Speculation and Price Indeterminacy in Financial Markets*

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Abstract
We explore how speculative trading causes price indeterminacy in financial markets. Contrary to standard finance theory, we argue that speculating investors’ difficulty in forming rational expectations induces security prices to deviate from the fundamental values. We conducted a laboratory asset market experiment with overlapping generations of investors. We find that in markets with speculating investors (i) price deviations are larger; (ii) price deviations increase as the holding period of investors shrinks (and frequency of security transfers increases); (iii) speculative trading creates upward (downward) pressure on prices when liquidity is high (low); and (iv) price expectations are formed through forward induction from recent price changes, instead of backward induction from the fundamentals. The results suggest that speculation causes price indeterminacy when dynamic formation of inter-temporal rational expectations is infeasible.

Keywords: Experimental economics; speculating investors; rational expectations; price efficiency; overlapping generations; backward and forward induction.

JEL-Classification: C91; G11; G12.

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1. Introduction

It has long been argued that short-term speculative trading induces price volatility in security markets. Short-term speculators are only concerned with capital gains. Their valuation of the stock critically depends on future price expectations which are sensitive to noisy information, higher order expectations, and even recent price changes (Keynes 1936, Shiller 2000, Stiglitz 1989). Therefore, in a market populated by speculators, stock prices can be susceptible to volatility, bubbles and indeterminacy.

Standard finance theory, however, does not attribute higher price volatility to speculation. Even short-term speculators are assumed to form rational expectations of future transaction prices by ascribing rational expectations to subsequent generations of investors and conducting backward induction to arrive at the present price. In the resulting rational expectation equilibrium (REE) prices are equal to the fundamental values.

Several recent theoretical models seek to fill this gap. First, the rational bubble literature shows that when securities with infinite maturity are traded in a market populated by short-term investors, price bubbles (price deviation from fundamentals) can emerge as the REE (e.g. Blanchard and Watson 1982, Tirole 1985). In a second class of models deviation from fundamentals is rooted in future investors’ noisy beliefs or irrationality (Abreu and Brunnermeier 2003, Allen et al. 2006, DeLong et al. 1990a, 1990b, Dow and Gorton 1994, Froot et al. 1992, Scheinkman and Xiong 2003). We should point out that both these classes of models, as well as the standard finance theory, utilize rational expectation hypothesis. Even the second class of models assume that at least the current investors form rational expectations by considering how future prices are determined by future investors’ beliefs or behavior (whether rational or not).

However, rational expectations hypothesis is not empirically supported by field surveys and experimental data on financial markets. Using the survey data on future stock mar-
ket returns, Greenwood and Shleifer (2014) and Vissing-Jorgensen (2003) show that expectations of future stock market returns are inconsistent with rational expectations. From the survey data on exchange rate expectations, Frankel and Froot (1987, 1990) and Taylor and Allen (1992) show that short-term exchange rate expectations of market participants are formed not by rational expectation (fundamental analysis), but rather by extrapolation of recent rate changes (technical analysis). Hommes, et al. (2005) and Hommes (2011) report experimental evidence that the observed expectations of asset prices in the laboratory are not consistent with rational expectations.

In absence of empirical support for rational expectations, it seems reasonable to suppose that even if rational expectations hypothesis is a useful tool in theoretical models, it is a quite difficult task for investors to form such expectations in financial markets.

Given this background, we explore whether short-term speculative trading affects the formation of security prices, from a perspective totally different from the previous literature. We focus on investors’ difficulty in forming rational expectations and claim that this difficulty is a cause of price indeterminacy in financial markets. In Section 2, we argue that the feasibility of markets attaining the REE in standard finance theory depends critically on whether two assumptions hold: (1) all generations of investors form rational expectations, and (2) this expectation formation is common knowledge among all generations of investors. We argue that these assumptions are too strong to hold in practice. Some generation of investors may not form rational expectations, and even if all generations do so, the challenge of such expectations to be common knowledge across the generations is unlikely to be met. In those cases, there is little reason for short-term speculators to form rational expectations of future prices, and therefore little reason for current prices to be near the fundamental value; instead they become indeterminate. In addition, as the holding period of investors in a security with a given maturity gets shorter, the number of times the security will change hands through trading
during its lifetime increases. We hypothesize that with this increase, the chances of the current and all the future generations forming rational and common knowledge expectations also declines, and the chances and the magnitude of price indeterminacy should increase.

Exploring the empirical validity of the above argument on data gathered from actual financial markets is difficult for several reasons. First, the fundamental value of the security to serve as a benchmark for measuring price deviation or volatility is rarely known in reality.\(^1\) Second, it is difficult to rule out reverse causality from price volatility to the prevalence of speculators in a market, and their holdings periods. We therefore adopt an experimental approach where we choose the fundamental values and control the number of speculating investors and their holding periods in the laboratory.

In Section 3, we introduce a radically new design of a set of experimental security markets, unlike the design of earlier asset market experiments such as Smith et al. (1988). Our design has two unique features. First, following the theoretical framework in Section 2, the market has an overlapping generations structure (Tirole, 1985) in which each period has two generations of investors present in the market. Members of entering, “young” generations are endowed with cash, so they can buy securities from the overlapping “old” generation whose members exit the market at the end of the period after selling their securities (see Figure 1). Second, a single kind of simple securities is traded in these markets. Each security pays only one (terminal) non-stochastic common knowledge dividend (of 50) at the end of the last period (Period 16) of the session. Only the very last generations of investors collect this dividend for each unit of the security at the end of Period 16, and are called “dividend-collecting investors”. Other generations, called “speculating investors”, exit the market before receiving dividend and trade only for capital gains.\(^2\)

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\(^1\) Xiong and Yu (2011) is an exception. They examine the case of a dozen put warrants traded in China that went so deep out of money in 2005-2008 that their fundamental values were practically zero. They show that warrants traded at prices significantly above zero and confirm the emergence of bubbles.

\(^2\) In their models, Allen et al. (2006) call these investors “short-lived investors” and Froot et al. (1992) call them
We design this overlapping generations structure to create speculating investors who can trade only for capital gains (without ever being able to collect the dividends) and to examine whether their trades induce prices to deviate from the fundamental value of 50.\(^3\) We also vary the length of holding periods of investors (inverse of the frequency of transfers of security among investors) to see its effect on price indeterminacy. Furthermore, our choice of the single non-stochastic common knowledge dividends paid to holders of the security at the end of the last period leaves little room for doubt in the mind of any subject that the fundamental value of the security is indeed 50.\(^4\)

The standard security pricing model predicts that the market price of this security should be close to the fundamental value of 50, throughout, as 50 is the price at the REE at which each generation of investors arrive through backward induction. However, this REE outcome is not supported in the laboratory. The experimental results (Section 5) show that with speculating investors in the market, transaction prices deviate substantially from the fundamental value of 50. Specifically, we find that (i) in periods with only speculating investors present prices are more likely to depart from fundamentals, compared to prices in periods in which dividend-collecting investors are present; (ii) prices are more likely to depart from fundamentals as the securities changes hands among investors more often over their 16 period life (i.e., the holding period of investors shrinks); (iii) higher liquidity provided through higher cash endowments in the market raises prices above the fundamental value and prices fall short of the fundamental value in low-liquidity sessions; (iv) by examining price expectation data submitted by predictors (non-trading subjects) during the experiment we conclude that in

\(^3\)Deck et al. (2011) design an overlapping generation structure experiment in a Smith et al. (1988) setting. Their experiment focuses on the effect of money injection on prices, accompanied by the entry of new generations. They do not examine the effect of speculating trading.

\(^4\)Also note that our experimental setting excludes two factors—infinitive maturity and heterogeneity of dividend expectations—that are supposed to cause prices to deviate from fundamentals in recent theoretical models (Blanchard and Watson 1982, Tirole 1985, Allen et al. 2006, DeLong et al. 1990a, 1990b, Dow and Gorton 1994, Froot et al. 1992). By doing so, we examine if the deviation between prices and fundamentals may be rooted in more basic difficulty of forming rational expectations and arriving at REE.
the presence of only speculating investors, price expectations are formed based not on back-
ward induction from the fundamentals (not by rational expectations), but forward induction
from recent price changes.

These laboratory results suggest that speculation may lead to mispricing of securities
in financial markets outside the laboratory as well, causing positive and negative price bub-
bles depending on the availability of liquidity.

2. Speculation and Security Prices

This section presents a model to examine whether or not speculating investors induce
price indeterminacy. In particular, we critically examine the standard security pricing model,
which argues that REE assures prices to be equal to the fundamental value.

Consider a security that matures at time $t + m$. For simplicity, assume that the security
pays only a terminal dividend $D$ at time $t + m$. $D$ is non-stochastic and common knowledge
among the investors. Without loss of generality, assuming a zero discount rate, the fundamen-
tal value of the security at time $t$ is:

$$F_t = D$$

2.1. Pricing in a market populated by dividend-collecting investors

We define dividend-collecting investors as those who hold the security to its maturity
at $t + m$ to collect its cash dividends $D$. The value of the security to such an investor at time $t$,
$V_t$ (and its price $P_t$ in a market populated by such investors) is equal to the fundamental value
of the security $D$:

$$P_t = V_t = D$$

2.2. Pricing in a market populated by speculating investors
Next consider speculating investors with holding periods \( k < m \), who buy the security at time \( t \), hold it for \( k \) periods, and sell it at \( t+k \) to exit the market before the security matures and pays its dividend \( D \). The value of the security to these investors \( V_t \) and its price \( P_t \) in a market populated by such homogenous investors is:

\[
P_t = V_t = E_t(P_{t+k})
\]  (3)

where \( P_{t+k} \) is the security price at \( t + k \) and \( E_t(.) \) is the investors’ homogeneous expectation at time \( t \). Price \( P_t \) depends on the investor’s expectation of the future sales price, \( E_t(P_{t+k}) \). In this market, the price depends on investors’ expectations; it is not necessarily anchored to the fundamental value.

The standard security pricing models, however, assume that speculating investors form rational expectations of future prices through a recursive process from near to distant future, and their backward induction results in an REE in which the current price of the security is equal to its fundamental value. The argument is as follows. Investors at \( t \) rationally expect that equation (3) holds for the subsequent generation of investors at \( t+k \):

\[
P_{t+k} = V_{t+k} = E_{t+k}(P_{t+2k}).
\]  (4)

Investor at \( t \) use equation (4) to form their expectations of \( P_{t+k} \):

\[
E_t(P_{t+k}) = E_t(E_{t+k}(P_{t+2k}))
\]  (5)

where \( E_t(E_{t+k}(.)) \) is the expectation of investor at time \( t \) of expectation of an investor at time \( t+k \) about contents of (.) above. \( P_t \) is obtained by substituting (5) into (3).

\[
P_t = E_t(E_{t+k}(P_{t+2k})).
\]  (6)

The price of the security at time \( t \) depends on the investor’s expectations at time \( t \) of the subsequent generation’s expectations at time \( t+k \) of price at \( t+2k \) (second-order expectations).

To form the second-order expectations \((E_t(E_{t+k}(P_{t+2k})))\), update (3) by 2\( k \) time periods,

\[
P_{t+2k} = E_{t+2k}(P_{t+3k}).
\]  (7)
The rational expectation of investors at time \( t+k \) is

\[
E_{t+k}(P_{t+2k}) = E_{t+k}(E_{t+2k}(P_{t+3k})).
\] (8)

Then, the second-order expectation of investors at time \( t \) is:

\[
E_t(E_{t+k}(P_{t+2k})) = E_t(E_{t+k}(E_{t+2k}(P_{t+3k}))).
\] (9)

Substituting (9) into (6), we get:

\[
P_t = E_t(E_{t+k}(E_{t+2k}(P_{t+3k}))).
\] (10)

Equation (10) indicates that \( P_t \) depends on the investors’ third-order expectations of \( P_{t+3k} \).

To form the third-order expectations, update (3) by \( 3k \) time periods and obtain the rational expectation of investors at time \( t+2k \) of \( P_{t+3k} \), and so on. Repeating this substitution process, we obtain the price equation including higher order expectations of subsequent prices:

\[
P_t = E_t(E_{t+k}(E_{t+2k}(P_{t+3k})))...).
\] (11)

Finally, at time \( t+m-k \), the price should be equal to the terminal dividend \( D \) that the last \( (m/k) \text{th} \) generation of investors receives from the security:

\[
P_{t+m-k} = D.
\] (12)

Then investors at time \( t+m-2k \) should form their rational expectations of \( P_{t+m-k} \) using equation (12):

\[
E_{t+m-2k}(P_{t+m-k}) = D.
\] (13)

Substituting (13) into (11),

\[
P_t = E_t(E_{t+k}(E_{t+2k}(E_{t+m-3k}(D))...)).
\] (14)

By assumption, since \( D \) is common knowledge,

\[
P_t = D = F_t.
\] (15)

This completes the derivation of the REE that yields \( P_t = F_t \). Under the standard security pricing model, even in a market populated by speculating investors, the price of the security with fixed maturity is determined through the investors recursively forming a series of rational
expectations and conducting backward induction, and the price is equal to the fundamental value of the security. It suggests that the formation of the security price does not depend on the presence of speculating investors with shorter holding periods.

2.3. Feasibility of rational expectations

The standard security pricing model outlined above critically depends on two assumptions:

Assumption 1: Investors form rational expectations of future prices, knowing that future generation of investors exhaust arbitrage opportunities.

Assumption 1 means that investors at time $t$ rationally expect $P_{t+k}$ knowing that equation (4) holds at time $t+k$, and that investor at time $t+m-2k$ rationally expect $P_{t+m-k}$ knowing that equation (12) holds.

Assumption 2: Investors’ rational expectation formation is common knowledge among all generations of investors.

Assumption 2 implies that investors at time $t$ form second-order expectations of $P_{t+2k}$ (equation (9)) knowing that investors at time $t+k$ form rational expectations of $P_{t+2k}$ (equation (8)); investors at time $t$ form third-order expectations of $P_{t+3k}$ knowing that investors at time $t+k$ know that investors at time $t+2k$ form rational expectations, and so on.

Assumption 1 requires investors not only to have cognitive ability to surmise the market where they will sell the security, but also to believe that subsequent generations of investors are rational and that they make trades in a frictionless market. However, as recent theoretical models assume (Abreu and Brunnermeier 2003, Amershi and Sunder 1987, DeLong et al. 1990a, 1990b), investors may not believe in other investors’ rationality. Further, market
frictions such as borrowing and short-sales constraints may prevent perfect arbitrage (as models such as Allen et al. 1993 and Scheinkman and Xiong 2003 assume).

Assumption 2 places even higher demands on human cognition. Investors must not only form rational expectations themselves, but also believe that the subsequent generations of investors also do so. Further, they should believe that the future generations of investors also believe that their successors also form rational expectations. Generally, expectation formation is private, and investors can hardly know how investors of subsequent generations form their expectations.

Therefore, assumptions 1 and 2 are strong and cannot be expected to hold in practice. Some generations of investors may not form rational expectations, due to their limited cognitive ability, or because they do not believe the subsequent generation of investors’ rationality. Or even if they form rational expectations, rational expectations may not be common knowledge across generations. Suppose that one generation ($i^{th}$ generation) of investors do not form rational expectations, or even if they do, they do not believe that the subsequent generation of investors form rational expectations. Then the repeated substitution process to obtain equation (11) stops at $t+(i-1)k$ or $t+ik$ and consequently the price is not linked to the terminal dividend $D$. In this case, in a market populated by speculating investors, prices are no longer anchored to the fundamental values. The above argument opens the possibility that the formation of the security price depends on investors’ holding periods and consequent frequency of transfers through market transactions. We explore this possibility by conducting laboratory experiment described in the next section.

3. Design of the experiment

*Overlapping generations structure*
We implement a security market experiment with an overlapping-generations structure as depicted in Figure 1. We design this structure to create speculating investors in the laboratory. Each market session consists of 16 trading periods of 120 seconds each.\textsuperscript{5} The security traded has a maturity of 16 periods and pays a single, common knowledge terminal dividend, $D = 50$, at the end of Period 16 to its holders from the last generation. This dividend structure is far simpler than Smith et al. (1988) where the security pays numerous (period-by-period) stochastic dividends generating a declining fundamental value. We chose this simpler dividend structure in order to minimize subjects’ confusion and to gather data from markets populated only by speculating investors.\textsuperscript{6}

(Figure 1 about here)

At the beginning of Period 1, the initial generation of investors (G0) is endowed with units of the security and no cash. There are also ‘entering generations’ (G1, up to G8) in a market, each being a cohort of investors starting with cash but no securities. They can use their cash to buy securities from the ‘older’ generation, then sell them to the next ‘younger’ generation and exit the market, just when another generation enters (or the session ends). There are two overlapping generations of five investors each in the market at any time (for a total of ten active investors).

Only the very last generations of investors collect the dividend ($D = 50$), which is paid for each unit of the security at the end of Period 16. They are considered dividend-collecting investors as described in Section 2.1, who hold the security until maturity to collect the dividend. No other generation of investors can collect any dividend. They are considered

\textsuperscript{5} We chose 16 periods to (i) have the lowest number divisible by 2, 4, and 8; (ii) ensure that each generation is in the market for at least two periods (one to buy, one to sell the securities); and (iii) to complete each market session in approximately 90 minutes.

\textsuperscript{6} Smith et al.’s (1988) design makes it difficult to create speculating investors (who do not receive dividend and trade only for capital gains) in the overlapping-generations structure. In addition, our design of the security differs from previous experimental studies featuring constant fundamental values (Porter and Smith 1995, Smith et al. 2000, Nousair et al. 2001, Kirchler et al. 2012, Stöckl et al. 2015, all of which yield efficient pricing). In our experiment, a security with a single lump sum common knowledge dividend without uncertainty is chosen to examine our research question (the effect of the presence of speculating investors) and minimize subjects’ confusion.
speculating investors as described in Section 2.2, trading the security only for capital gains. Any securities these investors hold at the time of their exit are worthless. This design ensures that even in T1, where G0 and G1 are present for all 16 periods each asset needs to be traded at least once (from a member of G0 to a member of G1) to realize its dividend.

Figure 1 illustrates that in Treatment T1, dividend-collecting investors (G1) are present in all 16 periods of the market session. In T2, T4, and T8 some periods have only speculating investors active in the market (Periods 1-8 in T2, Periods 1-12 in T4, and Periods 1-14 in T8) and in other periods dividend-collecting investors (the last generation) are present in the market (Periods 9-16 in T2, Periods 13-16 in T4 and Periods 15-16 in T8). Within each treatment the market structure (number of investors, number of securities and cash endowment of an entering generation) remains unchanged over the 16 periods.

Treatments

The experiment has a 4x2 design in which the first treatment (number of entering generations) takes four different values and the second treatment (liquidity) takes two values (see Table 1). By varying the number of entering generations (1, 2, 4, and 8), we control the maximum holding periods of security for each generation (e.g., in T4 a maximum of 4 periods for G0 and G4, and 8 periods for G1-G3). Henceforth, these maximum holding periods are referred to as simply “holding periods”.

The liquidity treatment varies the initial cash-to-asset value ratio (commonly referred to C/A = amount of cash available to trade securities in the economy/the total fundamental value of all securities) for H (=10) and L (=2). Treatments are denoted as Txy with $x \in \{1,2,4,8\}$.

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7 These are only the maximum and not the actual holding periods, because an investor of G1 in T4, for example, may choose to wait till period 3 to buy a security and sell it in period 5 and thus hold it only for two periods.
or \( 8 \) indicating the number of entering generation changes and \( y \in \{H \text{ or } L\} \) indicating high and low-liquidity treatments.

*(Table 1 about here)*

**Security and cash endowments**

Only the initial generation of investors (G0) is endowed with units of the security. All others (G1-G8) are initially endowed with cash only. The cash endowment of an entering generation is ten (or two) times the amount needed to buy all securities at their terminal dividend value in H (L) treatments.\(^8\) The amount of cash going out of the market with the exiting subjects will, of course, vary with each generation change and will be equal to the cash endowments of the entering subjects only by chance. To equalize the per period trading ‘workload’ across treatments, security and cash endowments are varied so as to keep the expected number of transactions for the entire 16-period session fixed at 160, independent of the number of generations (see Table 2 for details). Furthermore, to ensure that the total number of securities in the experimental market stays constant throughout the session, any securities in the hands of exiting investors are distributed at zero cost to randomly chosen members of the entering generation. This arrangement ensures that no buyer is forced to buy a security at a price unacceptable to him/her, and the sellers have an incentive to sell their securities before exiting the market.\(^9\)

*(Table 2 about here)*

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\(^8\) A higher C/A-ratio allows investors to take additional risk in trading the security. In H (L) treatments each individual investor initially holds an amount of cash that is twice (0.4 times) the total (fundamental) value of all asset in the market. While the C/A-ratio is deliberately high in H treatments, a C/A-ratio of 2 in L treatments ensures that investors are able to make transactions at reasonable frequencies. See Kirchler et al. (2012), Nous-sair and Tucker (2014), and references therein on the effects of cash endowments on mispricing.

\(^9\) One may argue that the pressure on the exiting generation to sell its securities at the risk of forfeiture may create a downward pressure on market prices. As shown in the results section, the prices in the low-liquidity treatments tend to be below the fundamental value, but not in the high-liquidity treatments. Therefore, the downward-pressure hypothesis is not a consistent explanation of the observed data.
Participation and subject circulation

To keep the total number of subjects within reasonable limits we recruit 18 subjects for each session.\(^{10}\) In every period, two generations (ten subjects in total) are active investors, while the other eight (five in T1) subjects are “predictors” who are rewarded on the basis of how accurately they predict the average trading price at the beginning of each period. Investors can buy and sell securities freely as long as neither their cash nor the security holdings become negative. When a generation exits the market, five subjects are randomly chosen from the pool of eight predictors to form the newly entering generation for the next period, and the exiting generation joins the pool of predictors. Subjects stay in this pool for two or more periods. This rotating mechanism allows each generation of investors to gain experience and understanding of the environment without significantly interfering with the purpose of the experiment (see Lim et al. 1994, Marimon and Sunder 1993). Since the subjects cannot know whether and when they will reenter the market, it is virtually impossible for their anticipations about any future reentry into the market to influence their current behavior.

Trading mechanism

The trading mechanism used is a continuous double auction with open order book with the opportunity to cancel a bid or ask before it is accepted, single-unit trades, and shorting constraint (no negative holdings of cash or securities allowed at any time). The single unit trades help homogenize the amount of trading “workload” per period across treatments. All cash and security balances are carried over to the following period until the investor exits. Each trading period lasts for 120 seconds with a digital wind-down clock on the trading screen. Earnings accounts are shown on a history screen at the end of each period (see Appendix A for details).

\(^{10}\) In treatment T1 we invite only 15 subjects instead of 18 since no rotation is needed. Ten subjects trade through all 16 periods and the other five serve as ‘predictors’ (to be explained below).
**Investor payoff**

The final earnings of each member of the last generation of investors are calculated as 
[number of securities in their hands at the end of Period 16] × [terminal dividend of 50] + [cash holdings at the end of Period 16]. The final earnings of all other generations of investors are equal to [their cash holdings at time of exit]. Any unsold securities in the hands of these investors are forfeited, and randomly distributed in integer units among the members of the incoming generation at zero cost.\(^{11}\) The final earnings of investors are converted to euros at a pre-announced rate and paid out.\(^{12}\)

**Prediction task**

Of the 18 subjects (15 subjects in T1), eight (five in T1) act as observer/predictors in each period. At the beginning of each period, they are required to submit a prediction of the average transaction price of that period. Predictors’ earnings depend on the precision of their forecast. They earn 140 units of cash for a perfect forecast with one unit deduction for each unit of error (subject to zero minimum).\(^{13}\) Calculations of period as well as cumulative earnings are shown on the history screen at the end of each period (see Appendix A for details).

**Session termination**

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\(^{11}\) During 48 sessions, a total of 970 securities were forfeited across 768 periods. This was mostly due to holders being unable to sell at a price acceptable to them. Forfeiture rates markedly increased with the number of generation changes and ranged from 1.1 percent of shares in T1H to 23 percent in T8L.

\(^{12}\) The conversion is done at a predetermined rate announced at the outset. We use different rates for the first, transition, and last generations and the low/high-liquidity treatments to ensure identical average euro payouts. See Table 2 for details.

\(^{13}\) The amount earned was later exchanged to Euros at a rate of 133:1. Hence, roughly one euro could be earned per prediction round.
Subjects are informed through common knowledge instructions (with their understanding tested through a written questionnaire, see Appendix B for details) that the session ends with Period 16, when each unit of the security pays a dividend $D = 50$ to its holders from the last entering generation. Earnings of each investor and predictor are calculated as described above, converted into euros, and paid to the subjects in private.

*Implementation*

The experiment was conducted in the Innsbruck-EconLab using z-tree (Fischbacher, 2007) in autumn 2013 with a total of 828 University of Innsbruck students (bachelor and master students from different fields). We ran 48 sessions in total (eight treatments of six sessions each). Most subjects had participated in other economics experiments earlier, but none participated in more than one session of the present study. Subjects were recruited using ORSEE by Greiner (2004). At the beginning of each session subjects had 15 minutes to read the instructions on their own and their questions were answered privately. This was done to minimize any possible experimenter bias. Afterwards, the trading screen was explained in detail, followed by a questionnaire and two trial periods to allow subjects to become familiar with the environment, investor and prediction tasks, and mapping from experimental actions and events to their payoffs, and to test their comprehension.\(^{14}\) In both the trial periods, all subjects played dual roles of investor and predictor. As an example, instructions for treatment T2L, along with screen shots, are provided in Appendix A.

4. Hypotheses

As discussed in Sections 2.1 and 2.2, in standard security pricing models the nature of investors (dividend-collecting vs. speculating) in a market does not affect the formation of

\(^{14}\) We implemented this procedure to minimize mispricing due to subjects’ confusion or misunderstanding.
security prices. In a market populated with dividend-collecting investors, arbitrage induces prices toward the fundamental values; even in a market populated with speculating investors, recursive formation of rational expectations of future prices and resulting REE keeps prices near fundamental values. Following this argument, prices in our market experiment should be equal to the value of terminal dividend (50), irrespective of the market being populated with speculating or dividend-collecting investors.

On the other hand, in laboratory experiments, we often observe that security prices deviate from the fundamental values. In most previous security market experiments, subjects stay in the market throughout the session and collect dividends from the securities they hold at the end; they correspond to the dividend-collecting investors (the last generation) in our model and experiment.\(^{15}\) Even in those experiments security prices are rarely equal to the fundamental values exactly (Plott and Sunder 1982, 1988); such deviations are often attributed to noise trading arising from subjects’ gradual and imperfect learning, confusion and irrationality.\(^{16}\) We should not expect transaction price noise to be absent in our markets either. Since the magnitude and impact of the noise trading does not vary much across markets, we pose the following null hypothesis from REE in standard security pricing models:

**Hypothesis I\(_0\):** Deviations of prices from the fundamental value are the same during periods when only speculating investors are present compared to periods when dividend-collecting investors are present in the market.

As shown in Figure 1, periods with only speculating investors (who do not collect terminal dividends) are periods 1-8 in T2, periods 1-12 in T4, and periods 1-14 in T8. Periods with both speculating and dividend-collecting investors are periods 1-16 in T1, periods 9-16 in T2, periods 13-16 in T4, and periods 15-16 in T8. Hypothesis I\(_0\) states that the proximity of prices

\(^{15}\) See e.g. Smith et al. (1988) and the large follow-up literature reviewed in Palan (2013).

\(^{16}\) This is true even when the security traded has a simple dividend structure, e.g. in Smith et al. 2000, Lei et al. 2001, and Kirchler et al. 2012. None of the mentioned papers, however, features overlapping generations of investors.
to the fundamental value (terminal dividend 50) should be similar between the two sets of periods.

In contrast, in Section 2.3, we considered the possibility that prices in a market with speculating investors may not reach REE and get unhinged from the fundamental value. Speculating investors may not recursively form rational expectations of future prices due to the difficulty in forming their own rational expectations and/or believing in forming of rational expectations by subsequent generations of investors. This possibility leads us to the following alternative hypothesis:

**Hypothesis Ia**: Deviations of prices from the fundamental value are larger during periods when only speculating investors are present compared to periods when dividend-collecting investors are present in the market.

We shall compare the magnitude of price deviations between the two sets of periods, and examine if the experimental data reject the null hypothesis of no difference in favor of the alternative.

Next, we shall examine whether, for a security of a given maturity, the length of investors’ holding period influences pricing. In the four treatments (T1, T2, T4, and T8) of our experiment the security always has the same time to maturity (16 periods) and pays the same terminal dividend (50), but the holding periods/number of periods in the market of the generation are different.

In T1, both G0 and G1 stay in the market for 16 periods (the average holding period of investors is 16 periods). In T2, G0 stay for eight periods, G1 stay for 16 periods, and G2 stay for eight periods (the average holding period is 10.7 periods). In T4, G0 stay for four periods, G1-G3 stay for eight periods, and G4 stay for four periods (the average holding period is 10.7 periods). In T8, G0 stay for eight periods, G1-G3 stay for eight periods, and G4 stay for four periods (the average holding period is 8 periods).

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17 As explained in fn.7, we refer to the maximum holding period as simply holding period. The average of actual holding period among investors is half as large as the maximum holding period.
od is 6.4 periods). In T8, G0 stay for two periods, G1-G7 stay for four periods, and G8 stay for two periods (the average holding period is 3.6 periods). According to standard security pricing models, price paths should not differ across these four treatments; investors of each generation should recursively form rational expectations and prices at all times should equal the fundamental value of 50. However, as discussed in Section 2.3, it may be difficult for investors of all generations to form common knowledge rational expectations. This gives rise to the alternative hypothesis that, as the average length of holding period becomes shorter (and the number of remaining transfers of the security across generations until it matures increases), failure to form common knowledge rational expectations and departure of prices from the fundamentals become more likely. We set up the following null and alternative hypotheses:

**Hypothesis II_0**: For a security of a given maturity, the deviation of prices from the fundamental value is not affected by the length of investors’ holding periods.

**Hypothesis II_A**: For a security of a given maturity, the deviation of prices from the fundamental value increases as the length of investors’ holding periods becomes shorter.

While Hypothesis II_0 predicts that Treatments T1, T2, T4, and T8 do not affect the price deviations from the fundamentals, Hypothesis II_A predicts that the price deviation is the largest in T8 and the second largest in T4, third in T2, and the smallest in T1.

In many models, one of the key assumptions is frictionless markets. One of the most relevant frictions in markets is a liquidity constraint. To examine whether this factor plays a role for pricing in our markets we vary the total amount of cash in a market by a factor of five. In treatments H (T1H, T2H, T4H, T8H) the total amount of cash in the market is 10 times the total value of all securities (the cash-to-asset value ratio, C/A-ratio is 10), while in treatments L the C/A-ratio is 2. In standard finance theory, the amount of liquidity should not affect prices, as it does not change the security’s fundamentals. However, prior experimental evi-
idence suggests that liquidity significantly affects security prices: prices can be higher when liquidity is higher either through initial cash endowments or conditions which influence the C/A-ratio (Ackert et al. 2006, Breaban and Noussair 2014, Caginalp et al. 1998, Caginalp et al. 2001, Caginalp and Ilieva 2008, Deck et al. 2012, Haruvy and Noussair 2006, King et al. 1993, Kirchler et al. 2012, Noussair et al. 2012, Porter and Smith 1995). We explore whether the amount of liquidity, measured by the C/A ratio, influences the price levels and price deviations from fundamentals in our markets. We set up the following null and alternative hypotheses:

**Hypothesis III₀**: Prices will be the same irrespective of the total amount of cash in the market.

**Hypothesis III₁**: Prices will be higher if the total amount of cash in the market is higher.

5. Results

5.1 Overview

Figures 2 and 3 show the evolution of transaction prices for each of the six independent sessions (mean transaction prices by period in thin grey lines) and the fundamental value (red bold line) for high-liquidity treatments (T₁H, T₂H, T₄H, and T₈H) and low-liquidity treatments (T₁L, T₂L, T₄L, and T₈L), respectively.¹⁸ Note that the fundamental value – the terminal dividend of 50 – is constant across all periods throughout our experiment. Broken vertical lines mark the entry/exit points of overlapping generations of investors (compare Figure 1). The thick blue line with hollow circular markers is the volume-weighted average of six sessions in each panel.

¹⁸ We dropped two transactions that occurred above 800 from the analyses; the first transaction was at 999 in period 9 of a T₂H market and it was one of 64 transactions in that period; it was probably a keyboard error made under heavy/fast trading. Second observation was at 900 in period 16 of a T₂H market, and it was the only transaction in that period; it was probably caused by boredom because there had been no transactions in period 15. We repeated the analyses without dropping these two outliers and confirmed that the results were qualitatively unchanged. Note that no session ended before period 16. The two sessions appearing to have ended early did not see transactions (although several bids and asks) in the periods before the end of the market.
Figure 2 for high-liquidity sessions shows that in T1H markets (the upper left panel) when the dividend-collecting entering generation (G1) is always present, prices are usually close to fundamentals (50) throughout the session. While prices are relatively high in Period 1, they tend towards fundamentals with time (except in one session), and they converge to the fundamental value in the last period (Period 16) in four of the six markets. This result is consistent with the earlier experimental studies with constant fundamental values which report that prices tend to converge to the fundamentals (Porter and Smith 1995, Smith et al. 2000, Noussair et al. 2001, Kirchler et al. 2012, Stöckl et al. 2015). In addition, as in the earlier studies, convergence is noisy, especially transactions near 100 in one market in Period 16. It suggests that arbitrage is far from perfect even in the last period.

In contrast, in the other treatments (T2H, T4H, T8H), where only the last entering generations stay in the market long enough to collect dividends, deviation of prices from fundamentals is greater and more persistent. Usually prices only converge towards fundamentals once the dividend-collecting investors (of the last generation) enter. The visual inspection suggests that (i) the price formation is different between periods in which dividend-collecting investors are present and periods in which only speculating investors present, and (ii) the same securities (with the same dividend and the same maturity) have different price paths among the four treatments (T1H, T2H, T4H and T8H). These results are inconsistent with the prediction of REE and appear to reject Hypotheses I0 and II0 in favor of I_A and II_A for the high-liquidity treatments.

The low-liquidity sessions depicted in Figure 3 exhibit a similar tendency. While prices are close to fundamentals in periods with dividend-collecting investors (of the last generation) present, they deviate from fundamentals in periods with only speculating investors. In all periods in T1L, Periods 9-16 in T2L, Periods 13-16 in T4L, and Periods 15-16 in
T8L where the respective (dividend-collecting) last generation is present, prices are close to or converge near the fundamental value. They significantly deviate from the fundamentals in other periods. In addition, while price deviations from the fundamental value tend to be positive in high-liquidity treatment in Figure 2, they tend to be negative for the low-liquidity sessions in Figure 3. This observation favors rejecting the null hypothesis III\(_0\) for alternative III\(_A\).

5.2 Analyses of price deviations from the fundamental value

To examine hypotheses I and II we need to calculate deviations of prices from the fundamental value with a measure of mispricing per period. In the recent experimental security market literature, the degree of mispricing is usually measured by Relative Absolute Deviation (RAD) proposed by Stöckl et al. (2010).

\[
RAD = \frac{1}{N} \sum_{t=1}^{N} |P_t - F_t| / |\bar{F}|
\]

(16)

where \(|P_t - F_t|\) are the deviations of (volume-weighted) mean price from the fundamental value in period \(t\), \(|\bar{F}|\) is the absolute average fundamental value in the session, \(t\) denotes period number, and \(N\) stands for the total number of periods. \(RAD\) measures the average level of mispricing across all periods of the session.

As we wish to compare the degree of price deviations among periods even within a session (e.g., between the periods with dividend-collecting investors and those with only speculating investors), we propose \(Period-RAD\), a measure of mispricing per period.

\[
Period-RAD = |P_t - F_t| / F_t
\]

(17)

In our experiment, as \(F_t\) (fundamental value in period \(t\)) is constant at a value of 50 throughout the session, \(Period-RAD\) becomes

\[
Period-RAD = |P_t - 50| / 50.
\]

(18)
We calculated \textit{Period-RAD} for each of 16 periods in 24 high-liquidity sessions (six sessions $\times$ four treatments) and 24 low-liquidity sessions.\textsuperscript{19}

\textit{(Table 3 about here)}

The two panels of Table 3 show the six-session average of \textit{Period-RAD} for each period of the high and low-liquidity treatments. Periods with dividend-collecting investors (the last generation) present are shaded in grey and those with only speculating investors present are not shaded. Also, the periods in which the same two generations trade, are bordered in bold. In both Panels A (high-liquidity session) and B (low-liquidity session), we find that (for a given period sequence number) \textit{Period-RAD} is almost always larger in markets with only speculating investors (white cells) than in periods with dividend-collecting investors (grey-shaded cells). Figure 4 shows the average \textit{Period-RAD} for each period sequence number, comparing the markets with dividend-collecting investors (e.g. Period 1 in T1) with those with only speculating investors (e.g. Period 1 in T2, T4, and T8), in high (panel A) and low liquidity (panel B) sessions, respectively. We observe that for all period sequence numbers in high and low liquidity treatments (14 high and 14 low liquidity period sequence numbers), the average \textit{Period-RAD} across markets with only speculating investors is larger than the one across markets with dividend-collecting investors. This corroborates that for any given period sequence number, the price deviation from the fundamentals is larger in markets with only speculating investors compared to that in markets with dividend-collecting investors. On average, price deviations differ by a factor of 2.45 (4.06) under high (low) liquidity.

\textit{(Figure 4 about here)}

\textsuperscript{19} We excluded three periods from the sample of high-liquidity sessions: period 16 in Market 5 of T1H and period 15 in Market 5 of T2H had no transactions and period 16 in Market 5 of T2H had only the outlier transaction price of 900 (see, footnote 14). We also deleted three periods for the low-liquidity sample (periods 11 and 13 in Market 3 in T1L and period 14 in Market 3 of T8L had no transactions). These deletions reduced the sample size for each liquidity treatment to 381. The resulting average of \textit{Period-RAD} is 0.735 across all high-liquidity sessions and 0.333 for the low-liquidity sessions.
Table 4 confirms these observations. It compares the average Period-RADs across all periods with dividend-collecting investors (0.401 in H and 0.140 in L) with periods populated only by speculating investors (1.024 in H and 0.502 in L). The respective difference (0.623 in H and 0.362 in L) is large in absolute terms and statistically significant at the 1% level for each liquidity treatment (two-sided t-test). The Null hypothesis $H_0$ (that the presence of speculating investors makes no difference in price deviations) can be rejected in favor of the alternative $H_A$ (that the presence of speculating investors increases mispricing). Apparently, speculating investors do not tend to value the securities by forming rational expectations of future prices. The REE hypothesis does not hold in our laboratory markets, although theoretically, the REE would seem to be an obvious outcome of this simple market environment.

(Table 4 about here)

In Section 2.3, we discussed that with fewer entering generations left, it should be relatively easier for speculating investors to form rational expectations about the future prices, as compared to situations where many generations are yet to enter the market (because then they have to form higher-order expectations through a recursive process over more generations). To examine whether the number of security transfers across generations of investors that remain till maturity affects mispricing, we calculated averages of Period-RAD across periods with only speculating investors, conditional on the number of yet-to-enter generations until maturity (one in Periods 1-8 in T2, Periods 9-12 in T4, and Periods 13-14 in T8; two in Periods 5-8 in T4 and Periods 11-12 in T8; and so on.

(Figure 5 about here)

The resulting average Period-RADs are given in Figure 5. The figure shows that the averages of Period-RAD are high even when the number of remaining security transfers across generations is one (0.677 in H and 0.546 in L liquidity sessions), and both are significantly different from 0.401 (in H) and 0.140 (in L) in the presence of dividend-collecting
investors. This suggests that speculating investors have difficulty in forming rational expectations even if it involves only one future generation left. This difficulty may arise from investors’ limited cognitive ability in rationally expecting the next generation’s valuation, and/or from investors’ doubt about whether the future generations will exhaust all arbitrage opportunities; they may not believe in the next generation’s rationality and in the market’s perfection. Standard security pricing models to derive REE assume not only that investors form rational expectations (Assumption 1) but also that such expectations are common knowledge (Assumption 2). Our experimental results cast doubt on the empirical validity of even Assumption 1. It does not seem to be easy for investors to rationally expect others’ valuation and/or future market conditions. The results support the idea of Adam and Marcet’s (2011) theoretical research suggesting that if investors are rational based on their subjective beliefs but they have only imperfect market knowledge (lack of knowledge regarding others’ preferences and beliefs), the stock price ceases to be anchored in the fundamental value.

In Table 5, we see that the length of investors’ holding periods affects the deviation of the security price from the fundamentals. We calculated the average of Period-RAD for T1, T2, T4, and T8, respectively, and compared them across these four treatments. Average Period-RAD in the high-liquidity treatments is the smallest (0.421) in T1, 0.586 in T2, 0.739 in T4, and the largest (1.187) in T8 (see panel A in Table 5), which are mostly statistically different from each other (see panel B in Table 5 which provides the difference in Average Period-RAD across treatments). The pattern is similar in the low-liquidity treatments, though with generally lower numbers. We conclude that given the maturity of the security, the shorter the holding period, and the higher the number of remaining security transfers across generations of investors, the greater the deviation of prices from fundamentals. This result rejects Hypothesis II0 in favor of alternative IIA.

(Table 5 about here)
One may argue that our experimental results are consistent with the theoretical predictions of previous literature, showing that investors’ short-term speculation gives rise to price bubbles (e.g., Allen, et al. 2006, Blanchard and Watson 1982, DeLong, et al. 1990a, 1990b, Dow and Gorton 1994, Froot et al. 1992, Tirole 1985). We should note, however, that our findings on the price indeterminacy associated with short-term speculation are obtained even in markets where the security has finite maturity and the dividend value has no uncertainty and is common knowledge, which excludes important factors postulated to cause bubbles in the prior literature. In our markets price deviations and volatility stem from the difficulties of investors in forming rational expectations, whereas the above literature assumes that investors can form rational expectations of future prices.

5.3 Liquidity supply and mispricing

Hypothesis III explores whether liquidity supply in the market affects overall mispricing and the price level. Visual inspection of Figures 2 and 3 already gives a tentative answer, as prices tend to be above the fundamental value in the high-liquidity sessions, but below the fundamental value in the low-liquidity sessions.

To assess the direction of price deviations from fundamentals, we replace the relative absolute deviation measure \((Period-RAD)\) used in the preceding subsection by the relative deviation measure \((Period-RD)\):

\[
Period-RD = \frac{(P_t - 50)}{50} \tag{18}
\]

where \(P_t\) is the mean price of period \(t\). \(Period-RD\) is an analog of \(RD\) (Relative Deviation), proposed by Stöckl et al. (2010) which measures the average level of raw (not absolute) price deviations across all periods throughout the session. The resulting average of \(Period-RD\) across all markets with high-liquidity is positive \((0.534)\), but negative \((-0.222)\) across all

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\(20\) This overpricing is consistent with the findings of the previous literature on security market experiments: in a
low-liquidity sessions; the difference (0.756) is statistically significant at the 1% level. This result rejects hypothesis III₀ in favor of alternative IIIₐ and confirms the impression from Figures 2 and 3, where prices are mostly above the fundamental value in high-liquidity sessions and below the fundamental value in low-liquidity sessions.

(Table 6 about here)

Note that this liquidity effect on prices is larger when there are only speculating investors in the market. Analyzing the data in more detail, Table 6 compares average Period-RD in periods with dividend-collecting investors present to those with only speculating investors. In high-liquidity treatments (C/A ratio = 10), the average Period-RD across periods with dividend-collecting investors is 0.295 (significantly different from zero at the 1% level), which indicates that prices are on average 29.5% higher than the fundamentals. On the other hand, the average Period-RD across periods with only speculating investors is much higher (0.741) and the difference (0.446) is statistically significant at the 1% level. This suggests that with high-liquidity, speculating investors amplify the magnitude of overpricing in financial markets. Usually, in a market dominated by dividend-collecting investors, prices above the fundamentals should be more or less driven towards fundamentals by the arbitrage transactions of dividend-collecting investors. However, in a market dominated by speculating investors who care only about future sales prices, if investors have difficulties in forming rational expectations, they would not be likely to conduct arbitrage between high prices and fundamentals. Consequently, positive price deviations from fundamentals may persist over time.

In the low-liquidity treatments (C/A-ratio = 2), the average of Period-RD when dividend-collecting investors are present is -0.087, which is small and negative but significantly different from zero at the 1% level. This indicates that the security prices under the funda-

market with investors who can receive dividends (corresponding to dividend-collecting investors in our experiment), a larger cash-to-asset value ratio is associated with greater positive mispricing (see, Palan’s (2013) survey article).
mentals are not completely driven to fundamentals by the purchases of the dividend-collecting investors in our experiment. This imperfect arbitrage may be due to investors not having sufficient cash to buy securities at this level of liquidity.\footnote{Note that a no-borrowing constraint is imposed in our experiment.} In the absence of dividend-collecting investors, the average \textit{Period-RD} is $-0.340$, which is significantly lower than $-0.087$ at the 1\% level. This result indicates that with comparative shortage of liquidity, investors’ short-term speculation magnifies the undervaluation in financial markets. Figure 6 presents \textit{Period-RD} classified by the number of generations left to enter the market. In the high-liquidity treatments (Panel A) \textit{Period-RDs} generally increase with the number of generations left to enter the market, with all but one of the \textit{Period-RDs} being significantly larger than in the periods when the dividend-collecting last generation is present. Similarly, in low-liquidity treatments (Panel B) five out of seven values of the \textit{Period-RDs} are significantly smaller (more negative) than the \textit{Period-RD} when the dividend-collecting last generation is present.

(Figure 6 about here)

We conjecture that lower prices in low-liquidity treatments could be caused by speculating investors’ fear of future market illiquidity.\footnote{In the high-liquidity treatments this is less likely as each individual investor has enough money to “buy the whole market”, i.e., buy all the assets in the market at their fundamental value.} Suppose that speculating investors have difficulties in rationally expecting future sales prices and observe weak buy-order and low transaction prices in some period of our experiment. Then, they may sell the security now even at prices below 50, fearing that they may not be able to sell all their securities before their exit, or may be forced to dump them in fire sales. This behavior of speculating investors would tend to drive prices below fundamentals. This conjecture is supported by theoretical analyses of financial liquidity crises by Bernardo and Welch (2004) and Morris and Shin (2004). They point to speculating investors selling securities expecting future market declines, and causing price drops. It is also consistent with an empirical study by Cella et al. (2013)
who find that during episodes of market turmoil, short-term investors sell more than long-term investors, and stocks held mostly by short-term investors experience larger price drops than stocks held mostly by long-term investors. In addition, Morris and Shin’s (2004) model predicts a V-shaped pattern in prices around the liquidity crisis; after the crisis, prices go back to fundamentals through the long-term investors’ arbitrage transactions. Cella et al. (2013) also report that stocks held mostly by short-term investors experienced large price reversals after the turmoil. These V-shaped price paths from theoretical and empirical studies are also observed in our low-liquidity sessions. As Figure 3 shows, in T2L, T4L, and T8L markets, prices tend to decline when there exist only speculating investors, but they generally recover and converge to fundamentals once dividend-collecting investors (the last generation) enter the market.

5.4 Formation of Expectations

If speculating investors have difficulties in forming rational expectations of future prices, how do they form their expectations? We use the data on expectations we gathered in our experiment to explore how the predictors form their expectations.23

We postulate two models of the price expectation formation process; one is the fundamental model and the other is the trend model (Hirota and Sunder 2007). The fundamental model assumes that investors form expectations of future prices based on backward induction from the deviation of prices from the fundamental value of the security.

\[ E_t(P_{t+k}) = P_t + \alpha(F_t - P_t) \]  

(19)

where \( \alpha (>0) \) is the adjustment coefficient. With this model, investors expect future price appreciation (depreciation) if the fundamental value, \( F_t \), is higher (lower) than the current price, \( P_t \). In this model any \( \alpha > 0 \) is consistent with the fundamental model, with \( \alpha = 1 \) corre-

23 We rely on predictors’ estimates in the analysis of expectation formation as these estimates do not bias the price formation process in the market. Since the market information sets of the investors and predictors are identical, there is no \textit{a priori} reason to believe that the predictions of the two sets of subjects would be different.
sponding to perfect and instantaneous rational expectation formation supposed by the standard security pricing models $E_t(P_{t+k}) = F_t$ for any $k$ in any period $t$.

On the other hand, the trend model assumes that investors form their expectations about the future price through forward induction based on recently observed price changes.

$$E_t(P_{t+k}) = P_t + \beta(P_t - P_{t-k})$$  \hspace{1cm} (20)

In this model, if $\beta > 0$, recent price increases (decreases) cause investors to expect further price increases (decreases) in the future; if $\beta < 0$, recent price increases (decreases) cause investors to expect future price decreases (increases). With this model, investors’ expectation of the future prices are based solely on recent price movements, irrespective of the fundamental value of the security.

We can combine (19) and (20) into a general specification for expectation formation:

$$E_t(P_{t+k}) = P_t + \alpha(F_t - P_t) + \beta(P_t - P_{t-k})$$  \hspace{1cm} (21)

This combined model allows for the possibility that investors use some combinations of backward induction from fundamentals and forward induction from recent prices.

During the experiment, we collected data on expected mean transaction prices from the predictors at the beginning of each period. To use these data for estimation, we set $k = 1$.

Then, rearranging terms, (19), (20) and (21) become

$$E_t(P_{t+1}) - P_t = \alpha(F_t - P_t)$$  \hspace{1cm} (22)

$$E_t(P_{t+1}) - P_t = \beta(P_t - P_{t-1})$$  \hspace{1cm} (23)

$$E_t(P_{t+1}) - P_t = \alpha(F_t - P_t) + \beta(P_t - P_{t-1})$$  \hspace{1cm} (24)

where $F_t = 50$ (the terminal dividend) throughout all periods in all sessions in the experiment.\(^{24}\)

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\(^{24}\) Hommes et al. (2005) investigate the price expectation formation in asset market experiments. They report that about half of participants follow the linear autoregressive predictions with 2 lags (AR(2) prediction) which can be interpreted as a trend following strategy (trend extrapolators or contrarians). Using our notation, AR(2) prediction is expressed as $E_t(P_{t+1}) = \gamma + \beta_1 P_t + \beta_2 P_{t-1}$ and it becomes our trend model (equation (23)) when $\gamma = 0$, $\beta_1 + \beta_2 = 1$, and $\beta_2 = -\beta$. 

30
The cross-sectional average of the predictors’ price expectations (for the following period) is used as $E_t(P_{t+1})$, and the average price of the previous period and the one before that are used as $P_t$ and $P_{t-1}$, respectively. We estimated equations (22), (23) and (24) using ordinary least squares regression with constant terms. We used data from the periods with and without dividend-collecting investors for each of high and low-liquidity treatments. Table 7 shows the estimation results.

(Table 7 about here)

Overall, we find that the coefficient of $(F_t - P_t)$ in the fundamental (FUND) model ranges from 0.070 to 0.401, which is significantly more than zero but less than one (at 1% level). These findings show that the perfect rational expectation formation ($E_t(P_{t+1}) = F_t$) is not supported not only in periods with only speculating investors but also in periods with dividend-collecting investors.25

Although the data rejects the instantaneous rational expectation formation, it reveals that the fundamental value of the security plays a role of anchor to the expectation of future price in markets with dividend-collecting investors. If we first look at the results of high-liquidity sessions (upper half of Table 7), we find that in the presence of dividend-collecting investors, backward induction from fundamental values fits the data better than the forward induction from recent prices. The coefficient of $(F_t - P_t)$ is significantly positive (0.197) in the fundamental (FUND) model, but the coefficient of $(P_t - P_{t-1})$ is not significant in the trend (TREND) model. In the combined (COMBINED) model, only the fundamental factor $(F_t - P_t)$ is statistically significant. These results suggest that in periods with dividend-collecting investors, the fundamental value of the security not only determines the transaction prices but also affects the future price expectations. Arbitrage transactions of dividend-collecting investors enable market participants to expect that future prices will converge to the fundamentals.

25 This result is consistent with the empirical results shown by Greenwood and Shleifer (2014). They show that expectations of investors captured by the surveys are not at all the expectations obtained from rational expectation models.
In contrast, the data from periods in which only speculating investors are present support the trend model better than the fundamental model. In these periods, the coefficient of $(F_t - P_t)$ in the FUND model shrinks (to 0.109) to remain marginally significant. However, it becomes much smaller (0.078) and insignificant in the combined (COMBINED) model. On the contrary, the coefficient of $(P_t - P_{t-1})$ is -0.301 and -0.270 in the trend (TREND) model and the combined (COMBINED) model, respectively, and both are statistically significant at the 1% level. These results suggest that in a market with only speculating investors, investors tend to form their expectations of future prices on the basis of recently observed prices through forward induction, and not on the basis of the fundamental value through backward induction. Also, the negative coefficient of $(P_t - P_{t-1})$ shows that market participants expect price reversals; a price rise of 1 from the previous period lowers the expectation of next period price by about 0.3. This pattern of reversal in expectations is also observed in foreign exchange markets (Frankel and Froot 1987, Taylor and Allen 1992). It is in a sharp contrast to the momentum (extrapolative) expectations reported on stock market return in the field (Greenwood and Shleifer 2014, Vissing-Jorgensen 2003), and in laboratory stock market prices (Hirota and Sunder 2007 and Hommes et al. 2005).

We observe the same tendency in the results for low-liquidity sessions (lower half of Table 7). For the periods with dividend-collecting investors, the coefficient of $(F_t - P_t)$ is significantly positive in both the fundamental (FUND; 0.401) and the combined (COMBINED; 0.419) models. For the periods with only speculating investors, the coefficient of $(P_t - P_{t-1})$ is significantly negative in both trend (TREND; -0.162) and combined (COMBINED; -0.180) models. These results confirm that the expectations about future prices are formed based on

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26 $(F_t - P_t)$ is also significant in the fundamental and combined models, albeit with much smaller estimated coefficients (0.070 and 0.065) as compared to the periods with dividend-collecting investors (0.401 and 0.419). We can infer that the trend model is better supported over the fundamental model in periods with speculating investors for low as well as high-liquidity sessions.
the fundamentals in a market with dividend-collecting investors, and are based on recent price changes in a market with only speculating investors.

6. Discussion and Concluding Remarks

This paper proposes, and empirically tests in the laboratory, the idea that security prices tend to deviate from fundamental values when markets are populated by speculating investors. In such markets, investors’ expectations about the future cash flows beyond their own personal holding periods are not relevant for valuation, because cash flows beyond the holding periods are replaced in trading decisions by expectations about the future prices. Standard finance theory, however, claims that even in such markets prices tend toward the fundamental value constituting the rational expectation equilibrium (REE). We argue that this well-known proposition critically depends on implausibly strong assumptions about all generations of investors forming common knowledge rational expectations. We conjecture that these assumptions cannot be met in practice, causing prices to deviate from fundamentals and become indeterminate in financial markets populated by speculating investors.

We conduct security market experiments with overlapping generations structure where all investors have identical common knowledge beliefs about the fundamental value of the security. Our laboratory results show that (i) deviations of prices from fundamental values increase significantly when only speculating investors are present in the market. This result is consistent with our proposition that speculating investors fail to form rational expectations to bring prices into the proximity of fundamental values. (ii) We further find that the larger the number of remaining security transfers across generations till maturity of the security (the shorter the holding period), the larger the absolute mispricing in the market. (iii) We vary liquidity supply across our treatments and find that higher liquidity leads to overpricing of the security, while low-liquidity on average leads to underpricing of the security, and these over-
and under-pricing are amplified by the presence of speculating investors. (iv) When specu-
lat- 
ing investors are present, price expectations are formed based not on backward induction from 
the fundamentals (not by rational expectations), but on forward induction from recent price 
changes.

These laboratory results do not support the REE prediction made by standard finance 
theory. Given our results, it is reasonable to consider that price indeterminacies and bubbles in 
markets outside the laboratory may arise from the presence of speculating investors. The 
mechanism for the price bubbles observed in our laboratory is unlike the mechanisms sug-
gested in the extant theoretical literature – rational bubble models (e.g. Blanchard and Watson 
1982, Tirole 1985) and heterogeneous belief models (e.g. Allen et al. 2006, DeLong et al. 
1990a, 1990b, Dow and Gorton 1994, Froot et al. 1992). We find that even in a very simple 
market environment, it is a difficult task for speculating investors to form common knowledge 
rationa l expectations of future prices. Analysis of the price prediction data gathered in the 
laboratory also confirms this, casting doubt on the standard assumption about the investors’ 
ability to form rational expectations. Since securities traded in real financial markets have 
more complex features (uncertainty, information asymmetries, heterogeneous beliefs regard-
ing future cash flows), we conjecture that investors in the field face greater challenges in 
forming rational expectation. Building theories by relaxing the assumption underlying rational 
expectations seems to be one way to explain the price volatility and indeterminacy in financial 
markets (see, for example, Adam and Marcet 2011).

In some earlier experiments, financial markets converge to the static REE (Plott and 
Sunder 1982, 1988) in which traders are able to infer the current state of the world from the 
observed market phenomena. In contrast, the REE examined in our markets is dynamic or 
inter-temporal; investors’ expectations of future prices are based on a series of rational expec-
tations on future investors’ behavior and their expectations. This dynamic REE is implausible since it requires investors of extraordinary cognitive and coordination ability.

Several implications emerge from this study. First, greater inefficiency, pricing anomalies, and the so-called “behavioral” phenomena which cause security prices to depart from fundamentals are more likely to be observed when markets are populated with speculative investors. Second, the excess price volatility in real stock markets reported by previous empirical studies (e.g. LeRoy and Porter 1981, Shiller 1981) may be caused by the existence of speculative investors. This raises the empirical question of whether stock price volatility is larger in periods and markets with more speculative investors. Third, securities with longer maturities are more prone to price indeterminacy. Given investors’ holding periods, as the maturity becomes longer, the number of generations that hold the security between the present and the maturity date increases, and it becomes more difficult for investors to form rational expectations and prices tend to deviate more from fundamentals. Fourth, the securities with longer durations are more likely to deviate from the fundamentals.27 As the duration of a security increases, investors receive a smaller portion of its value from cash flow within their holding periods and a larger fraction of their valuation depends on capital gains (future sales prices) for which they face a difficulty in forming expectation. This interpretation is consistent with historical observation that price bubbles often occur in securities with longer duration, such as high-growth and new technology stocks. Fifth, this duration argument points to a possibility that dividend policy matters in security valuation, which challenges Miller and Modigliani’s (1961) irrelevance proposition, the tax arguments notwithstanding. As firms with larger payout ratios have shorter durations, we should expect that their stock prices are more stable and closer to the fundamentals than the prices of firms with smaller or zero payouts. Sixth, monetary policy and prudence policy would matter for the stabilization of security

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27 Duration is the weighted average time of a security’s cash flows.
prices. Our laboratory data show that excess or shortage of liquidity causes prices to deviate significantly from fundamentals in markets with speculating investors. This finding implies that controlling money stock and credit availability are important for stabilizing not only the real economy but also security prices when markets are dominated by speculating investors. Seventh, to the extent security prices are destabilized by speculating investors, it is possible to develop an argument to support higher tax rates on short-term capital gains. However, effectiveness of policies for suppressing price bubbles and indeterminacy is a subject for future exploration.
References


Table 1: Treatment overview

<table>
<thead>
<tr>
<th>No. of entering generations</th>
<th>Liquidity</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>HIGH (C/A-ratio=10)</td>
<td>LOW (C/A-ratio=2)</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>T1H</td>
<td>T1L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>T2H</td>
<td>T2L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>T4H</td>
<td>T4L</td>
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</tr>
<tr>
<td>8</td>
<td>T8H</td>
<td>T8L</td>
<td></td>
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Table 2: Treatment parameterization

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<th>T1H</th>
<th>T1L</th>
<th>T2H</th>
<th>T2L</th>
<th>T4H</th>
<th>T4L</th>
<th>T8H</th>
<th>T8L</th>
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<tbody>
<tr>
<td>Market setup</td>
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<td>Number of generations</td>
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<td>3</td>
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<td>5</td>
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<tr>
<td>Terminal dividend $D$</td>
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<td>50</td>
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<tr>
<td>Initial no. securities/investor $G_0$</td>
<td>32</td>
<td>32</td>
<td>16</td>
<td>16</td>
<td>8</td>
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<tr>
<td>Initial no. securities/G1-G8</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Total securities outstanding</td>
<td>160</td>
<td>160</td>
<td>80</td>
<td>80</td>
<td>40</td>
<td>40</td>
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<td>20</td>
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<tr>
<td>Total value of securities</td>
<td>8,000</td>
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<td>4,000</td>
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<td>2,000</td>
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<tr>
<td>Initial cash/investor $G_0$</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td>Initial cash/investor G1-G8</td>
<td>16,000</td>
<td>3,200</td>
<td>8,000</td>
<td>1,600</td>
<td>4,000</td>
<td>800</td>
<td>2,000</td>
<td>400</td>
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<tr>
<td>Total cash</td>
<td>80,000</td>
<td>16,000</td>
<td>40,000</td>
<td>8,000</td>
<td>20,000</td>
<td>4,000</td>
<td>10,000</td>
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<td>Cash-to-asset value ratio (C/A-ratio)</td>
<td>10</td>
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<td>10</td>
<td>2</td>
<td>10</td>
<td>2</td>
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<td>2</td>
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<td>Invited subjects (3n+3)</td>
<td>15$^a$</td>
<td>15$^a$</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
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<td>Participating subjects</td>
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<td>108</td>
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<td>Exchange rates (Taler/€)</td>
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<td></td>
<td></td>
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<td>Generation 0 (G0)</td>
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<td>100</td>
<td>100</td>
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<td>Transition generations</td>
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<td>100</td>
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<td>100</td>
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<td>100</td>
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<tr>
<td>Last generation</td>
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<td>200</td>
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<tr>
<td>Predictors</td>
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<td>133</td>
<td>133</td>
<td>133</td>
<td>133</td>
<td>133</td>
<td>133</td>
<td>133</td>
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<tr>
<td>Expected payout/subject (€)</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
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<td>16</td>
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</tr>
</tbody>
</table>

Notes: The following parameters are identical across all treatments: Number of investors/generation (5); number of active generations (2); active investors (10 investors); period length (120 sec.); total number of periods (16); number of markets per treatment (6); number of expected transactions (160).

$^a$ In treatments T1L and T1H we invited 15 subjects instead of 18 as no subject pool for future generations is needed. Ten subjects were investors, and five served as predictors.
Table 3: Average *Period-RAD* by Treatment and Period

Panel A: High-liquidity Sessions

<table>
<thead>
<tr>
<th>Period</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>1.423</td>
<td>0.582</td>
<td>0.354</td>
<td>0.293</td>
<td>0.301</td>
<td>0.321</td>
<td>0.390</td>
<td>0.374</td>
<td>0.382</td>
<td>0.396</td>
<td>0.303</td>
<td>0.323</td>
<td>0.286</td>
<td>0.387</td>
<td>0.259</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>1.825</td>
<td>1.016</td>
<td>0.310</td>
<td>0.406</td>
<td>0.467</td>
<td>0.536</td>
<td>0.541</td>
<td>0.477</td>
<td>0.676</td>
<td>0.865</td>
<td>0.705</td>
<td>0.313</td>
<td>0.232</td>
<td>0.468</td>
<td>0.232</td>
<td>0.179</td>
</tr>
<tr>
<td>T4</td>
<td>1.552</td>
<td>1.471</td>
<td>1.342</td>
<td>1.038</td>
<td>1.182</td>
<td>0.960</td>
<td>0.798</td>
<td>0.499</td>
<td>0.697</td>
<td>0.509</td>
<td>0.470</td>
<td>0.559</td>
<td>0.325</td>
<td>0.210</td>
<td>0.167</td>
<td>0.040</td>
</tr>
<tr>
<td>T8</td>
<td>1.879</td>
<td>1.249</td>
<td>1.373</td>
<td>1.392</td>
<td>1.409</td>
<td>1.498</td>
<td>1.177</td>
<td>0.991</td>
<td>1.108</td>
<td>1.082</td>
<td>1.607</td>
<td>1.733</td>
<td>1.019</td>
<td>0.647</td>
<td>0.550</td>
<td>0.273</td>
</tr>
</tbody>
</table>

Panel B: Low-liquidity Sessions

<table>
<thead>
<tr>
<th>Period</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.226</td>
<td>0.139</td>
<td>0.106</td>
<td>0.098</td>
<td>0.077</td>
<td>0.101</td>
<td>0.103</td>
<td>0.138</td>
<td>0.152</td>
<td>0.158</td>
<td>0.147</td>
<td>0.070</td>
<td>0.084</td>
<td>0.083</td>
<td>0.085</td>
<td>0.085</td>
</tr>
<tr>
<td>T2</td>
<td>0.596</td>
<td>0.425</td>
<td>0.299</td>
<td>0.278</td>
<td>0.503</td>
<td>0.695</td>
<td>0.743</td>
<td>0.760</td>
<td>0.342</td>
<td>0.352</td>
<td>0.222</td>
<td>0.146</td>
<td>0.071</td>
<td>0.053</td>
<td>0.085</td>
<td>0.115</td>
</tr>
<tr>
<td>T4</td>
<td>0.385</td>
<td>0.489</td>
<td>0.495</td>
<td>0.543</td>
<td>0.517</td>
<td>0.527</td>
<td>0.556</td>
<td>0.653</td>
<td>0.535</td>
<td>0.530</td>
<td>0.511</td>
<td>0.459</td>
<td>0.341</td>
<td>0.163</td>
<td>0.110</td>
<td>0.052</td>
</tr>
<tr>
<td>T8</td>
<td>0.527</td>
<td>0.214</td>
<td>0.249</td>
<td>0.398</td>
<td>0.315</td>
<td>0.313</td>
<td>0.355</td>
<td>0.499</td>
<td>0.446</td>
<td>0.584</td>
<td>0.628</td>
<td>0.741</td>
<td>0.663</td>
<td>0.679</td>
<td>0.230</td>
<td>0.066</td>
</tr>
</tbody>
</table>

Notes: Cells shaded grey are periods where the last, dividend-collecting generation of investors is present. In the other periods (no shading) only speculating investors are present.
Table 4: Comparison of Average Period-RAD between Periods with Dividend-collecting Investors and Periods with only Speculating Investors

<table>
<thead>
<tr>
<th></th>
<th>(1) Periods with dividend-collecting investors</th>
<th>(2) Periods with only speculating investors</th>
<th>Difference (2)−(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High liquidity Session (Treatment H)</td>
<td>0.401 (177)</td>
<td>1.024 (204)</td>
<td>0.623***</td>
</tr>
<tr>
<td>Low liquidity Session  (Treatment L)</td>
<td>0.140 (178)</td>
<td>0.502 (203)</td>
<td>0.362***</td>
</tr>
</tbody>
</table>

Notes: Sample size is in parentheses. *** indicates that the difference is statistically significant at 1% level by two-sided t-test.
Table 5: Investors’ Holding Periods and Average Period-RAD

Panel A: Average Period-RAD by Treatment

<table>
<thead>
<tr>
<th>Treatment (Average holding periods)</th>
<th>T1 (16.0 periods)</th>
<th>T2 (10.7 periods)</th>
<th>T4 (6.4 periods)</th>
<th>T8 (3.6 periods)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-liquidity session (H)</td>
<td>0.421 (95)</td>
<td>0.586 (94)</td>
<td>0.739 (96)</td>
<td>1.187 (96)</td>
</tr>
<tr>
<td>Low-liquidity session (L)</td>
<td>0.116 (94)</td>
<td>0.355 (96)</td>
<td>0.429 (96)</td>
<td>0.429 (95)</td>
</tr>
</tbody>
</table>

Notes: Sample size is in parentheses.

Panel B: Differences between Average Period-RAD across Treatments

<table>
<thead>
<tr>
<th>High-liquidity Session (H)</th>
<th>T2</th>
<th>T4</th>
<th>T8</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.165*</td>
<td>0.318***</td>
<td>0.766***</td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td>0.153</td>
<td>0.601***</td>
</tr>
<tr>
<td>T4</td>
<td></td>
<td></td>
<td>0.448***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low-liquidity Session (L)</th>
<th>T2</th>
<th>T4</th>
<th>T8</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.239***</td>
<td>0.313***</td>
<td>0.313***</td>
</tr>
<tr>
<td>T2</td>
<td>0.075</td>
<td>0.074</td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td></td>
<td></td>
<td>0.000</td>
</tr>
</tbody>
</table>

Notes: Two-sided t-test significance levels * (10%), ** (5%) and *** (1%).
Table 6: Comparison of Average *Period-RD* between Periods with dividend-collecting Investors and Periods with only Speculating Investors

<table>
<thead>
<tr>
<th></th>
<th>(1) Periods with dividend-collecting investors</th>
<th>(2) Periods with only speculating investors</th>
<th>Difference (2)−(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-liquidity session</td>
<td>0.295 (177)</td>
<td>0.741 (204)</td>
<td>0.446***</td>
</tr>
<tr>
<td>(Treatment H)</td>
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<tr>
<td>Low-liquidity session</td>
<td>−0.087 (178)</td>
<td>−0.340 (203)</td>
<td>−0.253***</td>
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<tr>
<td>(Treatment L)</td>
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</table>

Notes: *** indicates that the difference is statistically significant at 1% level by two-sided t-test.
Table 7: Price Expectations Model Estimates

<table>
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</thead>
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<td>Periods with dividend-collecting investors</td>
<td></td>
<td>Periods with only speculating investors</td>
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<tr>
<td></td>
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<td>COMBINED</td>
<td>FUND</td>
<td>TREND</td>
<td>COMBINED</td>
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<td>Const.</td>
<td>1.672**</td>
<td>-0.709</td>
<td>1.733**</td>
<td>4.159**</td>
<td>-2.611*</td>
<td>0.515</td>
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<tr>
<td></td>
<td>(0.622)</td>
<td>(1.595)</td>
<td>(0.620)</td>
<td>(1.895)</td>
<td>(1.310)</td>
<td>(1.449)</td>
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<tr>
<td>(F_t - P_t)</td>
<td>0.197***</td>
<td>0.211***</td>
<td>(0.043)</td>
<td>0.109*</td>
<td>(0.061)</td>
<td>(0.075)</td>
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<tr>
<td></td>
<td>(0.031)</td>
<td>(0.044)</td>
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<td>(0.049)</td>
<td>(0.043)</td>
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</tr>
<tr>
<td>(P_t - P_{t-1})</td>
<td>0.020</td>
<td>0.067</td>
<td>-0.301***</td>
<td>-0.270***</td>
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<tr>
<td></td>
<td>(0.031)</td>
<td>(0.044)</td>
<td>(0.061)</td>
<td>(0.049)</td>
<td>(0.043)</td>
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<td>0.002</td>
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<td>0.00</td>
<td>0.39</td>
<td>0.14</td>
<td>0.30</td>
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Notes: Standard errors clustered by session in parenthesis. Significance levels: * (10%), ** (5%) and *** (1%).
**Figure 1: Overlapping generations**

| Treatment | Period | # of Subjects | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | End of 16 |
|-----------|--------|---------------|---|---|---|---|---|---|---|---|---|-----|-----|-----|-----|-----|-----|---------|
| T1        |        |               | 5 | G0| G1|    |    |   |   |   |   |     |     |     |     |     |     |     | D       |
| T2        |        |               | 5 | G0| G1| G2|    | D |   |   |   |     |     |     |     |     |     |     |         |
| T4        |        |               | 5 | G0| G1| G2| G3|    |   |   |   |     |     |     |     |     |     |     |         |
| T8        |        |               | 5 | G0| G1| G2| G3| G4| G5| G6| G7| G8  |     |     |     |     |     |     |         |

Notes: D means that the last generation of investors receives terminal dividends (50) at the end of Period 16.
Figure 2: Period-wise Average Transaction Prices in High-liquidity Treatments.

Notes: Volume-weighted mean prices from six individual sessions (grey lines), mean prices across the six individual sessions (blue bold line with hollow circles) and Fundamental Value (FV, red bold straight line) by period on vertical axis. Each panel is identified by treatment: T1H, T2H, T4H, and T8H.
Figure 3: Period-wise Average Transaction Prices in Low-liquidity Treatments.

Notes: Volume-weighted mean prices from six individual sessions (grey lines), mean prices across the six individual sessions (blue bold line with hollow circles) and Fundamental Value (FV, red bold straight line) by period on vertical axis. Each panel is identified by treatment: T1L, T2L, T4L, and T8L.
Figure 4:
Average Period-RAD for each period number: Comparison between the markets with dividend-collecting investors and those with only speculating investors.

Panel A: high-liquidity treatments; Panel B: low-liquidity treatments.

Notes: In periods 15 and 16 dividend-collecting investors are present in all treatments (see, Table 3). Therefore only black bars are shown for these two periods.
Figure 5: Average Period-RAD Conditional on the Number of Entering Generations Left. Panel A: High-liquidity Treatments; Panel B: Low-liquidity Treatments.

Notes: Grey shaded bars represent values based on periods where only speculating investors were present. The black bold line represents periods where dividend-collecting investors were present. ***, **, or * indicates that the average Period-RAD across periods where only speculating investors were present is significantly different at 1%, 5%, or 10% level, respectively, from the average Period-RAD across periods with dividend-collecting investors (two-sided t-test).
Figure 6: Average Period-RD Conditional on the Number of Entering Generations Left. Panel A: High-liquidity Treatments; Panel B: Low-liquidity Treatments.

Notes: Grey shaded bars represent values based on periods where only speculating investors were present. The black bold line represents periods where dividend-collcting investors were present. ***, **, or * indicates that the average Period-RD across periods where only speculating investors were present is significantly different at 1%, 5%, or 10% level, respectively, from the average Period-RD across periods with dividend-collcting investors (two-sided t-test).
Appendix A: Instructions of the experiment

We welcome you to this experimental session and kindly ask you to refrain from talking to each other for the duration of the experiment. Please follow the instructions given by the experimenter. If you have any questions regarding the procedure or the instructions of the experiment, contact one of the supervisors by raising your hand and your question will be answered privately. Violation of instructions risks forfeiting all your earnings.

General Instructions
This is an experiment in market decision making. The instructions are simple, and if you follow them carefully and make good decisions, you will earn more money.

In this session, we conduct a market experiment in which you can trade an security we shall call “shares”. You are a member of a cohort of 18 subjects. The composition of this cohort remains constant throughout the experiment. You will participate in the market as an active investor (“investor”) only in some, not all, periods. If you do not actively participate in the market you will be asked to make certain predictions about the market.

The process of assignment to the trading role in the market will be described shortly. This session consists of a total of 16 periods and trading in each period lasts for 120 seconds.

Your total earnings from participating in the market as a investor and from the prediction task, denoted in Talers throughout the experiment, will be converted into Euros and paid to you in cash at the end of the session. The more Talers you earn, the more Euros you will take home.

Course of the experimental session
Market experiment
Instructions to the experiment and explanation of the trading mechanism
2 trial periods (not relevant for payment) and questionnaire
Market experiment
Private payment

33 Instructions are for T2L. Instructions for other treatments and German translations used in Innsbruck are available from the authors upon request. Trading screens are identical across treatments (except parameter values).
Active market participants

Assignment process
Figure 1 illustrates the assignment process in the session. At the beginning of Period 1, five subjects will be randomly assigned to Cohort 1 while another five will be randomly assigned to Cohort 2. Members of these two cohorts will participate in trading in Periods 1 to 8. The remaining eight subjects will constitute the “pool” and its members will participate in the prediction task (see below), not in trading, in these periods.

At the end of Period 8, five of the eight members of the pool are randomly chosen to form Cohort 3 who enters the market beginning Period 9; members of Cohort 2 stay in the market; and members of Cohort 1 leave the market to join the pool.

The pool always has eight members who predict, and the market always has a total of 10 members (5 from each of the two cohorts) who trade. After period 8, the “old” cohort 1 leaves the market, and the new Cohort 3 enters. Note that your entry and exit from the market (i.e., which cohort you will be a part of) will be determined by a random (but fair) program.

Figure 1

<table>
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<th>Period</th>
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<td>Cohort 2</td>
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<tr>
<td>Cohort 3</td>
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Share value
At the end of the session (period 16), any shares in the hands of the members of Cohort 3 will pay a dividend of 50 Taler per unit, while the shares held by cohort 2 will not pay a dividend. The shares do not pay any other dividends in earlier periods and are worthless after paying the dividend at the end of Period 16 to members of Cohort 3.

Endowments and payment
Cohort 1 will enter the market at the beginning of Period 1 with an endowment of 16 shares in the hands of each member and no cash. When they exit the market at the end of Period 8, any remaining shares in their hands are worthless. When cohort 1 exits, any unsold shares
(worthless to them) will be distributed among randomly chosen members of the entering cohort at no cost.

*Cohort 2* will enter the market at the beginning of period 1 with an endowment of 1,600 Taler each and no shares. They may use these Talers to buy any number of shares they wish to. Again, when they exit the market at the end of Period 16, any remaining shares in their hands are worthless.

Cohort 3 also enters the market with 1,600 Talers each and will be able to use these Talers to buy any shares they wish to during periods 9-16. At the end of Period 16, any shares remaining in their hands pay a dividend of 50 Taler each, which is added to their Taler holdings.

When Cohort 1 and 2 leave the market their Taler holdings will be converted into EURO at the following exchange rates: **Cohort 1 and 2**: 100 Taler = 1 Euro; **Cohort 3**: 200 Taler = 1 Euro.

**Trading**

Trading will take place through a double auction (see Figure 2, explained in detail later on by the instructor). As a buyer you can submit as many bids as you wish, each for a single share, provided that you have enough cash to pay if your bids are accepted. Buying a share reduces your cash balance by the purchase price. Similarly, as a seller you can submit offer prices at which you are willing to sell each of the shares you own. You can accept any offer submitted by others if you have the cash to pay; and you can accept any bid from others if you own a share. If a bid or ask is accepted, a transaction is recorded at the bid/ask price. Prices are determined only by the bids, asks and acceptances submitted by the investors in the market. Note that neither your share nor the Taler inventories are allowed to fall below zero. Outstanding bids and offers can be canceled at any time without cost. All bids and asks are automatically cancelled at the end of a period.
Figure 2: Trading screen

Investor:
Information about your task (investor), period you leave the market, current Share and Taler holdings.

Predictors:
Information about your task (predictor) and your forecast.

List of all BIDS from all investors - your own bids are written in blue. The bid with blue background is always the most attractive, yielding the highest revenues for the seller.

List of all ASKS from all investors - your own asks are written in blue. The ask with blue background is always the most attractive, because it is the cheapest for the buyer.

SELL: You sell one unit, given the price with the blue background.

BUY: You buy one unit, given the price with the blue background.

Current Market Price (of Stock)

Price - Chart of current period

Summary tables of your own BIDS and ASKS. With the "CANCEL"-buttons you can delete your own limit orders.

BID: enter the price you are willing to pay for one unit. Trade does not take place until another participant accepts your bid!!!

ASK: seller's analogue to BID - see above.

- your own limit orders are written in blue background.
- your limit order will appear above the corresponding chart.
Market predictions

At the beginning of each period participants who do not actively participate in the market are asked to predict the average of the prices at which shares will be traded during that period. Those participants will be able to monitor the market. At the end of each period, their prediction will be compared to the actual average trading price. The more accurate the prediction, the more Talers they earn.

Each period, you will earn 140 Taler minus the absolute value of your prediction error. For example, suppose, you predict a price of PP and the actual average trading price is AP, you have a prediction error of |PP-AP|, and your prediction earnings will be 140 minus |PP-AP|.

Taler will be converted into EURO at an exchange rate of 133 Taler = 1 Euro. You have 30 seconds to enter your prediction. If you do not enter a prediction value in time or your earnings would be negative, you will earn 0 Euro.

At the end of each period you see a History Screen (Figure 3) for 15 seconds providing you with cumulative information.

Important information

- No interest is paid for Taler holdings.
- Each trading period lasts for 120 seconds.
- You have 30 sec. to enter your prediction.
- The session ends after 16 periods.
- Offers to buy/sell shares can be placed in the range from 0 to 999 Taler (with at most one decimal places).
- Members of Cohort 3 (and only this cohort) receive a dividend of 50 Talers per share for their holdings at the end of Period 16. Shares are worthless thereafter.
- Use the full stop (.) for decimal.
**Trial periods**
Before the actual session starts, there will be two trial periods to familiarize you with the trading mechanism. Each participant will be an active investor split into two cohorts. Members of Cohort 1 receive 4 shares and no Taler, while members of Cohort 2 receive 400 Taler and no shares. The security pays a dividend of 50 to members of Cohort 2. In contrast to the main experiment, you will also make predictions about the average trading price. Trial periods have no influence on your Euro earnings!

**Figure 3: History screen**

- **Closing Price of the security and payment from market participation (in the respective period).**
- **Period, subjects' task.**
- **End-of-period share and Taler holdings.**
- **Average trading price, predictions and payment from the prediction task.**
- **Price-Chart, displaying average prices of previous periods.**

**Your payment from the experiment**
Your payment from the experiment equals the sum of earning from participation in the market plus the sum of earning from the prediction task. This amount will be paid to you in cash.

\[
\text{Your payment} = \text{Sum of earnings from market experiment} + \text{Sum of earnings prediction tasks}
\]
Appendix B: Questionnaire for understanding (correct answers in italic font).

1. How many trading periods are there during the session? *16*
2. For how many seconds does one trading period last? *120 sec*
5. Can you buy a share when you do not have enough cash to pay for the purchase? *Yes/No.*
6. Can you sell a share when you do not have a share? *Yes/No.*
7. What are the two ways of buying a share? (i) *Submit a bid or accept an open offer to sell (ask).* (ii) Submit an offer (ask) or accept an open offer to buy (bid). (iii) Submit a bid or accept an open offer to buy (bid). (iv) Submit an offer (ask) or accept an open offer to sell (ask).
8. What are the two ways of selling a share? (i) Submit a bid or accept an open offer to sell (ask). (ii) *Submit an offer (ask) or accept an open offer to buy (bid).* (iii) Submit a bid or accept an open offer to buy (bid). (iv) Submit an offer (ask) or accept an open offer to sell (ask).
9. You are a member of cohort 2. How are your Taler converted into real euros? (i) Exchange rate of 50 (100) Taler to 1 Euro. (ii) Exchange rate of 100 (500) Taler to 1 Euro. (iii) Exchange rate of 200 (1000) Taler to 1 Euro. *Values in parenthesis for high cash treatments. Correct answers vary by treatment.*
10. Are you allowed to talk, use email, or surf the web during the session? *No.*
11. Your role is “predictor”: You predict a price which is 8 Taler less than the actual average price of the period. What is your profit (in Taler)? *140-8=132*
12. You are a member of cohort 1 and you will leave the market at the end of that period. What is the value of the shares you are holding at the end of the period? (i) Shares have a value 50. (ii) *Shares have a value of 0.* (iii) Shares have a value of 200.