficiency is the same in the two treatments.

**Hypothesis 3:** The absolute time difference between turning points of prices and turning points of fundamentals is the same in the two treatments.

We also consider the effect that repetition of the market has on the price efficiency measures. Specifically, we consider whether efficiency changes with repetition of the market, and if so, whether it does so in a similar direction and at a similar rate in both treatments. Define  $D_m^j$

<sup>7</sup> We require a turning point to be a period other than the first or last period of a market (that is, not period 1 or period  $T$ ), since a maximum or minimum in these periods can not necessarily be interpreted as a change in direction. If more than one period in a given session satisfies the relevant inequality, the turning point of prices is defined as the average of these periods.

$= (D(p_m^{j1}, f^j), \dots, D(p_m^{j5}, f^j))$  as the vector of Total Dispersion in the five sessions of treatment  $j$  at experience level  $m$ , and define  $B_m^j$ ,  $TE_m^j$ , and  $TP_m^j$  analogously. Also denote  $\dot{D}_m^{ji} = D(p_m^{ji}, f^j) / D(p_{m-1}^{ji}, f^j)$  and  $\dot{D}_m^j = (\dot{D}_m^{j1}, \dots, \dot{D}_m^{j5})$ . This is the vector of percentage changes in Total Dispersion between markets  $m-1$  and  $m$  in treatment  $j$ . Define  $\dot{B}_m^j$ ,  $\dot{TE}_m^j$ , and  $\dot{TP}_m^j$  in an analogous manner.

We advance two sets of null hypotheses about the effect of repetition on inefficiency. The first set, grouped and stated as Hypothesis 4a, is that repetition has no effect on inefficiency. The hypothesis is evaluated separately for  $D_m^j$ ,  $B_m^j$ ,  $TE_m^j$ , and  $TP_m^j$  and also for each treatment separately. For example, for Total Dispersion in the Peak treatment, we test whether  $D_m^P$  is drawn from the same distribution as  $D_{m-1}^P$ . The second set, grouped as Hypothesis 4b, is that any percentage change in an inefficiency measure that occurs as trader experience is gained is the same in the Peak and the Valley treatments. Specifically, we test whether  $\dot{D}_m^V$  is drawn from the same distribution as  $\dot{D}_m^P$ , and conduct analogous tests for the other inefficiency measures.

**Hypothesis 4a:** The markets exhibit the same level of inefficiency as they are repeated.

**Hypothesis 4b:** The rate of change in inefficiency measures as the markets are repeated is identical in the two treatments.

### III. THE EXPERIMENT

#### a. General structure and treatments

The experiment consisted of ten experimental sessions conducted in the economics laboratory at Tilburg University, the Netherlands. The sessions were conducted in English and participants were all students enrolled at Tilburg University. In each session, nine subjects traded in a sequence of four markets, each identical in parametric structure. Each market consisted of 15 periods, during which individuals could trade units of an asset. The asset's lifetime equaled the 15 periods during which the market was in operation. An experimental currency called "francs", converted to Euros at the end of the experiment, was used for all payments and transactions



within the experiment.

The experiment had two treatments: *Peak* and *Valley*. The *Peak* treatment was characterized by a time path of fundamentals that was increasing during the first half of each market and decreasing during the second half. The fundamental value attained a peak value in period 8 of each market in the *Peak* treatment. The *Valley* treatment consisted of markets in which the fundamental value was decreasing in the early periods of the market, and increasing in later periods. In two of the *Valley* sessions (V1 and V2), the trough of fundamentals occurred in period 9, whereas the trough occurred in period 8 for the other three sessions (V3 - V5)<sup>8</sup>. The time path of fundamentals in the two treatments, illustrated in Figure 1, is explained in more detail in the next section. Subjects knew at all times what the fundamental value would be in all future periods, and thus the change in the trend of fundamentals was anticipated. The instructions provided to subjects are given in appendix B.

[Figure 1: About Here]

## b. Fundamental values and initial endowments

The fundamental value of the asset arose from three sources: dividends, taxes, and a final buyout (a payment for each unit of asset held at the end of the market to the unit's owner). These were payments to or by the current owners of the asset on each unit they held. At any point in time the fundamental value was the sum of the expected future payments from all three sources. Specifically, the fundamental value of a unit of the asset during any period was equal to the sum of the expected dividends and final buyout it would generate, minus any taxes that remained to be paid on the unit. Thus, the fundamental value of one unit of the asset at any point in time was the expected value of the stream of payments that resulted from holding the unit for the remainder of the current market. The three different sources of value were included in the design merely to induce the appropriate dynamic patterns in fundamental values<sup>9</sup>. The number and timing of future dividend draws, tax payments, and final buyouts in the current market was always common knowledge.

After every period, each unit of the asset paid a dividend to its current owner. Dividends

---

<sup>8</sup> In the analysis that follows, we use the actual fundamentals in a session to calculate all measures and in conducting all statistical tests, taking into account the slight differences in fundamental values between sessions V1-V2 and V3-V5.

<sup>9</sup> The same pattern could have been achieved solely through an appropriately specified dividend process. However, this would have required a non-stationary dividend distribution that included negative "dividends", an unfamiliar concept that we felt would be difficult for participants to comprehend.

were drawn independently for each period from a four-point distribution with equal probability mass at 0, 8, 28, and 60 francs. This is the same distribution that was used in the original study of Smith et al. (1988) and a number of later studies that extended this work (see for example King et al., 1993; Porter and Smith, 1995; Haruvy and Noussair, 2006). The expected dividend in any period was thus equal to 24 francs, and the expected future dividend stream equaled 24 multiplied by the number of periods remaining in the current market. A die roll after each period determined the dividend for all units for the period. The payment of a dividend at the end of a period reduced the fundamental value by 24 francs immediately after the payment, since the number of future dividend payments decreased by one.

Certain periods of each market were tax periods. After every tax period, subjects paid a fixed inventory tax of 48 francs for each unit in their possession. In the *Peak* treatment, the first seven periods of each market were tax periods. In the *Valley* treatment, the last seven periods of each market were tax periods in sessions *V1* and *V2*. The last eight periods were tax periods in sessions *V3* - *V5*. The purpose of the tax periods was to create an increasing fundamental value for the periods during which the tax was in effect. During a tax period, the difference between the expected dividend to be received and the tax to be paid that period was always equal to -24. Thus, after each tax period, the fundamental value increased by 24 francs, as the future liability on each unit of the asset decreased by 24 francs.

The third determinant of the fundamental value was the final buyout. In the *Valley* treatment, each unit yielded a final payment at the end of period 15 of 216 francs, in addition to any dividends and taxes that were collected and paid. In the *Peak* treatment, the final buyout value was implicitly zero. The final buyout value increased the fundamental value of the asset for the entire life of the asset. Its sole purpose was to ensure that the asset always had a positive fundamental value.

Thus,  $f_t^j$ , the fundamental value in period  $t$  of treatment  $j$  equaled

$$f_t^j = \sum_i^T E(d_i) - \sum_i^T \tau_i^j + B^j \quad (3)$$

where  $d_t$  and  $\tau_t^j$  denote the dividend and the tax in effect in period  $t$  of treatment  $j$ ,  $T = 15$  is the final period of the market, and  $B^j$  is the final buyout.  $E(d_t) = 24$  for all  $t$  and both treatments.  $\tau_t^j = 48$  for  $t = 1, \dots, 7$  in the *Peak* treatment, for  $t = 8, \dots, 15$  in sessions *V1* and *V2*, and for  $t = 9, \dots, 15$  in sessions *V3* - *V5*, and  $\tau_t^j = 0$  at all other times.  $B^j = 0$  for *Peak* and  $B^j = 216$  for *Valley*. Dividends and final buyout payments were added to individuals' cash balances at the time they were paid, and taxes were subtracted from cash balances at the moment they were incurred. This meant that dividend payments added to and taxes subtracted from the cash that could be used for

subsequent purchases.

At the beginning of a session, each subject was assigned one of three different trader types (I, II, or III), and he remained the same type for the entire session. There were three traders of each type in each session. A trader type was defined by the initial endowment of units and cash with which a subject of that type began each market. The initial asset endowments of type I, II, and III traders were one, two and three units of the asset, respectively. In the *Peak* treatment, the initial cash endowments of the trader types (I, II, and III) were 1281, 1257, and 1233 francs, respectively, whereas the initial cash endowments were 1113, 921, and 729 francs for the three types in the *Valley* treatment.<sup>10</sup>

### c. Market organization and timing

In each market period, subjects could exchange units of the asset for francs among each other. The markets were computerized and used continuous double auction trading rules (Smith, 1962) implemented with the z-Tree computer program (Fischbacher, 2007) developed at the University of Zurich. In a continuous double auction, the market is open for a fixed interval of time. At any time, any agent, who has sufficient cash or units to conclude the transaction, may submit an offer to the market. An offer specifies a price at which the agent is willing to either buy or sell a share. Any trader with sufficient funds and units of asset to complete the transaction may accept any outstanding offer at any point in time. All offers were displayed to all agents on their computer screens. Upon acceptance of an offer, a trade was conducted and the asset and cash transferred between the transacting parties.

No short sales or borrowing were allowed. Inventories of assets and cash carried over from one period to the next so that for each individual, the quantities of cash and assets held at the beginning of period  $t+1$  were the same as those held at the end of period  $t$ , adjusting for any dividends received and/or taxes paid.

The sequence of events in a session was as follows. The experimenter first distributed

---

<sup>10</sup> These cash and asset endowments were chosen to approximately equalize expected earnings across all trader types and treatments. Expected earnings are equal for each of the three types within a treatment under the assumption that individuals hold their initial endowment and make for the entire trading horizon (except for sessions V1 and V2 where they differ very slightly). In the same sense, expected earnings are equal for a given type in the Peak treatment, and in sessions V3 – V5 of the Valley treatment. Actual realized earnings at the individual level depend on the distribution of asset holdings, the dividend realizations, and the trading strategies employed. The existence of types was not communicated to participants, who only knew their own initial endowments.

and read aloud a detailed explanation of how to make and accept offers with the electronic trading interface. This took approximately five minutes. For the next ten minutes subjects practiced trading using the interface. Activity during this phase did not count toward final earnings. After the practice phase was completed, the rest of the instructions, which described all other aspects of the experiment, were handed out and read aloud by the experimenter. Subjects then received their initial endowments of the asset and cash and the first of the four asset markets began. The initial endowments of cash and asset for a given individual were identical in each of the four markets, and thus the markets were *ex ante* identical, except for the prior experience level of the participants. Each of the 15 periods of a market lasted two minutes, and during these two minutes trading was possible at any time. At the end of markets one, two, and three, subjects were informed that their next task in the experiment would be to participate in another 15-period market.

A subject's entire earnings over a market were equal to the amount of cash he held at the end of the final period of that market, after the last dividend, tax and final buyout were paid. This was equal to his initial endowment of cash, plus any earnings from dividends, minus any taxes paid, plus proceeds from sales of shares, minus expenditures on purchases of shares, plus any final buyout received. A subject's earnings for the entire experiment were equal to the sum of his earnings from each of the four markets, plus an additional participation fee of five Euros. Francs were converted to Euros at a rate of 200 francs to 1 Euro and subjects were paid in cash anonymously at the end of the session. Sessions averaged 3 hours in duration and average subject earnings were 36 Euros (USD 56).

#### IV. RESULTS

Figures 2a and 2b show the time series of median transaction prices by period in each of the Peak and the Valley sessions, respectively. The bold lines indicate the fundamental value. Each of the time series of data corresponds to one session.<sup>11</sup> Overall, the figures indicate that (i) prices are usually higher than fundamental values, (ii) prices deviate less from fundamentals as traders

---

<sup>11</sup> The data on the volume of trade indicate that all of the markets were thick and active. Consider market Turnover, a measure of market activity employed in the analysis of experimental markets (King et al., 1993; Van Boening et al., 1993; Porter and Smith, 1995). Turnover equals the total volume of trade over the  $T$ -period market horizon, divided by the total stock of units, which is the total inventory of units of asset all individuals hold. Table A2 in Appendix A reports the value of Turnover for each of the ten sessions of the experiment. The table indicates that in the Peak treatment, the average value (across sessions) of Turnover is 7.8 in market 1, and declines to 2.6 by market 4. In the Valley treatment, the average value is 7.8 in market 1, and decreases to 3.3 in market 4. These high levels of transaction activity indicate that the markets were active and that the episodes of mispricing that we observe are not a phenomenon associated with thin markets.

become more experienced, (iii) prices track fundamentals more closely in later than in earlier periods within a market, (iv) deviations from fundamentals are larger in the Valley than in the Peak treatment and (v) repetition of a market decreases price deviations more in Peak than in Valley.

In markets 1 and 2 of the Peak treatment, shown in figure 2a, prices are usually greater than fundamentals in the early periods of the market, and then operate at close to fundamentals in the latter periods. Sessions 2 and 4 experience particularly large booms<sup>12</sup>. By market 4, prices track fundamentals closely in four of the five Peak sessions. In the Valley treatment, shown in figure 2b, prices begin substantially below fundamental value in market 1. The prices then typically exhibit booms relative to fundamentals, increasing to levels well above fundamentals by the middle of the market and remaining above fundamentals for the remainder of the market. In subsequent markets, prices exceed fundamentals throughout the life of the asset. Late in markets 3 and 4, prices tend to crash to near fundamentals, which they then track for the remainder of the market. However, in those markets of the Valley treatment exhibiting a price trough and rebound, the time of the turnaround in prices is typically later than the turning point of fundamentals. Overall, the figures suggest that prices track fundamental values better in the Peak than in the Valley treatment. Result 1 reports the findings of our analysis of relative price level efficiency in two treatments.

[Figures 2a and 2b: About Here]

**Result 1: Price levels in Peak sessions are closer to fundamentals than they are in Valley sessions. That is, price level inefficiency is greater in the Valley than in the Peak treatment. Hypothesis 1 is rejected.**

**Support for Result 1:** Figure 3 displays the observed values of Total Dispersion and Total Bias in the two treatments, averaged across the five sessions within each treatment<sup>13</sup>. Recall that values of Total Dispersion and of Total Bias closer to zero indicate lower price level inefficiency. In figure 3, the measures are normalized by the value of the measure in market 1 of the Peak treatment. The results show that mispricing in Valleys is consistently greater than in Peaks by markets 3 and 4.

---

<sup>12</sup> To avoid rescaling of the figures, the prices of some periods in market 1 of sessions P2 and P4 are not shown. These prices are 600, 800, and 600 in periods 7 – 9 of market 1 of P2, and 800, 750, and 700 in periods 8 – 10 of market 1 of P4.

<sup>13</sup> The values of each measure for each market in each session of the Peak and Valley treatments are given in table A1 in the appendix. The table also reports the values of trend and turning point inefficiency for each market and session.

[Figure 3: About Here]

Table 1 indicates the results of two-sided rank-sum tests of differences in Total Dispersion and Total Bias between the two treatments. The test is conducted separately for the data from each of the four markets, which correspond to four different trader experience levels. Each session is used as the unit of observation, so that there are five observations from each treatment for each market. The columns indicate the mispricing measure under consideration. The rows correspond to the market(s) used for the comparison. The table shows that the hypothesis of equality between the two treatments can be rejected at the 5% level for both measures in favor of the alternative that they come from different distributions, for markets 3 and 4. Neither of the measures is significantly different between treatments if only the data from markets 1 or 2 is considered. □

[Table 1: About Here]

We now turn to trend inefficiency, the measure of how consistently price changes, from one period to the next, fail to be in the same direction as movements in fundamental values. We find that trend inefficiency is lower in Peak than in Valley, for markets with either inexperienced or experienced participants.

**Result 2: Price trends more accurately reflect underlying trends in fundamentals in Peak than in Valley markets. Trend inefficiency is greater in the Valley than in the Peak treatment. Hypothesis 2 is rejected.**

**Support for Result 2:** Table 2 shows the fraction of periods in which prices and fundamentals move in the same direction in each treatment for each market. The entries in the table are equal to  $1 - TE$  and thus higher values in the table correspond to lower trend inefficiency. The first row of data, labeled *Peak Treatment*, shows the percentage of periods in the Peak treatment, in which prices and fundamentals move in the same direction. The next two rows indicate the similar percentage, for the subset of periods in which fundamentals are increasing (row 2) and decreasing (row 3) separately. The next three rows display the analogous data for the Valley treatment. The first four columns display the data for each market separately, and the fifth column contains the pooled data for all markets.

[Table 2: About Here]

Table 2 shows that, in over three quarters of periods in the Peak treatment, prices move in the same direction as fundamentals. In market 1 this percentage is 81.4%, and after decreasing somewhat in market 2, recovers to 82.9% in market 4. Peak market prices are especially likely to follow the same trend as fundamentals when fundamentals are decreasing (90.7% of periods) in the later periods of the markets. In the Valley treatment, price movements are in the same direction as fundamental changes in fewer than half of the periods in markets one and two, and reach a level of consistency of greater than 60% only by market 4. No systematic difference in the level of trend inefficiency is observed between periods in which fundamentals are increasing versus when they are decreasing. Table 1 indicates the results of the test of the hypothesis that the distribution of Trend Inefficiency is the same across treatments (as indicated previously, each session is used as the unit of observation). The hypothesis is rejected in markets 1 and 2 at the 5% level, and in market 4 at the 10% level. □

We now turn to turning point inefficiency, the relationship between the timing of the turning point of fundamentals and the turning point in prices. Our observations are summarized below as Result 3.

**Result 3: Turning point inefficiency is greater in the Valley than in the Peak treatment. Hypothesis 3 is rejected. By market 4 in the Peak treatment, the average turning point of prices in the Peak treatment is very close to that of fundamentals. In the Valley treatment, the turning point of prices is consistently later than that of fundamentals.**

**Support for Result 3:** Figure 4 shows the difference between the turning points in prices and in fundamentals by market in each session. Positive values on the horizontal axis indicate that prices change direction later than fundamentals. The vertical axis indicates the number of sessions (out of a total of five) that the difference between the two turning points equals the value of the horizontal axis for the market shown in the panel. The turning points of prices are on average earlier than those for fundamentals in the Peak treatment in markets 1 – 3, but the difference is close to zero by market 4. The average turning point of prices in *Valley* is close to that of fundamentals in market 1, although all but one of the actual turning points of prices is at least 4 periods away from the turning point of fundamentals. However, in Valley, after the first market,

price turning points are consistently later than those of fundamentals, and later than those in the *Peak* treatment.

The fourth column of data in table 4 contains the significance levels of rank-sum tests of the hypothesis that the distribution of Turning Point Inefficiency is equal between the two treatments. The tests show that in market 4, the hypothesis of equality is rejected at the 5% level. The hypothesis is rejected at the 10% level for market 1. □

[Figure 4: About Here]

We now consider the effect of experience on market efficiency. The patterns are summarized as our Result 4.

**Result 4: Price level inefficiency decreases with repetition in the Peak but not in the Valley treatment. Hypothesis 4a and 4b are rejected.**

**Support for Result 4:** Figure 3 shows the evolution of price level inefficiency in the markets as they are repeated and traders gain experience. In the Peak treatment, there is a tendency for market mispricing to decrease with repetition and thus for price level inefficiency to decline. In the Peak treatment, each measure of mispricing has an average value in market 4 that is less than 1/3 of the value in market 1. However, in the Valley treatment, Total Dispersion is only on average 30% lower in market 4 than in market 1, and Total Bias is a mere 2% lower. While the measures are comparable in magnitude in market 1, by market 4 the Total Dispersion is 3.13 and the Total Bias is 4.25 times greater in Valley than in Peak.

Comparing the treatments with regard to changes in trend and turning point inefficiencies with repetition yields a mixed picture. While improvement in the Trend Inefficiency between markets 1 and 4 is more rapid in the Valley treatment in percentage terms, the decrease in Turning Point Inefficiency is greater in percentage terms in Peak than in Valley. However, both begin from a much more inefficient base in market 1 in the Valley than in the Peak treatment. Tables 2 and A1 indicate that the average trend inefficiency decreases from .186 to .171 in Peak, and from .6 to .371 in Valley. Figure 4 shows that the average turning point inefficiency decreases from 1.4 in market 1 to 0.4 in market 4 for the Peak treatment. It also decreases from 4.4 in market 1 to 2.4 in market 4 of the Valley treatment.

Table 5 reports the results of the following two types of statistical tests. The first type is a



sign test that considers whether an inefficiency measure is decreasing between market  $m-1$  and market  $m$  within the same session, in a significant majority of the sessions. The test is conducted for each of the two treatments separately. For this test, there are fifteen observations in each treatment (5 sessions \* (4 - 1) consecutive markets). The hypothesis and the resulting significance level of the sign test are reported in the first two rows of data in the table. The second type of test, reported in the final row of table 3, is a rank sum test of whether the distribution of percentage changes in an inefficiency measure from one market to the next is significantly different between the two treatments.

The table indicates, in the first two rows of data, the levels of significance at which we can reject the null hypotheses that an inefficiency measure is the same or increasing between market  $m-1$  and  $m$  within the sessions. The first row shows that for the Peak treatment, the null hypothesis is rejected for both Total Dispersion and Total Bias at the 5% level. For Valley, the same hypotheses cannot be rejected, indicating that there is no significant decrease in the values of these measures with repetition. We do reject the hypothesis, for the Valley data, that Trend Inefficiency is constant or increasing from one market to the next in favor of the hypothesis that it is decreasing. However, recall that the Trend Inefficiency levels in the Valley treatment in markets one and two are greater than 50%, the value that would result if price movements were purely random, so the improvement occurs from a very low base.

[Table 3: About Here]

The last row of the table indicates the significance level of a rank-sum test of the hypothesis that the magnitude of percentage changes in an inefficiency measure from one market to the next is equal between the two treatments. Significant values indicate rejection of the hypothesis of equality. The data show that the improvement in price level inefficiency is significantly different between Peak and Valley by both measures at  $p < .025$ . The improvement is also greater for turning point inefficiency at the  $p < .1$  level of significance. □

In sessions 2 and 4 of the Peak treatment, an interesting pattern can be seen in Figure 2a. In market 1 of these two sessions, large bubbles are observed in roughly the middle third of the life of the asset. In market 2, prices rise to relatively high levels early in the life of the asset, suggesting speculation on an impending repetition of the pattern of the previous market. Individuals demand more of the asset, pushing up prices, based on the belief that prices will

follow a similar trajectory as in the prior market. Afterward, prices begin to decline before the period of peak prices in the preceding market, suggesting that individuals anticipate a peak to occur at roughly the same time in market 2 as has previously occurred in market 1, and supply units to the market before the time at which they anticipate a decline in prices. Thus, the dynamic pattern from one market to the next is consistent with the idea that the change in the price trajectory from one market to the next within a session reflects (a) expectations of a repetition of the price time series that occurred in the prior market, in conjunction with (b) the use of profitable strategies given those expectations.<sup>14</sup>

To explore whether this backward propagation of prices is a feature of the overall data, we test whether changes in prices in period  $t$ , between one market to the next, can be explained by the difference between the previous market's prices in period  $t + 1$  relative to period  $t$ . Consider the following regression specifications:

$$p_{m,t} - p_{m-1,t} = \beta_1 + \beta_2(p_{m-1,t+1} - p_{m-1,t}) \quad (4a)$$

$$p_{m,t} - p_{m-1,t} = \beta_1 + \beta_2((p_{m-1,t+1} - f_{t+1}) - (p_{m-1,t} - f_t)) \quad (4b)$$

Here,  $p_{m,t}$  is the price in period  $t$  of market  $m$  (indices for session and treatment are suppressed for expositional clarity). The rationale for this specification is the following. Suppose a trader believes that prices in the current market will be the same as those in the previous market. Then, if prices in the prior market  $m-1$  increased between periods  $t$  and  $t+1$  ( $p_{m-1,t+1} > p_{m-1,t}$ ), the trader's demand in period  $t$  of market  $m$  increases in anticipation of the price increase in the next period. This behavior causes prices to increase in period  $t$  of the current market  $m$  relative to the price in period  $t$  to the prior market  $m-1$ . An analogous effect would occur for price decreases. A positive  $\beta_2$  would reveal this effect: it measures how much the change in price between periods  $t$  and  $t+1$  in the previous market affects the period  $t$  price in the current market. Equation (4a) considers the effect for absolute price levels and (4b) for deviations of prices from fundamentals.<sup>15</sup>

[Table 4: About Here]

<sup>14</sup> Haruvy et al. (2007) have suggested that a similar dynamic is at work for markets with declining fundamental values.

<sup>15</sup> Note that the dependent variable in equation (4b),  $p_{m,t} - p_{m-1,t}$ , is also equal to the difference between markets  $m-1$  and  $m$  in terms of the difference between fundamental value and price in period  $t$ ,  $(p_{m,t} - f_t)$  since  $f_t$  is the same in markets  $m-1$  and  $m$ .

The results of the regression, presented in Table 4, suggest that behavior is consistent with a certain amount of response to beliefs that previous price patterns will be repeated. For the Peak treatment, the  $\beta_2$  coefficients are positive and significant under both specifications, and have values of .59 and .63 in equations (4a) and (4b) respectively. For the Valley treatments the  $\beta_2$  coefficients are also positive and significant, with larger values in the Peak treatment, indicating that the backward propagation of prices is even stronger in the *Valley* sessions.

## V. CONCLUSION

We construct experimental markets to obtain the first empirical observations, from a controlled laboratory study, of the behavior of asset markets that experience a peak or a trough in fundamentals. We focus on how well the market tracks the fundamental value, how well it reflects trends in fundamentals, and how well it reveals the timing of a change in trend. We also consider how these measures of pricing accuracy evolve as traders gain more experience through repetition of the market. The results are not obvious a priori in light of the strong tendency of experimental asset markets to generate bubbles and crashes when traders are inexperienced, a result that nonetheless has only been established for assets with fundamental values that are monotonically decreasing or constant over time.

We observe that mispricing relative to fundamental values is typical in markets populated with inexperienced subjects. As individuals gain experience, prices move much closer to fundamental values in the Peak treatment, in a manner similar to that observed in previous studies of experimental markets with declining fundamental values. However, in the time frame we are able to observe, four repetitions of a 15-period market, the Valley treatment does not move appreciably closer to fundamentals. Price changes from one period to the next are typically in the same direction as the change in fundamentals in the Peak treatment, but not in the Valley treatment. The observed peaks and troughs in prices accurately reflect the timing of the turnaround in fundamental values in Peak, but are systematically too late in Valley.

Thus, we find a strong difference between the price efficiency of a market when the underlying fundamentals rise to a peak and then decline, and that of a market where the fundamentals decline to a trough and experience a subsequent increase. In the Peak treatment, while the market experiences bubbles and crashes when traders are inexperienced, the markets operate at close to fundamentals after participants have acquired experience in the environment. On the other hand, a trough in fundamentals appears to represent a more challenging environment

for the market to achieve price efficiency. Prices consistently fail to reflect the level, the direction of the trend, and the timing of the turnaround of fundamentals in the Valley treatment. The Valley treatment is the first experimental environment of which we are aware, in which asset markets populated by individuals with this level of experience with a stationary environment, do not track fundamental values closely.

There is considerable debate in the economics profession about the extent to which markets produce prices that reflect underlying fundamental values. The evidence we obtain here, from ten experimental sessions, suggests that the answer may be that it depends on the properties of the process underlying fundamental values and the dynamics the process exhibits over time. We identify a strong asymmetry between how asset markets respond to peaks and troughs in fundamentals. This occurs even though the treatments are constructed to be similar in the level of complexity, in the monetary stakes involved, in the institutional structure, and in the characteristics of the individuals participating. Indeed, there may also be characteristics of the time path of fundamentals, other than whether they exhibit peaks and troughs, that enhance or impede the ability of a market to track fundamentals. Our research indicates that characteristics of the fundamental value, in addition to the well-known influences of the institutional structure and the level of sophistication of traders, are determinants of price efficiency. While this is clearly a property of the laboratory markets we study, it may also be a feature of markets outside the laboratory. If so, it suggests a conjecture that the tendency of markets to conform more closely to some trajectories of fundamentals than others might potentially reconcile differing conclusions on the extent to which asset markets display price efficiency.

## REFERENCES

- Abreu, Dilip, and Markus K. Brunnermeier, 2003. "Bubbles and Crashes", *Econometrica*, Vol. 71, No. 1. (January), pp. 173-204.
- Ball, Sheryl B., and Charles A. Holt, 1998. "Classroom Games: Speculation and Bubbles in an Asset Market", *Journal of Economic Perspectives*, vol. 12(1), Winter, pages 207-18.
- Brunnermeier, Markus K., and Christian Julliard, 2008. "Money Illusion and Housing Frenzies", *Review of Financial Studies*, forthcoming.
- Camerer, Colin, and Keith Weigelt, 1993. "Convergence in Experimental Double Auctions for Stochastically Lived Assets", with K. Weigelt, in D. Friedman & J. Rust (Eds.), The Double Auction Market: Theories, Institutions and Experimental Evaluations, Redwood City, CA: Addison-Wesley, 355-396.
- De Long, J. Bradford; Andrei Shleifer; Lawrence H. Summers; Robert J. Waldmann, 1990. "Noise Trader Risk in Financial Markets", *Journal of Political Economy*, Vol. 98, No. 4. (August), pp. 703-738.

- Dufwenberg, Martin, Tobias Lindqvist, and Evan Moore, 2005. "Bubbles and Experience: An Experiment", *The American Economic Review*, Volume 95, Number 5 (December), pp. 1731-1737.
- Fama, Eugene F., 1998. "Market efficiency, long-term returns, and behavioral finance", *Journal of Financial Economics*, Volume 49, Issue 3, 1 September, Pages 283-306.
- Fischbacher, U. 2007. "z-Tree: Zurich Toolbox for Ready-Made Economic Experiments", *Experimental Economics*, Volume 10, No. 2, pp. 171-178.
- French, Kenneth R., and James M. Poterba, 1991. "Were Japanese stock prices too high?" *Journal of Financial Economics*, Volume 29, Issue 2 (October), Pages 337-363.
- Froot, Kenneth A., and Maurice Obstfeld, 1991. "Intrinsic Bubbles: The Case of Stock Prices", *American Economic Review*, vol. 81(5) (December), pages 1189-214.
- Garber, P. M., 1990. "Famous First Bubbles", *Journal of Economic Perspectives*, Vol. 4, No. 2, pp 35-54.
- Haruvy, E.; Y. Lahav; C. N. Noussair, 2007. "Traders' Expectations in Asset Markets: Experimental Evidence", *American Economic Review*, Volume 97(5) (December), pp. 1901-1920.
- Haruvy, E., and C. N. Noussair, 2006. "The Effect of Short Selling on Bubbles and Crashes in Experimental Spot Asset Markets", *Journal of Finance* 61 (June), 1119-1157.
- Hussam, R, D. Porter, and V. L. Smith, 2007. "Thar She Blows: Can Bubbles Be Rekindled With Experienced Subjects?" Working paper, Chapman University.
- King, Ronald L.; Vernon L. Smith; Mark V. van Boening; and Arlington W. Williams, 1993. "The Robustness of Bubbles and Crashes in Experimental Markets", in *Nonlinear Dynamics and Evolutionary Economics*, Richard H. Day and Ping Chen, eds., Oxford Press.
- LeRoy, Stephen F, 2004. "Rational Exuberance", *Journal of Economic Literature*, vol. 42, no. 3 (Fall), pp. 783-804.
- Lei, Vivian; Charles N. Noussair; Charles R. Plott, 2001. "Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality", *Econometrica*, Vol. 69, No. 4. (July), pp. 831-859.
- Malkiel, Burton G. 2003. "The Efficient Market Hypothesis and Its Critics", *Journal of Economic Perspectives*, vol. 17, no. 1 (Winter) pp 59-82.
- Noussair, Charles, Stephane Robin and Bernard Ruffieux, 2001. "Price Bubbles in Laboratory Asset Markets with Constant Fundamental Values", *Experimental Economics*, vol. 4, June, pp 87-105.
- Pastor, Lubos and Pietro Veronesi, 2006. "Was there a Nasdaq bubble in the late 1990s?" *Journal of Financial Economics*, Volume 81, Issue 1, July, pp. 61-100.
- Reshmaan, N. Hussam; Porter, David and Vernon L. Smith: "Thar' She Blows: Rekindling Bubbles with Experienced Subjects", *American Economic Review*, forthcoming.
- Roll, Richard, 1988. "R<sup>2</sup>", *Journal of Finance*, Vol. 43, No. 3, pp. 541-566.
- Scheinkman, Jose and Wei Xiong, 2003. "Overconfidence and Speculative Bubbles", *Journal of Political Economy*, (December), pp. 1183-1219.

- Shiller, Robert J, 1981. "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?", *American Economic Review*, vol. 71, no. 3 (June), pp 421-436.
- , 2003, "From Efficient Markets Theory to Behavioral Finance", *The Journal of Economic Perspectives*, Vol. 17, No. 1 (Winter), pp. 83-104.
- Smith, Vernon L., 1962. "An Experimental Study of Competitive Market Behavior", *Journal of Political Economy*, Volume 70, No. 2, pp. 111-137.
- Smith, Vernon L , Gerry L. Suchanek, and Arlington W. Williams, 1988. "Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets", *Econometrica*, vol. 56, no. 5 (September) pp. 1119-51.
- Temin, Peter; Hans-Joachim Voth, 2004. "Riding the South Sea Bubble", *American Economic Review*, Vol. 94, No. 5. (December), pp. 1654-1668.
- Tirole, Jean, 1982. "On the Possibility of Speculation under Rational Expectations", *Econometrica*, Vol. 50, No. 5. (September), pp. 1163-1181.
- Van Boening, Mark V. & Williams, Arlington W. & LaMaster, Shawn, 1993. "Price bubbles and crashes in experimental call markets", *Economics Letters*, vol. 41(2), pages 179-185.

Table 1:  
Rank Sum Tests of Treatment Differences in Inefficiency Measures: Significance Level at  
which the Hypothesis of Equal Distributions Across Treatments Can Be Rejected

<b>Market</b>	<b>Total Dispersion</b>	<b>Total Bias</b>	<b>Trend Inefficiency</b>	<b>Turning Point Inefficiency</b>	<b>N</b>
<b>1</b>	0.347	0.465	0.008	0.086	10
<b>2</b>	0.175	0.175	0.035	0.287	10
<b>3</b>	0.047	0.047	0.245	0.595	10
<b>4</b>	0.028	0.028	0.090	0.034	10

Table 2: Fraction of Periods in Which Price and Fundamental Value Movements Are in the Same Direction, Overall, and for Periods with Decreasing and Increasing Fundamentals Separately

	<i>Market 1</i>	<i>Market 2</i>	<i>Market 3</i>	<i>Market 4</i>	<i>All Markets</i>
Peak Treatment	.814	.729	.757	.829	.782
Peak Treatment, when $f_t^P > f_{t-1}^P$	.686	.571	.629	.743	.657
Peak Treatment, when $f_t^P < f_{t-1}^P$	.943	.886	.886	.914	.907
Valley Treatment	.400	.414	.514	.629	.489
Valley Treatment, when $f_t^V > f_{t-1}^V$	.515	.364	.545	.636	.515
Valley Treatment, when $f_t^V < f_{t-1}^V$	.297	.459	.486	.622	.466
All Periods and Treatments	.607	.571	.636	.729	.636



Table 3: Statistical Tests and Results of Hypotheses of No Change in Efficiency Measures Between Consecutive Markets and of Similar Rates of Change Between Treatments

Hypothesis/Significance Level of test of Hypothesis	Total Dispersion	Total Bias	Trend Inefficiency	Turning Point Inefficiency	N
Peak Treatment: Value of measure same or greater in market $m$ than in $m - 1$ Significance Level of Test of Hypothesis	$D_m^P = D_{m-1}^P$ .0037	$B_m^P = B_{m-1}^P$ .0176	$TE_m^P = TE_{m-1}^P$ .5000	$TP_m^P = TP_{m-1}^P$ .2539	15
Valley Treatment: Value of measure same or greater in market $m$ than in $m - 1$ Significance Level of Test of Hypothesis	$D_m^V(.) = D_{m-1}^V(.)$ .5000	$B_m^V(.) = B_{m-1}^V(.)$ .5000	$TE_m^V = TE_{m-1}^V$ .0461	$TP_m^V = TP_{m-1}^V$ .1334	15
Percent change of measure between market $m - 1$ to $m$ the same in Peak and Valley Significance Level of Test of Hypothesis	$\dot{D}_m^V = \dot{D}_m^P$ .0095	$\dot{B}_m^V = \dot{B}_m^P$ .0238	$\dot{TE}_m^V = \dot{TE}_m^P$ .1965	$\dot{TP}_m^V = \dot{TP}_m^P$ .0686	30

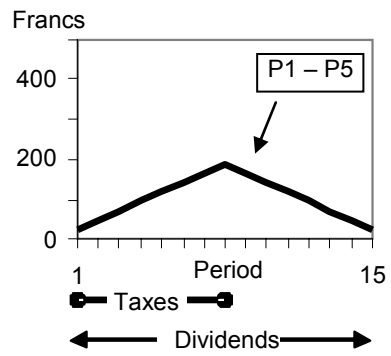
Table 4:  
Change in Period  $t$  Price Between Sequential Markets,  
as a Function of Activity in Prior Market (standard errors in parentheses)

	Peak Treatment	Valley Treatment	Peak Treatment	Valley Treatment
constant	-17.11*	-1.72	-16.87*	-3.15
	(6.68)	(8.31)	(6.72)	(5.87)
$p_{m-1,t+1} - p_{m-1,t}$	0.59**	1.18**		
	(0.10)	(0.11)		
$(p_{m-1,t+1} - f_{t+1}) - (p_{m-1,t} - f_t)$			0.63**	1.09**
			(0.10)	(0.09)
$N$	210	210	210	210

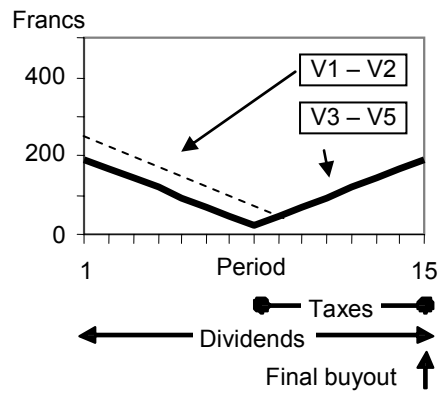
\*\* - significant at  $p < 0.001$

\* - significant at  $p < 0.02$

Figure 1:  
Time path of fundamentals in the two treatments,  
(a) Peak and (b) Valley treatments.



(a) Peak treatment.



(b) Valley treatment.

Figure 2a:  
Median Prices and Fundamentals in the Four Markets of the Peak Sessions

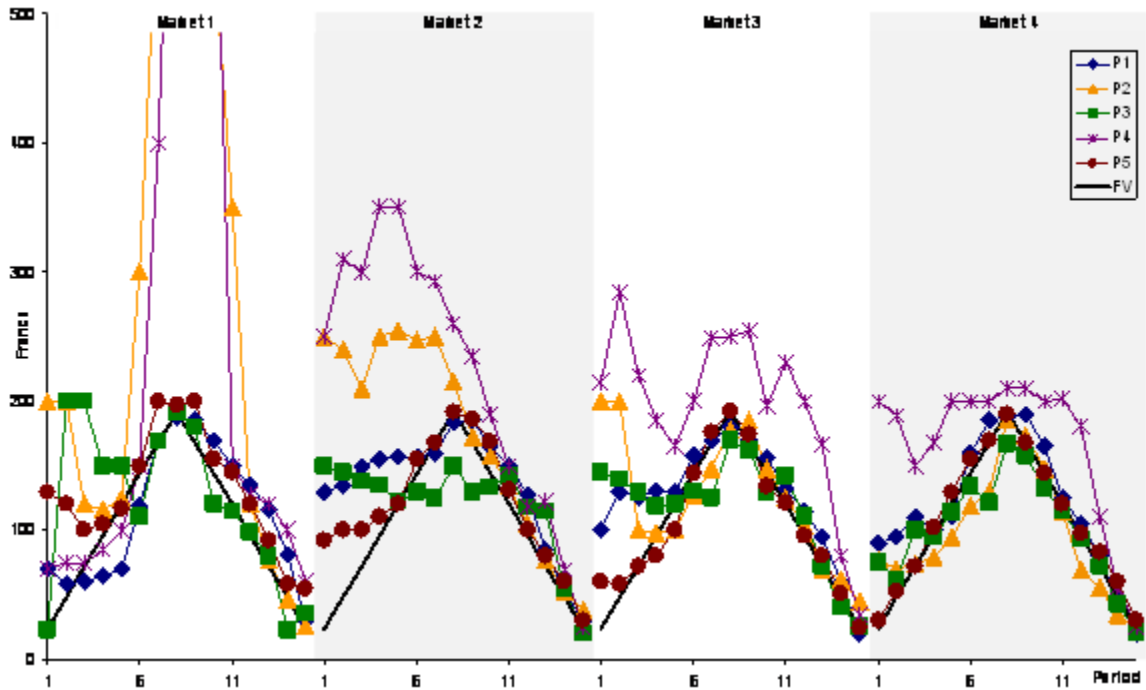


Figure 2b:  
Median Prices and Fundamentals in the Four Markets of the Valley Sessions

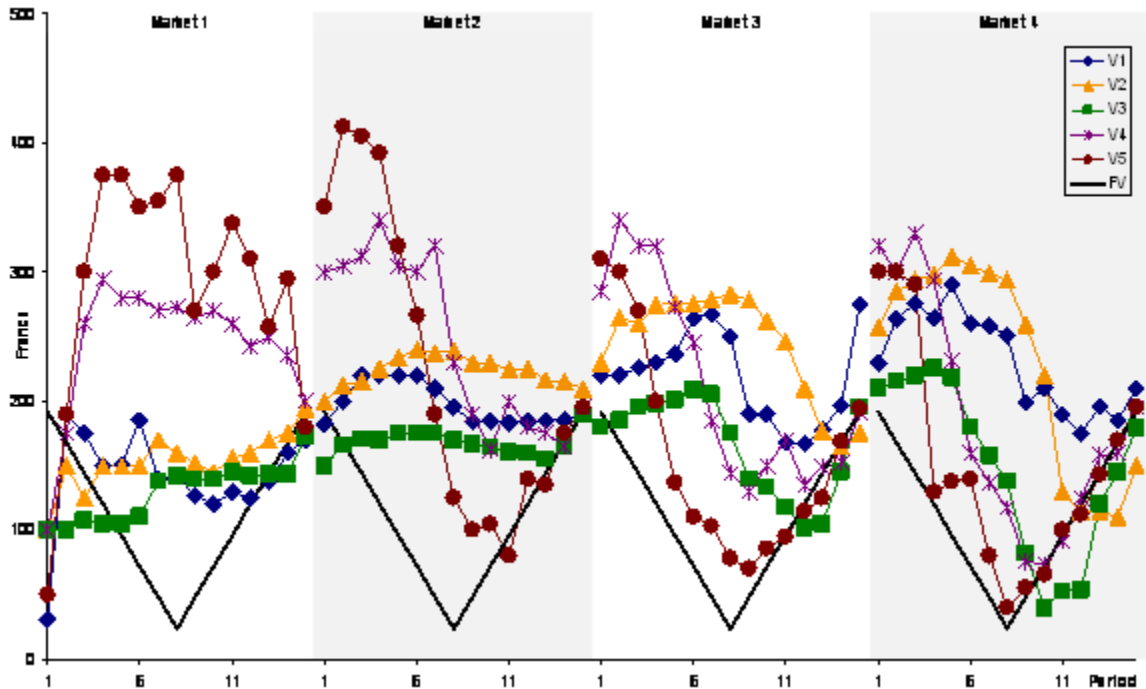


Figure 3:  
Price Level Inefficiency Measures in Peak (dark bars) and Valley (light bars),  
Averaged over Sessions (Value in Peak-Market 1 = 1.0)

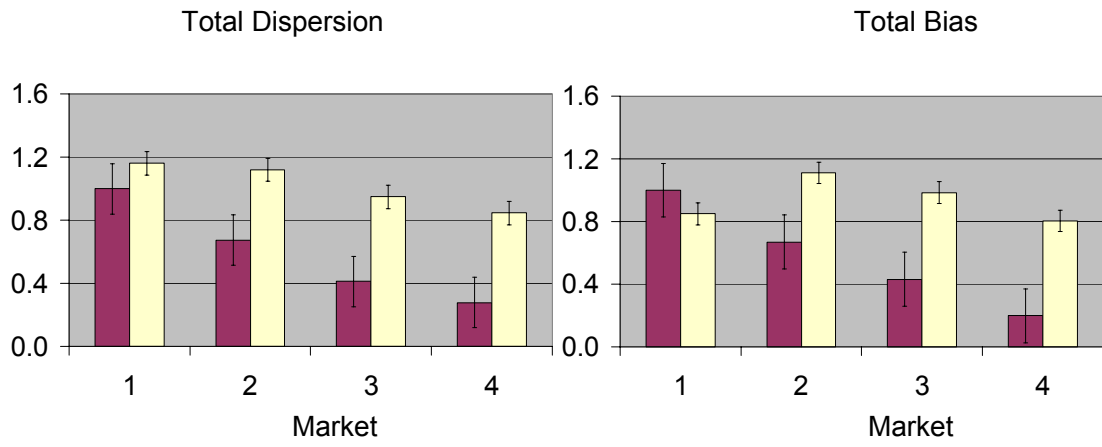
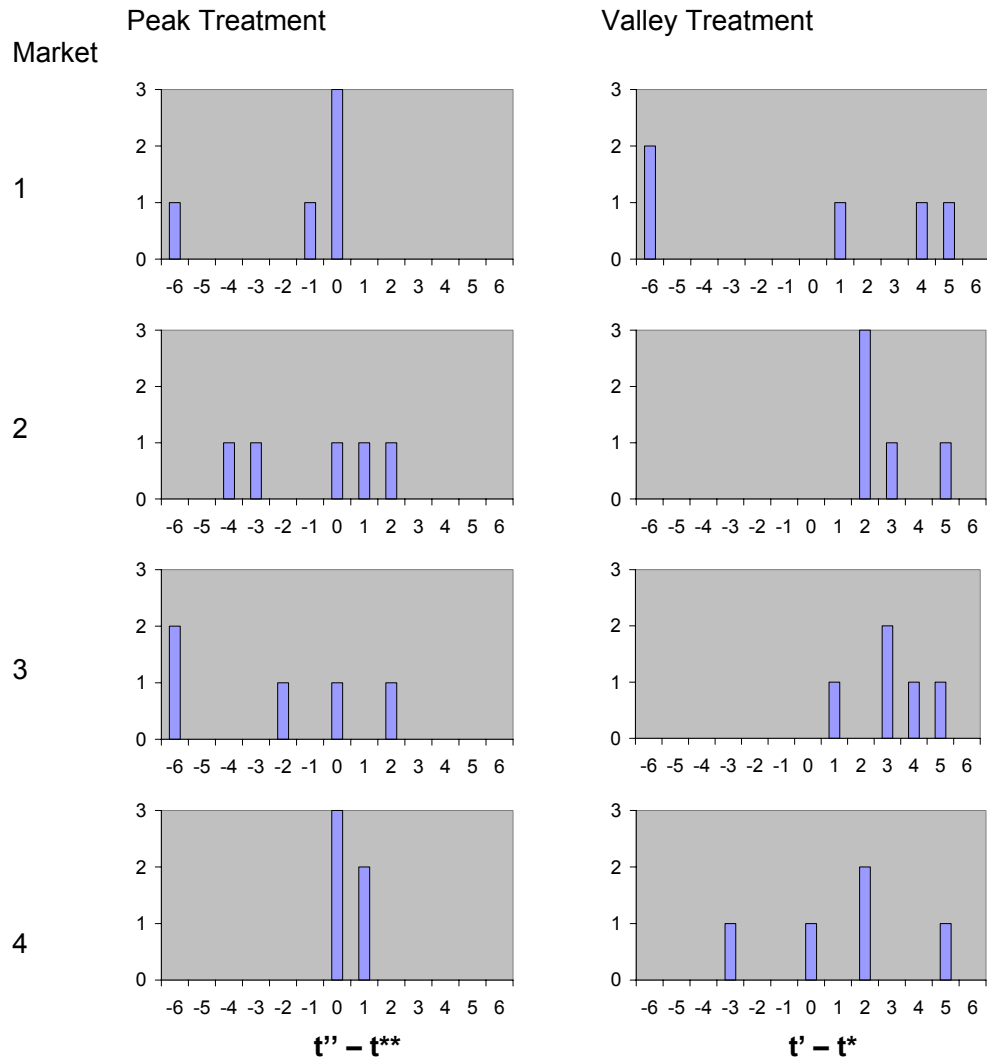


Figure 4: Differences Between Turning Point of Prices and Turning Point of Fundamentals by Session, Both Treatments and Each of the Four Markets



## Appendix A: Supplementary Data and Statistical Tests

This appendix contains three tables. The first table, A1, displays the values of the four measures of price efficiency (Total Dispersion, Total Bias, Trend Inefficiency, and Turning Point Difference) in each market of each session. The table also includes the averages across sessions within each treatment, and the between-session standard deviations.

The second table, A2, shows the values for several measures of market bubbles that previous authors (King et al., 1993; Porter and Smith, 1995; Haruvy and Noussair, 2006) have employed. These measures are:

(1) *Amplitude* =  $\max_t (P_t - f_t) / f_t - \min_t (P_t - f_t) / f_t$ , where  $P_t$  and  $f_t$  equal the median transaction price and fundamental value in period  $t$ , respectively.

(2) *Normalized Deviation* =  $\sum_i \sum_t |P_{it} - f_t| / (100 \cdot TSU)$ , where  $P_{it}$  is the price of the  $i^{\text{th}}$  transaction in period  $t$ .  $TSU$  is the total stock of units that agents hold.

(3) *Turnover* =  $\sum_t q_t / TSU$ , where  $q_t$  is the quantity of units of the asset exchanged in period  $t$ .

(4) *Boom Duration* = the greatest number of consecutive periods median transaction prices are above fundamental values.

(5) *Bust Duration* = the greatest number of consecutive periods median transaction prices are below fundamental values.

In the table, the measures are reported for each market within each session. The table also includes averages across sessions for each treatment, as well as between session standard deviations.

Finally, Table A3 contains the results of an analysis of the differences between treatments of each of the measures defined above. The tables report, for each measure and in each market, the significance level at which the hypothesis that the values for both treatments are drawn from the same population can be rejected.

**Table A1:  
Measures of Mispricing by Session and Market**

Total Dispersion

Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	375.50	2697.00	489.00	2289.50	414.50	1253.1	(1142.0)	658.50	801.50	742.00	2135.00	2924.00	1452.2	(1023.5)
2	519.50	1118.50	576.50	1786.50	258.00	851.8	(609.0)	1025.50	1352.00	907.50	1982.00	1736.00	1400.6	(457.4)
3	368.50	499.50	438.50	1394.50	118.50	563.9	(486.4)	1230.50	1628.00	967.00	1519.00	708.00	1210.5	(381.3)
4	275.50	260.00	220.50	965.00	74.00	359.0	(348.0)	1391.50	1622.50	937.50	1089.00	584.50	1125.0	(402.2)

Total Bias

Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	130.50	2694.00	310.05	2225.55	407.55	1153.5	1208.0	45.45	219.45	229.05	1951.05	2616.00	1012.5	1186.4
2	485.55	1118.55	272.55	1786.50	258.00	784.5	660.4	874.50	1264.95	809.55	1975.95	1686.00	1321.5	506.5
3	336.45	353.55	225.45	1394.55	27.45	468.0	534.3	1190.55	1569.00	781.05	1486.95	658.05	1137.0	408.7
4	232.50	-88.05	-32.55	964.95	70.05	229.5	428.9	1371.45	1355.55	530.55	1063.05	555.45	975.0	413.3

Trend Inefficiency (Proportion of Periods with Opposite Trend in Fundamentals and Prices)

Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	0.07	0.14	0.36	0.07	0.29	0.19	(0.1)	0.43	0.43	0.71	0.71	0.71	0.60	(0.2)
2	0.07	0.29	0.50	0.43	0.07	0.27	(0.2)	0.57	0.79	0.64	0.64	0.29	0.59	(0.2)
3	0.14	0.29	0.36	0.36	0.07	0.24	(0.1)	0.64	0.79	0.64	0.29	0.07	0.49	(0.3)
4	0.14	0.07	0.21	0.43	0.00	0.17	(0.2)	0.43	0.64	0.36	0.21	0.21	0.37	(0.2)

Turning Point Difference

Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	0.00	0.00	6.00	0.00	1.00	1.4	(2.6)	8.00	8.00	7.00	7.00	7.00	7.4	(0.5)
2	1.00	3.00	7.00	4.00	0.00	3.0	(2.7)	8.00	8.00	7.00	2.00	3.00	5.6	(2.9)
3	0.00	7.00	0.00	6.00	0.00	2.6	(3.6)	3.00	5.00	4.00	1.00	1.00	2.8	(1.8)
4	1.00	0.00	0.00	0.00	0.00	0.2	(0.4)	3.00	5.00	2.00	2.00	0.00	2.4	(1.8)



**Table A2:  
Other Measures of Market Mispricing by Session and Market**

Amplitude														
Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	2.33	7.34	3.70	4.04	4.45	4.4	(1.8)	2.51	2.76	5.40	10.83	15.36	7.4	(5.6)
2	4.46	9.39	5.51	9.38	2.83	6.3	(3.0)	3.07	3.96	6.30	8.60	4.38	5.3	(2.2)
3	3.33	7.50	5.30	7.64	1.67	5.1	(2.6)	3.04	4.88	6.56	5.12	2.40	4.4	(1.7)
4	2.92	2.51	2.40	7.25	0.28	3.1	(2.6)	3.19	4.74	5.28	3.95	1.10	3.7	(1.6)

Normalized Deviation														
Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	2.34	6.78	4.78	8.23	1.16	4.7	(3.0)	5.09	7.22	4.94	7.10	6.23	6.1	(1.1)
2	1.91	2.81	1.80	6.79	0.72	2.8	(2.3)	5.99	5.98	3.36	4.07	3.04	4.5	(1.4)
3	0.54	1.77	1.05	2.05	0.24	1.1	(0.8)	3.70	5.65	3.80	2.41	1.25	3.4	(1.7)
4	0.64	1.08	0.26	1.97	0.09	0.8	(0.8)	2.61	4.09	2.67	1.49	1.10	2.4	(1.2)

Turnover														
Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	9.67	5.83	7.94	12.00	3.56	7.8	(3.3)	9.89	11.39	9.78	4.56	3.39	7.8	(3.6)
2	4.28	2.78	3.39	3.78	3.11	3.5	(0.6)	8.06	7.11	5.50	2.78	2.83	5.3	(2.4)
3	2.00	3.67	2.11	2.00	2.50	2.5	(0.7)	4.17	5.00	4.72	1.94	2.72	3.7	(1.3)
4	2.17	4.22	1.44	3.39	1.67	2.6	(1.2)	2.83	4.17	4.06	2.33	3.11	3.3	(0.8)

Boom Duration														
Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	7.00	13.00	4.00	10.00	10.00	8.8	(3.4)	8.00	11.00	8.00	14.00	13.00	10.8	(2.8)
2	7.00	15.00	5.00	15.00	7.00	9.8	(4.8)	12.00	13.00	11.00	13.00	10.00	11.8	(1.3)
3	7.00	4.00	1.00	15.00	3.00	6.0	(5.5)	14.00	12.00	10.00	13.00	10.00	11.8	(1.8)
4	5.00	4.00	3.00	15.00	4.00	6.2	(5.0)	14.00	11.00	9.00	10.00	9.00	10.6	(2.1)

Bust Duration														
Mkt	P1	P2	P3	P4	P5	AvgP	(s.d.)	V1	V2	V3	V4	V5	AvgV	(s.d.)
1	4.00	1.00	2.00	2.00	1.00	2.0	(1.2)	4.00	4.00	4.00	1.00	1.00	2.8	(1.6)
2	2.00	0.00	5.00	0.00	0.00	1.4	(2.2)	2.00	2.00	2.00	1.00	1.00	1.6	(0.5)
3	1.00	4.00	5.00	0.00	2.00	2.4	(2.1)	1.00	2.00	3.00	1.00	3.00	2.0	(1.0)
4	2.00	5.00	9.00	0.00	1.00	3.4	(3.6)	1.00	4.00	6.00	1.00	2.00	2.8	(2.2)

**Table A3: Significance Levels of Hypothesis Tests of Treatment Differences for Measures of Mispricing Given in Table 2\*\***

<b>Market</b>	<b>Amplitude</b>	<b>Turnover</b>	<b>Boom Duration</b>	<b>Bust Duration</b>	<b>Normalized Deviation</b>	<b>N</b>
<b>1</b>	0.4647	0.9168	0.2477	0.5023	0.3472	10
<b>2</b>	0.4647	0.4020	0.6004	0.3808	0.1172	10
<b>3</b>	0.4647	0.1732	0.0917	0.8266	0.0283	10
<b>4</b>	0.3472	0.3472	0.1116	0.7465	0.0283	10
<b>All</b>	0.7875	0.3297	0.8681	0.1944	0.0649	30

\*\* Rows 1 – 4: Significance Levels at Which Hypothesis of No Treatment Differences in Measures of Mispricing Listed in Table A2 Can Be Rejected. Row 5: Significance Level at Which Hypothesis of No Treatment Difference in Percentage Changes in Measures of Mispricing Listed in Table A2 From One Market to the Next Can Be Rejected.

## Appendix B: Experiment Instructions and Screen Displays

This appendix contains the instructions handed out to subjects and two screenshots of the trading program in action. Treatment-specific information is contained inside curly braces { } for the Peak treatment and square brackets [ ] for sessions V3-V5 of the Valley treatment (information for V1-V2 is omitted, as it is very similar to the information in V3-V5).

--- BEGIN INSTRUCTIONS ---

### 1. General Instructions

This is an experiment on decision making in a market. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment. The experiment consists of a sequence of trading Periods in which you will have the opportunity to buy and sell in a market. The currency used in the market is francs. All trading will be done in terms of francs. The cash payment to you at the end of the experiment will be in Euros. The conversion rate is: **200 francs to 1 Euro**.

### 2. How to use the computerized market

In the top right hand corner of the screen you see how much time is left in the current Period. The goods that can be bought and sold in the market are called Shares. In the center of your screen you see the current Period and the amount of Money you have available to buy Shares. To the left of the screen, you see the number of Shares you currently have.

If you would like to offer to sell a share, use the text area entitled "Enter offer to sell:" in the second column. In that text area you can enter the price at which you are offering to sell a share, and then select "Submit Offer To Sell".

Please do so now. Type in a number in the appropriate space, and then click on the field labelled "Submit Offer To Sell". You will notice that nine numbers, one submitted by each participant, now appear in the third column from the left, entitled "Offers To Sell". The lowest ask price will always be on the bottom of that list and will, by default, be selected. You can select a different offer by clicking on it. If you select "Buy", the button at the bottom of this column, you will buy one share for the currently selected sell price.

Please purchase a share now by selecting "Buy". Since each of you had offered to sell a share and attempted to buy a share, if all were successful, you all have the same number of shares you started out with. This is because you bought one share and sold one share.

When you buy a share, your Money decreases by the price of the purchase. When you sell a share, your Money increases by the price of the sale. You may make an offer to buy a unit by selecting "Submit offer to buy." Please do so now. Type a number in the text area "Enter offer to buy." Then press the red button labelled "Submit Offer To Buy". You can sell to the person who submitted the highest offer to buy if you click on "Sell". Please do so now.

In the middle column, labelled "Transaction Prices", you can see the prices at which Shares have been bought and sold in this period.

You will now have 10 minutes to buy and sell shares. This is a practice period. Your actions in the practice period do not count toward your earnings and do not influence your position later in the experiment. The only goal of the practice period is to master the use of the interface. Please be sure that you have successfully submitted offers to buy and offers to sell. Also be sure that you

have accepted buy and sell offers. You are free to ask questions during the practice period by raising your hand.

### 3. Specific Instructions for this Experiment

The experiment will consist of 15 trading periods. In each period, you are permitted to buy and sell shares. Shares are assets with a life of 15 periods. Your inventory of shares carries over from one period to the next. For example, if you have 5 shares at the end of period 1, you will have 5 shares at the beginning of period 2.

#### Dividends:

You may receive dividends for each share in your inventory at the end of each of the 15 trading periods. At the end of each trading period, including period 15, the experimenter will roll a six-sided die. The outcome of the roll will determine the dividend for the period. Each period, each share you hold at the end of the period earns you a dividend of:

- 0 francs if the die reads 1
- 8 francs if the die reads 2
- 28 francs if the die reads 3
- 60 francs if the die reads 4

If the roll is a “5” or “6”, the die is rolled again. Each of the numbers on the die is equally likely. This means that the average dividend is 24. We arrive at 24 by averaging the four equally likely dividends: 0, 8, 28, and 60. That is, we calculate  $(0 + 8 + 28 + 60)/4 = 24$ .

The dividends you earn from shares you own are automatically added to your money balance after each period.

[After dividends and taxes have been paid out at the end of period 15, the experimenter will purchase back all the shares in the market for 216 francs each from their current owners. This buyout value will be added to any dividends received in period 15.]

#### Holding Taxes:

At the end of the {first} [last] eight periods, you must pay a holding tax of 48 francs for each share in your inventory. That is, a tax is paid at the end of {period 1, period 2, ... and period 8} [period 8, period 9, ... and period 15]. No tax is paid at the end of each of the {last} [first] seven periods ({period 8, period 9, ... and period 15} [period 1, period 2, ... and period 7]).

The taxes you owe on shares are automatically subtracted from your money balance at the end of each of the {first} [last] eight periods.

### 4. Average Holding Value Table

You can use the **AVERAGE HOLDING VALUE TABLE** (attached at the end of this document) to help you make decisions. It calculates the average amount of dividends and holding taxes you will receive and pay if you keep a share until the end of the experiment. It also describes how to calculate how much in future dividends and holding taxes you give up on average when you sell a share at any time.

1. *Current Period*: the period during which the average holding value is being calculated. For example, in period 1, the numbers in the row corresponding to “Current Period 1” are in effect.

2. *Number of Remaining Dividends*: the number of times that a dividend can be received from the current period until the final period. That is, it indicates the number of die rolls remaining in the

lifetime of the asset. It is calculated by taking the total number of periods, 15, subtracting the current period number, and adding 1, because the dividend is also paid in the current period.

3. *Average Dividend*: the average amount of each dividend. As we indicated earlier, the average dividend in each period is 24 francs per share, except for the last period, which has an average dividend of  $24 + 216 = 240$  francs.

4. *Average Remaining Dividends*: the average value of all the dividends you will receive for each share you hold from now until the end of the experiment. It is calculated by multiplying Number of Remaining Dividends by Average Dividend.

5. *Number of Remaining Tax Payments*: the number of times that a tax must be paid on a share from the current period until the end of the experiment. It is calculated by taking the total number of tax periods, 8, and subtracting the number of tax periods that have already passed.

6. *Tax Amount*: the amount that the tax payment per share will be. As indicated earlier, there is no tax in the {last} [first] 7 periods, while the tax amount is 48 francs per share in the {first} [last] 8 periods.

7. *Remaining Taxes*: the total value of the taxes remaining on a share from now until the end of the experiment. That is, for each unit you hold in your inventory for the remainder of the experiment, you will pay the amount listed in column 7 in holding taxes. It is calculated by multiplying Number of Remaining Tax Payments by Tax Amount.

8. *Average Holding Value*: the average value of holding a share for the remainder of the experiment. That is, for each unit you hold in your inventory for the remainder of the experiment, the difference between the dividends you earn and the taxes you pay will on average be the amount listed here. It is calculated by subtracting Remaining Taxes from Average Remaining Dividends.

Please have a look at this table now and make sure you understand it. Feel free to raise your hand if you have a question. When you feel comfortable with it, please go on and answer the following practice quiz:

#### PRACTICE QUIZ

1. Suppose it is period 10. How much will you pay in taxes on a share if you hold it for the remainder of the experiment?

ANSWER: \_\_\_\_\_

2. Suppose it is period 10. How much do you expect to receive in dividends on a share if you hold it for the remainder of the experiment?

ANSWER: \_\_\_\_\_

3. Suppose it is period 10. What is the average value of holding a share for the remainder of the experiment?

ANSWER: \_\_\_\_\_

#### 5. Your Earnings

Your earnings for the experiment will equal the total amount of money that you have at the end. More specifically, your earnings will be:

the money you begin with  
+ any dividends you receive  
- any taxes you pay  
+ any money you receive from sales of shares  
- any money you spend on purchases of shares.

**6. Beginning the experiment** - From now on your decisions will count toward your earnings, so please think carefully before making them.

---- END INSTRUCTIONS ---

**Figure B1: Average Holding Value Given to Participants to Inform Them of Fundamental Value**

**AVERAGE HOLDING VALUE TABLE (Valley Treatment)**

(1) Current Period	(2) Number Remaining Dividends	(3) Average Dividend	(4) Average Remaining Dividends	(5) Number Remaining Tax Payments	(6) Tax Amount	(7) Remaining Taxes	(8) Average Holding Value
1	15	24	576	8	0	384	192
2	14	24	552	8	0	384	168
3	13	24	528	8	0	384	144
4	12	24	504	8	0	384	120
5	11	24	480	8	0	384	96
6	10	24	456	8	0	384	72
7	9	24	432	8	0	384	48
8	8	24	408	8	48	384	24
9	7	24	384	7	48	336	48
10	6	24	360	6	48	288	72
11	5	24	336	5	48	240	96
12	4	24	312	4	48	192	120
13	3	24	288	3	48	144	144
14	2	24	264	2	48	96	168
15	1	24 + 216	240	1	48	48	192

**Figure B2: Display Seen By Participants During Market Period**





**Figure B3: Display Shown to Participants at End of Period**

Period:		1
Your wealth before dividends and holding taxes:		729
Dividends per share		28
Holding tax per share:		0
Your shares		3
Total Dividends		84
Total Holding Taxes:		0
Total money		813
Total shares		3
Total earnings in the experiment		813

[CONTINUE](#)