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

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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 market 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.

I. INTRODUCTION

When market prices of different assets reflect their underlying fundamental values, markets provide accurate information to investors about the worth of the assets in question. 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 common 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 booms¹, followed by subsequent rapid declines or crashes, which 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.

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¹ 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), and then rapidly lost almost all of their value. Other examples include shares in the South Sea Company in the 1700s, which gained 700% between 1719 and 1720, only to lose the entire gains and more by 1721. After sustained price booms, the Dow Jones Industrial Average decreased by 89% between 1929 and 1931, the Nikkei index declined by 66% between 1989 and 1991, and the NASDAQ index lost 80% of its value between 1999 and 2003.
because such mispricing is at odds with classical economic and financial theory\(^2\). 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 relatively inconsequential phenomenon (Fama, 1998; Malkiel, 2003)\(^3\). 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-path of the fundamental. We consider the validity of this conjecture for a particular class of experimental market.

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 (Fama, 1970). Thus, tests of market efficiency are in fact joint tests of price efficiency and the assumptions made on the process guiding fundamentals. Ideally one would like to obtain an unambiguous measure of fundamental value to compare with market prices. This is not possible with field data because asset fundamentals are typically unobservable or not unambiguously defined. However, laboratory methods offer the advantage that they allow the fundamental value of an asset to be observed, controlled, and compared to transaction prices.

Indeed, a substantial body of work, beginning with Smith et al. (1988), 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.\(^4\) This 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

\(^2\) 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).

\(^3\) Summers (1986) notes that, when fundamentals are not observable, all of the observable implications of market efficiency that are observable (in non-experimental markets) may hold even if prices deviate from fundamentals.

\(^4\) 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.
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 (Porter et al., 2007).

In this paper, we study market behavior when the trend in fundamentals changes direction, that is, when fundamentals undergo a peak or a trough. A feature of many economic 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, 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. 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 behave asymmetrically with regard to the time path of fundamental values. Markets that experience a peak are more efficient than markets that experience a trough. Peak markets also 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 in asset markets and the particular process guiding the time path of fundamentals. The degree of market efficiency depends not only on factors such as the market institutions in place, the regulatory framework, and the number and sophistication of traders, which are controlled for in our markets, but also on the time path of the fundamental values.

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. Each treatment is in effect for five experimental sessions. Let the life of the asset be $T$ periods and $f^V_t$ and $f^P_t$, denote the fundamental value of the asset in period $t$ in the Valley and Peak treatments, respectively. Let $p^V_i$ denote the observed period median transaction price in period $t$ of session $i$ of the Valley treatment, and define $p^P_i$ analogously for the Peak treatment. Furthermore, let $p^i = (p^V_i, \ldots, p^V_i)$ be the 1x$T$ vector indicating the $T$-period price trajectory in session $i$ of treatment $j$, and define $f^i$ as the 1x$T$ vector of fundamental values in treatment $j$, so that $f^i = (f^V_1, \ldots, f^V_T)$.

Our market efficiency criteria measure the degree of consistency between the two series $p^i$ and $f^j$ in terms of three measures: (1) price levels, (2) price trends, and (3) timing of changes in price trend. We first compare the treatments with regard to price level efficiency: the accuracy of prices in revealing the level of fundamentals. To measure price level efficiency, we use two measures introduced by Haruvy and Noussair, 2006 that have been employed to measure the magnitude of price bubbles. These measures are Total Dispersion, and Total Bias. They are defined as follows.

\[
Total Dispersion \ D(p^i, f^j) = \Sigma_t |p^i_t - f^j_t|.
\]  

(1)

\[
Total Bias \ B(p^i, f^j) = \Sigma_t (p^i_t - f^j_t).
\]

(2)

Total Dispersion is a measure of overall discrepancy between prices and fundamentals, while Total Bias is a measure of systematic over or underpricing. The most basic question to pose is whether price levels track fundamental value to the same extent across treatments. Let $D^V(p^V_1, \ldots, p^V_5, q^V_1, \ldots, q^V_5, f^V_5)$ be the median value of the Total Dispersion across sessions of the Valley treatment, and define $D^P(\cdot)$, $B^V(\cdot)$ and $D^V(\cdot)$ analogously. Hypothesis 1 is that these median values do not differ significantly between treatments.

Hypothesis 1: Price levels track fundamentals equally closely in the two treatments. $D^V(\cdot)$

5 Appendix A contains a similar analysis for several other measures of deviation from fundamental value that have appeared in the experimental literature (see King et al. (1993) and Van Boening et al. (1993) for a more detailed description of these measures).

6 For a given measure of market efficiency, we evaluate whether the median value differs between treatments. Activity in each session is taken as an observation when calculating median values and conducting statistical tests so that there are five observations in each treatment.
While Hypothesis 1 is concerned with price level efficiency, Hypothesis 2 addresses a 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 $\Delta p_{it} = p_{it} - p_{it-1}$ and $\Delta f_{it} = f_{it} - f_{it-1}$. Let $D_{it} = 1$ if $\text{sign}(\Delta p_{it}) = \text{sign}(\Delta f_{it})$ and 0 otherwise, and define $TE_i = \sum D_{it}/T$. The variable $TE_i$, which we call trend efficiency, measures the percentage of periods in which price changes are in the same direction as fundamental value movements in session $i$ of treatment $j$. We compute the trend efficiency in each session, and test whether the median value of the trend efficiency, by session, differs between treatments. We let $TE_j$ denote the median value of trend efficiency, where the median is across sessions using each session as an observation, within treatment $j$.

**Hypothesis 2:** Price trends are equally consistent with trends in fundamentals in the two treatments. $TE^V = TE^P$.

We also consider whether the observed price vector accurately reflects the time at which 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. Let $t_i^*$ satisfy $p_{it_i^*} \leq p_{ih}$ for all $i$; and $t_i^{**}$ satisfy $p_{it_i^{**}} \geq p_{ih}$ for all $i$. These denote the turning points in prices in session $i$ of the Valley and Peak treatments, respectively. Furthermore, define periods $t'$ and $t''$ as the periods in which $f_{it'} \leq f_{ih}$ and $f_{it''} \geq f_{ih}$ for all $t$. We call periods $t'$ and $t''$ the turning point in fundamentals in the Valley and Peak treatments, respectively. If the turning point is efficient, $t_i^* = t'$ and $t_i^{**} = t''$, so that a price peak (trough) signals that the asset’s value has also reached a maximum (minimum). We define the turning point efficiency of a session as $TP_i^V = |t_i^* - t'|$ for a session of the Valley treatment, and $TP_i^P = |t_i^{**} - t'|$ for a session of the Peak treatment, and $TP^V$ and $TP^P$ are the medians across sessions in each treatment. Smaller differences indicate higher efficiency. Hypothesis 3 is that the median difference between turning points in prices and fundamentals is similar in the two treatments.

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7 We require turning points to be a period other than the first or last period of a market (that is, not period 1 or 15), since a maximum or minimum in these periods can not necessarily be interpreted as a change in direction.
Hypothesis 3: The difference between turning points of prices and turning points of fundamentals is the same in the two treatments. That is $TP^p = TP^v$.

As described in more detail below in section three, each experimental session consists of four repetitions of a $T$-period asset market with the same participants. This repeated market feature allows us to evaluate hypotheses 1 – 3 separately for each of the four resulting experience levels. It also allows us to track the groups over time and to consider the effect that repetition of the market has on the price efficiency measures. Specifically, we consider whether price efficiency improves at all with repetition in the market, and if so, whether it improves at similar rate in both treatments. Let the subscript $m$ on an efficiency measure index the repetition of the market. We advance the null hypotheses that repetition increases price level efficiency, and that it does so at a similar rate in both treatments.

Hypothesis 4: The markets become more efficient as they are repeated. The rate of improvement is identical in the two treatments. $D_m^V(.)/D_{m-1}^V(.) = D_m^P(.)/D_{m-1}^P(.) < 1$, $B_m^V(.)/B_{m-1}^V(.) = B_m^P(.)/B_{m-1}^P(.) < 1$, $TE_m^V/TE_{m-1}^V = TE_m^P/TE_{m-1}^P < 1$, $TP_m^V/TP_{m-1}^V < 1$. $TP_m^P/TP_{m-1}^P < 1$.

III. THE EXPERIMENT

3.1. 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 in later periods. 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). The time path of fundamentals in the two treatments, illustrated in Figure 1, is explained in more detail in the next section.

Figure 1: Time path of fundamental value in Peak (panel a) and Valley (panel b). Timing of dividends, taxes, and final buyout are indicated on the horizontal axis.

3.2. Fundamental values

The fundamental value of the asset arose from three sources: dividends, taxes, and a final buyout. 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. 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 were drawn independently for each period from a four-point distribution with equal mass at 0, 8, 8

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8 In the analysis that follows, we use the actual fundamentals in a session for various measures, taking into account the slight differences in fundamental values between sessions V1-V2 and V3-V5. Our main conclusions are not affected by this one period difference.

9 The same pattern could have been achieved solely through an appropriate dividend structure; however, this would have required a non-stationary dividend distribution that included negative “dividends”.

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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 following the payment by 24 francs, 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 had 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 being to ensure that the asset always had a positive fundamental value.

Thus, \( f_t^j \), the fundamental value in period \( t \), equaled

\[
f_t^j = \Sigma_t^T E(d_t) - \Sigma_t^T \tau_t^j + B^j
\]

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 \( B \) is the final buyout. \( E(d_t) = 24 \) for all \( t \) and both treatments. \( \tau_t^j = 48 \) for \( t = 1,...,7 \) in the Peak treatment, for \( t = 8,...,15 \) in sessions V1 and V2, and for \( t = 9,...,15 \) in sessions V3 - V5, and \( \tau_t^j = 0 \) in all other cases. \( B^j = 0 \) for Peak and \( B^j = 180 \) 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.
3.3. Initial endowments

Each subject was assigned one of three different trader types (I, II, or III) for the duration of a 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 endowments were 1113, 921, and 729 francs for the three types in the Valley treatment.10

3.4. Market organization and timing

In each period of a market, 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 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 and read aloud a step-by-step 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

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10 These cash and asset endowments were chosen to approximately equalize expected earnings across all trader types and treatments, while remaining as similar as possible to the parameterization most commonly used in the literature. Expected earnings are equal for each of the three types within a treatment under the assumption that individuals hold their initial endowment for the entire trading horizon (except for sessions V1 and V2 where they differ very slightly). Realized earnings at the individual level depend on the distribution of asset holdings, the dividend realizations, and the trading strategies employed.
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 the 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 they held at the end of the final period of that market, after the last dividend, tax and final buyout value were paid. This was equal to their 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 53).

4. RESULTS

Figures 2a and 2b show the time series of median 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. Overall, the figures indicate that (i) prices are usually higher than fundamental values, (ii) prices deviate less from fundamentals as traders 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 usually exhibit booms in the early periods of the market. The markets then operate at close to fundamentals in the

11 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 first employed in the analysis of experimental markets by King et al. (1993). 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 all ten sessions of the experiment. The table indicates that in the Peak treatment, the average value (across sessions) of Turnover is 7.80 in market 1, and declines to 2.58 by market 4. In the Valley treatment, the average value is 7.80 in market 1, and decreases to 3.30 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 of thin markets.
latter periods of the market. By market 4, prices track fundamentals closely in four of the five Peak sessions. In contrast, the Valley treatment, shown in figure 2b begins the first market, in which traders are inexperienced, with prices substantially below fundamental value. 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. In those markets of the Valley treatment that exhibit a price trough and rebound, the time of the turnaround in prices is generally later than the turning point of fundamentals. Overall, the figures suggest that prices track fundamental values better in markets that experience a peak than those that experience a trough. Result 1 reports the findings of our formal analysis of relative price level efficiency in two treatments.
Figure 2b: Median Prices Relative to Fundamentals in the Four Markets of the Valley Treatment, All Sessions

Result 1: Price levels in Peak sessions are closer to fundamentals than they are in Valley sessions. That is, price level efficiency is lower 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. For all measures, larger values indicate more mispricing in a market and thus lower efficiency. 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 higher than in Peaks by markets 3 and 4. By contrast, by market 4 the average value of both measures is considerably greater in the Valley than in the Peak treatment.

12 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.
Figure 3: Bubble measures in Peak (dark bars) and Valley (light bars), averaged over sessions

Table 1 indicates the results of rank-sum tests of differences between the Total Dispersion and Total Bias in the two treatments. The test is conducted separately for the data from each of the four markets, which correspond to the four trader experience levels. Each session is used as the unit of observation, so that there are 5 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 an equal median value in the two treatments can be rejected at the 5% level for both measures in favor of the alternative that they are lower in the Peak than in the Valley treatment in markets 3 and 4. Neither of the measures is significantly different if only the data from markets 1 or 2 is considered. □

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

<table>
<thead>
<tr>
<th>Market</th>
<th>Total Dispersion</th>
<th>Total Bias</th>
<th>Trend Efficiency</th>
<th>Turning Point Efficiency</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3472</td>
<td>0.4647021</td>
<td>0.007815</td>
<td>0.08567344</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>0.1745</td>
<td>0.1745253</td>
<td>0.035015</td>
<td>0.28733307</td>
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</tr>
<tr>
<td>3</td>
<td>0.0472</td>
<td>0.0472018</td>
<td>0.24479</td>
<td>0.59472934</td>
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<tr>
<td>4</td>
<td>0.0283</td>
<td>0.0282801</td>
<td>0.089686</td>
<td>0.03364803</td>
<td>10</td>
</tr>
</tbody>
</table>
We now turn to Trend Efficiency, the measure of how consistently price changes, from one period to the next, are in the same direction as movements in fundamental values. We find that trend efficiency is greater in Peak than in Valley, for markets with either inexperienced or experienced participants.

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

**Support for Result 2:** Table 2 shows the percentage of periods in which prices and fundamentals move in the same direction in each treatment for each market. 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.

<table>
<thead>
<tr>
<th></th>
<th>Market 1</th>
<th>Market 2</th>
<th>Market 3</th>
<th>Market 4</th>
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<td>.7571429</td>
<td>.8285714</td>
<td>.7821429</td>
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<td>.7428571</td>
<td>.6571429</td>
<td>35</td>
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<tr>
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<td>.8857143</td>
<td>.8857143</td>
<td>.9142857</td>
<td>.9071429</td>
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</tr>
<tr>
<td>Valley Treatment</td>
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<td>.5142857</td>
<td>.6285714</td>
<td>.4892857</td>
<td>70</td>
</tr>
<tr>
<td>Valley Treatment, when $f_t^V &gt; f_{t-1}^V$</td>
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<td>.3636364</td>
<td>.5454545</td>
<td>.6363636</td>
<td>.5151515</td>
<td>33</td>
</tr>
<tr>
<td>Valley Treatment, when $f_t^V &lt; f_{t-1}^V$</td>
<td>.2972973</td>
<td>.4594595</td>
<td>.4864865</td>
<td>.6216216</td>
<td>.4662162</td>
<td>37</td>
</tr>
<tr>
<td>All Periods and Treatments</td>
<td>.6071429</td>
<td>.5714286</td>
<td>.6357143</td>
<td>.7285714</td>
<td>.6357143</td>
<td>140</td>
</tr>
</tbody>
</table>

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, is back 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 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 more than 60% only by market 4. No systematic difference in the level of consistency is observed between periods in which fundamentals are increasing versus when they are decreasing. Table 1 indicates the results of the hypothesis that median Trend Efficiency is the same across treatments. The hypothesis is rejected in markets 1 and 2 at the 5% level, and in market 4 at the 10% level, in favor of the alternative that Trend Efficiency is greater in the Peak than in the Valley treatment.

We now turn to Turning Point Efficiency, 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 efficiency is greater in the Peak than in the Valley 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 points 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 in market 1. However, after the first market, price turning points are consistently later than those of fundamentals, and later than those in the Peak treatment.

Table 1, in the fourth column of data, indicates the significance level of rank-sum tests of the hypothesis that median Turning Point Efficiency TP is equal between the two treatments. The tests show that in market 4, the hypothesis of equality is rejected in favor of the alternative that
the differences are smaller in the Peak than in the Valley treatment at the 5% level. The hypothesis is rejected at the 10% level for market 1. □

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

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

Result 4: Price levels move closer to fundamentals with repetition in the Peak but not in the Valley treatment. Hypothesis 4a is supported for the Peak treatment but
hypothesis 4b is rejected.

Support for Result 4: Figure 3 shows the evolution of the price level efficiency 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 Efficiency to improve. In both treatments, each measure of mispricing has a value in market 4 that is less than 1/3 of the value in market 1. In the Valley treatment, Total Dispersion is 30% lower in market 4 than in market 1, and Total Bias is 2% lower. Figure 4 shows that the average turning point difference 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.

For the Price Level Efficiency measures, the decrease over time with repetition occurs more rapidly in the Peak than in the Valley treatment. While the measures are comparable in magnitude in market one, by market four the Total Dispersion is 3.13 and the Total Bias is 4.25 times greater in Valley than in Peak. While improvement in the Trend Efficiency between markets 1 and 4 is more rapid in the Valley treatment in percentage terms, the decrease in Turning Point Difference is greater in percentage terms in Peak than in Valley.

Table 5 reports the results of the following two types of statistical tests. The first type is a sign test considers whether the median value of the measure is decreasing between market \( m-1 \) and market \( m \) within the same session. 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 final row reports the results of rank sum tests of whether the change in an efficiency measure from one period 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 hypotheses that a bubble 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 hypothesis of equality of a measure in consecutive periods 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 Efficiency is constant from one market to the next in favor of the hypothesis that it is increasing. However, recall that the Trend Efficiency levels in the Valley treatment in markets one and two are lower that 50%, the value that would result if price movements were purely random, so the improvement occurs from a very low base.
Table 5: Statistical Tests and Results of Hypotheses of No Change in Efficiency Measures Between Consecutive Markets and of Similar Rates of Change Between Treatments

<table>
<thead>
<tr>
<th>Total Dispersion</th>
<th>Total Bias</th>
<th>Trend Efficiency</th>
<th>Turning Point Efficiency</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak value same between market ( m-1 ) and ( m )</td>
<td>( D_m^p(.)/D_{m-1}^p(.) = 1 )</td>
<td>( B_m^p(.)/B_{m-1}^p(.) = 1 )</td>
<td>( TE_m^p/TE_{m-1}^p = 1 )</td>
<td>15</td>
</tr>
<tr>
<td>Sig. Level</td>
<td>.0037</td>
<td>.0037</td>
<td>.2744</td>
<td></td>
</tr>
<tr>
<td>Valley value same between ( m-1 ) and ( m )</td>
<td>( D_m^v(.)/D_{m-1}^v(.) = 1 )</td>
<td>( B_m^v(.)/B_{m-1}^v(.) = 1 )</td>
<td>( TE_m^v/TE_{m-1}^v = 1 )</td>
<td>15</td>
</tr>
<tr>
<td>Sig. Level</td>
<td>.5000</td>
<td>.5000</td>
<td>.0461</td>
<td></td>
</tr>
<tr>
<td>Percent change in Peak and Valley the same</td>
<td>( D_m^p(.)/D_{m-1}^p(.) = 1 )</td>
<td>( B_m^p(.)/B_{m-1}^p(.) = 1 )</td>
<td>( TE_m^p/TE_{m-1}^p = 1 )</td>
<td>30</td>
</tr>
<tr>
<td>Sig. Level</td>
<td>0.0095</td>
<td>0.0238</td>
<td>0.1965</td>
<td></td>
</tr>
</tbody>
</table>

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

In sessions 2 and 4 of the Peak treatment, an interesting pattern can be seen in figure 1. In these two sessions, large bubbles are observed in roughly the middle third of the life of the asset in market 1. 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. 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. This pattern 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.\footnote{Haruvy et al. (2007) have suggested a similar dynamic is at work for markets with declining fundamental values.}

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 specification:

\begin{equation}
\begin{aligned}
    p_{m,t} - p_{m-1,t} &= \beta_1 + \beta_2 \cdot \text{vall} + \beta_3 \cdot (p_{m-1,t+1} - p_{m-1,t}) \\
    &\quad + \beta_4 \cdot \text{vall} \cdot (p_{m-1,t+1} - p_{m-1,t}) + \varepsilon_{m,t}
\end{aligned}
\end{equation}

Here, $p_{m,t}$ is the price in period $t$ of market $m$ (indices for session and treatment are suppressed for expositional clarity), and $\text{vall}$ is a dummy variable that equals 1 in the Valley treatment and 0 otherwise. 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, when 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 $m-1$. A similar effect would occur for price decreases. A positive $\beta_3$ 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. $\beta_4$ would indicate whether any such effect is stronger in the Valley than in the Peak treatment.\footnote{A slightly different specification assumes that traders may have expectations that changes in price differences from fundamental values from the previous market will reoccur. If traders behave in this manner, it is price deviations, not absolute price levels, which propagate backwards in time. This is captured with the model:

\begin{equation}
\begin{aligned}
    \text{dev}_{m,t} - \text{dev}_{m-1,t} &= \beta_1 + \beta_2 \cdot \text{vall} + \beta_3 \cdot (\text{dev}_{m-1,t+1} - \text{dev}_{m-1,t}) \\
    &\quad + \beta_4 \cdot \text{vall} \cdot (\text{dev}_{m-1,t+1} - \text{dev}_{m-1,t}) + \varepsilon_{m,t}
\end{aligned}
\end{equation}

Here $\beta_1$ measures the extent to which changes in price deviations from fundamentals between periods $t$ and $t+1$ in the preceding Peak market predict deviations in the current market, while $\beta_4$ allows for differences between treatments. The results are very similar to those reported in table 6. $\beta_3$ and $\beta_4$ are positive and highly significant, and have very similar magnitudes to the coefficients in table 6, thus yielding identical conclusions to the model in equation (6).}
Table 6: Change in Period $t$ Price Between Sequential Markets, as a Function of Activity in Prior Market

\[
p_{m,t} - p_{m-1,t} = \beta_1 + \beta_2 \cdot \text{val} + \beta_3 \cdot (p_{m-1,t+1} - p_{m-1,t}) + \beta_4 \cdot \text{val} \cdot (p_{m-1,t+1} - p_{m-1,t}) + \epsilon_{m,t}
\]

<table>
<thead>
<tr>
<th></th>
<th>Constant ($\beta_1$)</th>
<th>Valley Treatment ($\beta_2$)</th>
<th>Trend within Prior Market ($\beta_3$)</th>
<th>Interaction Term ($\beta_4$)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient</td>
<td>-20.65**</td>
<td>19.64</td>
<td>0.61***</td>
<td>0.60***</td>
<td>365</td>
</tr>
<tr>
<td>Std. Error</td>
<td>(8.89)</td>
<td>(12.25)</td>
<td>(0.08)</td>
<td>(0.19)</td>
<td></td>
</tr>
</tbody>
</table>

The results of the regression presented in Table 6 suggest that behavior is consistent with a certain amount of best-responding to beliefs that previous price patterns will be repeated. The positive and significant $\beta_3$ coefficient indicates that in the Peak sessions, approximately 60% of previous price increases are shifted backwards in time in the subsequent market. The significant $\beta_4$ coefficient means that the effect is even stronger in the Valley sessions.

5. 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. The results are not obvious a priori in light of the strong tendency of experimental asset markets to generate bubbles and crashes, a result that nonetheless has only been established for market environments 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. 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. Prices have a tendency to average above fundamentals in both treatments. Prices 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. In this sense, the Peak treatment behaves much like the declining fundamental value environment that has served as the focus of prior experimental research, beginning with Smith et al. (1988). On the other hand, a trough in fundamentals appears to represent a 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 an 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”. The degree to which a market exhibits price efficiency, at least for the type of markets studied here, 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 other characteristics of the time path of fundamentals 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.15

15 Indeed, Alan Greenspan, former chairman of the U.S. Federal Reserve, recently made the following comments suggesting the existence of a similar intuition among policymakers about asymmetries in market price adjustment to increases versus decreases in the variables that influence market prices.
REFERENCES


“There’s an implicit judgment that the coefficients [of an econometric model] work symmetrically on the upside and downside. I’m beginning to question whether that premise is true.”


“Fear as a driver [of market behavior], which is going on today, is far more potent than euphoria.”


One interpretation of the first comment is that markets react asymmetrically to changes in the variables that influence them. The second comment suggests that positive and negative shifts in economic conditions have effects of different magnitudes on market sentiment.
Markets”, *Journal of Finance* 61 (June), 1119-1157.


Appendix A: Supplementary Data and Statistical Tests

This appendix contains three tables. The first table, A1, displays the values of the two measures of Price Level Efficiency, Total Dispersion and Total Bias, 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 = \( \max_i (P_t - f_t) - \min_i (P_t - f_t) \), where \( P_t \) and \( f_t \) equal the median transaction price and fundamental value in period \( t \), respectively.

2. Relative Amplitude = \( \max_t (P_t - f_t) / f_t - \min_t (P_t - f_t) \)

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

4. Turnover = \( \sum_i q_i / TSU \), where \( q_i \) is the quantity of units of the asset exchanged in period \( t \).

5. Boom Duration = the greatest number of consecutive periods median transaction prices are above fundamental values.

6. 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, the significance level at which the hypothesis that the median values of a given measure are the same in a given market between the two treatments can be rejected.
Table A1: Total Dispersion and Total Bias by Session and Market

<table>
<thead>
<tr>
<th>Mkt</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>AvgP (s.d.)</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>AvgV (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>376</td>
<td>2697</td>
<td>489</td>
<td>2290</td>
<td>415</td>
<td>1253 (1142.0)</td>
<td>659</td>
<td>802</td>
<td>742</td>
<td>2135</td>
<td>2924</td>
<td>1452 (1023.5)</td>
</tr>
<tr>
<td>2</td>
<td>520</td>
<td>1119</td>
<td>577</td>
<td>1787</td>
<td>258</td>
<td>852 (609.0)</td>
<td>1026</td>
<td>1352</td>
<td>908</td>
<td>1982</td>
<td>1736</td>
<td>1401 (457.4)</td>
</tr>
<tr>
<td>3</td>
<td>369</td>
<td>500</td>
<td>439</td>
<td>1395</td>
<td>119</td>
<td>564 (486.4)</td>
<td>1231</td>
<td>1628</td>
<td>967</td>
<td>1519</td>
<td>708</td>
<td>1211 (381.3)</td>
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<tr>
<td>4</td>
<td>276</td>
<td>260</td>
<td>221</td>
<td>965</td>
<td>74</td>
<td>359 (348.0)</td>
<td>1392</td>
<td>1623</td>
<td>938</td>
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<td>585</td>
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<table>
<thead>
<tr>
<th>Mkt</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>AvgP (s.d.)</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
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<th>AvgV (s.d.)</th>
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<td>2694</td>
<td>310,05</td>
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Table A2: Values of Other Measures of Market Mispricing by Session and Market

<table>
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<tr>
<th></th>
<th>P1 P2 P3 P4 P5</th>
<th>AvgP (s.d.)</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>AvgV (s.d.)</th>
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<tr>
<td>1</td>
<td>96 609.5 186 629 109.5</td>
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<td>287.5 244.5 210 340.5 493</td>
<td>315.1 (111)</td>
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<tr>
<td>2</td>
<td>115 221.5 169 261 68 166.9 (78.0)</td>
<td>193.5 222 188 275 288.5</td>
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<tr>
<td>3</td>
<td>94 196.5 164 226 56 147.3 (70.8)</td>
<td>198 246.5 196 216 151</td>
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<tr>
<td>4</td>
<td>76 91.5 98 174 13 90.5 (57.5)</td>
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<tr>
<td><strong>Relative Amplitude</strong></td>
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<tr>
<td>1</td>
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<tr>
<td>4</td>
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<td>3.188 4.738 5.283 3.948 1.097 3.7 (2)</td>
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<td><strong>Normalized Deviation</strong></td>
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<tr>
<td>1</td>
<td>2.34 6.78 4.78 8.23 1.16 4.66 (3.0)</td>
<td>5.09 7.22 4.94 7.10 6.23</td>
<td>6.12 (1.1)</td>
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Table A3: Significance Levels at Which Hypothesis of No Treatment Differences in Measures of Mispricing Listed in Table A2 Can Be Rejected

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Appendix B: Experiment Instructions and Screen Displays

{Peak Treatment} [VALLEY treatment]

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 in 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.
### AVERAGE HOLDING VALUE TABLE (Valley Treatment)

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