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Investment Horizons and Price Indeterminacy in Financial Markets[*]

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Abstract

We examine how different investment horizons, and consequently the number of hands through which a security passes during its life, affect prices in a laboratory market populated by overlapping generations of investors. We find that (i) price deviations are larger in markets populated only by short-horizon investors compared to markets with long-horizon investors; (ii) for a given maturity of security, price deviations increase as investment horizons shrink (and frequency of transfers increases); and (iii) short investment horizons create upward pressure on prices when liquidity is high and downward pressure when liquidity is low.

Keywords: Experimental finance; short-horizon investors; rational expectations; price efficiency; overlapping generations.

JEL-Classification: C91; G11; G12.

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1. Introduction

According to standard finance theory, prices of securities are close to, or tend towards, their fundamental value – the sum of discounted present values of expected future cash flows. Variations in investment horizons of investors do not enter the theory. Even if a market is dominated by short-horizon investors, they are assumed to form rational and common knowledge expectations about the behavior of subsequent generations of investors all the way from near to distant future, and the resulting rational expectation equilibrium (REE) assures prices near the fundamental values at any time.

The feasibility of markets attaining the rational expectation equilibrium (REE) 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 be expected to hold in practice where heterogeneity of expectation formation across individuals and the lack of common knowledge thereof are more of a norm than an exception. Some investors, or entire generations of them, may not form rational expectations, and even if all generations of investors do so, the challenge of such expectations to be common knowledge across or even within the generations is unlikely to be met.

When these two conditions are not met, there is little reason for short-horizon investors to rationally expect future prices and therefore current market prices to equal the fundamental values of the securities traded. Market prices may be dominated by other factors and become indeterminate. For a security with a given maturity, as the investment horizon of investors gets shorter, the number of times the security will change hands (i.e., the number of generations that hold the security) between present and the maturity increases. With this increase, the chances of all these generations of investors forming rational expectations and such expectations being common knowledge also declines, and the likelihood and magnitude of price indeterminacy should be expected to get amplified.

Several theoretical contributions suggest that investors' short-trading horizons may cause security prices to deviate from their fundamental values. The rational bubble literature shows the possibility that price bubbles emerge as the rational expectation equilibrium (REE) for securities with infinite maturity (e.g. Blanchard and Watson 1982, Tirole 1985). In a second class of models deviation from fundamentals is rooted in short-horizon investors' heterogeneous beliefs about future dividends and prices; they form their expectations of future prices based on future investors' beliefs or noisy public information, and generate current prices that depart from fundamentals (Allen, et al. 2006, Delong, et al. 1990a, 1990b, Dow and Gorton 1994, Froot, et al. 1992). All these models assume that *at least* the current short-horizon investors form rational expectations of future prices considering how they are determined by future investors' behavior or beliefs (whether rational or not).

In contrast to the prior research, we explore the feasibility of investors forming rational expectation by dropping the infinite maturity and heterogeneity of dividend expectations. We design and conduct experimental markets in which a security has common knowledge finite maturity and common knowledge certain dividends. By excluding the factors that are supposed to cause the prices to deviate from the fundamentals in the above mentioned classes of models, we examine if the deviation between prices and fundamentals may be rooted in more basic difficulty of forming rational expectations and arriving at REE.

In our laboratory security markets, we vary the length of trading horizon of investors, and consequently the number of times the security changes hands during the 16 trading periods until maturity. A single kind of simple securities (each paying a single, certain, common knowledge terminal dividend of 50 at the end of Period 16) is traded in these markets. This simplest of designs leaves little room for doubt in the mind of any subject that the fundamental value of the security is 50. The security market has an overlapping generations structure (Tirole, 1985). In any given period, two generations of investors are in the market. Members of entering, “younger” generations are endowed with cash, so they can buy securities from the overlapping “older” generation which will leave the market. Investors can sell their securities to members of the following overlapping generation before exiting the market. Since only the members of the very last generation collect the dividends, all others are short-horizon investors trading in the hope of capital gains (see Figure 1).

Standard pricing models suggest that the market price of this security should be close to the fundamental value of 50 throughout. Indeed, the simple calculation of rational expectation equilibrium (REE) tells us that the price is equal to 50. Even though short-horizon investors exit the market and do not receive terminal dividends, they could rationally predict the future sales price being equal to 50, because they would consider that all subsequent generations of investors form the same rational expectations.

This REE outcome, however, was not supported in our laboratory. The experimental results show that with short-horizon investors in the market, transaction prices deviate substantially from the fundamental value of 50. Specifically, we find that (i) in periods with only short-horizon investors present prices are more likely to depart from fundamentals, compared to prices in periods with long-horizon investors present, (ii) prices are more likely to depart from fundamentals as investment horizons shrink (i.e., the securities changes hands more often over their 16 periods of life), and (iii) concerning liquidity we find that total amount of cash supplied in the market affects the direction of price deviation in a market with short-horizon investors. While prices tend to exceed the fundamental value in high-liquidity sessions, they 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 the presence of short-horizon investors, price expectations are formed based not on backward induction from the fundamentals, but forward induction from recent price changes. The data point to the possibility that short trading horizons amplify mispricing of securities in financial markets outside the laboratory, causing positive and negative price bubbles depending on the availability of liquidity. The model, experimental design, hypotheses, results and concluding remarks are given in the following sections.

2. Investment Horizons and Security Prices

Let us consider a security that matures at time $t+m$. For simplicity, 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 fundamental value of the security at time t is:

$$F_t = D \quad (1)$$

2.1. Pricing in a market with long-horizon investors

We define long-horizon investors as those whose investment horizons are longer than or equal to m. They hold the security to its maturity 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 homogenous investors) is equal to the fundamental value of the security D (without loss of generality, setting discount rate to zero):

$$P_t = V_t = D \quad (2)$$

2.2. Pricing in a market with short-horizon investors

Next consider short-horizon investors with investment horizon $k < m$, 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. The value of the security to these investors V_t and its price P_t in a market populated by such homogenous investors is:

$$P_t = V_t = E_t (P_{t+k}) \quad (3)$$

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, it seems that the price can take any value depending on investors' expectations, i.e., prices are not necessarily anchored to the fundamental value.

The standard security pricing models, however, assume that short-horizon investors form rational expectations of future prices through a recursive process from near to distant future, resulting in a rational expectation equilibrium (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 $t+k$.

$$P_{t+\mathrm{k}} = V_{t+k} = E_{t+k} (P_{t+2k}) \quad (4)$$

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

$$E_t (P_{t+k}) = E_t (E_{t+k} (P_{t+2k})) \quad (5)$$

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

$$P_t = E_t (E_{t+k} (P_{t+2k})) \quad (6)$$

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 $2k$ time periods,

$$P_{t+2k} = E_{t+2k} (P_{t+3k}). \quad (7)$$

The rational expectation of investors at time $t+k$ is

$$E_{t+k} (P_{t+2k}) = E_{t+k} (E_{t+2k} (P_{t+3k})). \quad (8)$$

Then, the second-order expectations of investors at time t are described as

$$E_t\,(E_{t+k}\,(P_{t+2k})) = E_t\,(E_{t+k}\,(E_{t+2k}\,(P_{t+3k}))) \tag{9}$$

Substituting (9) into (6), we get

$$P_t = E_t\,(E_{t+k}\,(E_{t+2k}\,(P_{t+3k}))). \tag{10}$$

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.

$$P_t = E_t\,(E_{t+k}\,(E_{t+2k}\,(...E_{t+m-2k}(P_{t+m-k})))...). \tag{11}$$

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

$$P_{t+m-k} = D. \tag{12}$$

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

$$E_{t+m-2k}\,(P_{t+m-k}) = D. \tag{13}$$

Substituting (13) into (11),

$$P_t = E_t\,(E_{t+k}\,(E_{t+2k}\,(...E_{t+m-3k}(D)))...). \tag{14}$$

By assumption, since D is common knowledge,

$$P_t = D = F_t. \tag{15}$$

This completes the derivation of the rational expectations equilibrium (REE) that $P_t = F_t$. Under the standard security pricing model, even when investors have short trading horizons, the price of the security with fixed maturity is determined through the investors recursively forming a series of rational expectations and is equal to the fundamental value of the security at any time. It suggests that the formation of the security price does not depend on the length of investment horizons.

2.3. Short investment horizon and 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, Delong, et al. 1990a, 1990b), investors may not believe 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 short-horizon 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' trading horizons. We explore this possibility by conducting laboratory experiment described in the next section.

3. Design of the experiment

Overlapping generations structure.

We implement security market experiments with an overlapping-generations structure as depicted in Figure 1. Each market session consists of 16 periods of 120 seconds each.[6] The

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

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.

Figure 1 about here

At the beginning of Period 1, the initial generation of traders (G0) is endowed with units of the security and no cash. There are also 'entering generations' (G1, up to G8) in a market. 'Entering generation' means that the cohort of traders enters the market with cash but no securities. They can buy securities from the 'older' generation, and then usually sell those securities to the next 'younger' generation, and exit the market when another generation enters (or the session ends). There are two overlapping generations of five traders each in the market at any time (for a total of ten active traders).

Only the very last generations of traders collect the dividend ($D = 50$), which is paid for each unit of the security at the end of Period 16. They are considered long-horizon investors as described in Section 2.1, who hold the security until maturity to collect the dividend. In our model and experiment, we define "long-horizon" to include the date maturity; it does not depend on the absolute number of periods for which the generation is present in the market. No other generation of traders collects any dividend. Any securities these traders hold at the time of their exit are worthless. They are the short-horizon investors as described in Section 2.2, and trade for capital gains.

In Treatment T1, long-horizon investors (G1) are present in all 16 periods of the market session. In T2, T4, and T8 some periods have only short-horizon 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 long-horizon 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 traders, 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). Varying the number of entering generations (1, 2, 4, and 8) induces investment horizons of 16, 8, 4, and 2 periods for initial generation, respectively, and changes the investment horizons for entering generations. The liquidity treatment varies the initial cash-to-security ratio (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 [1,2,4, or 8] indicating the number of entering generation changes and y [H or L] indicating high and low-liquidity treatments.

Table 1 about here

Security and cash endowments.

Only the initial generation of traders (G0) is endowed with units of the security. All other generations of traders (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 its terminal dividend value in H (L) treatments. 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 traders 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.[7]

Table 2 about here

Participation and subject circulation.

To keep the total number of subjects within reasonable limits we recruit 18 subjects for each session.[8] In every period, two generations (ten subjects in total) are active traders, 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. Traders 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 traders to gain experience and understanding of the environment without significantly interfering with the purpose of the experiment (see Lim et al., 1994 and 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 short-

[7]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 time pressure is not a consistent explanation of the observed data.

[8] 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).

ing 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 trader 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).

Trader payoff.

The final earnings of each member of the last generation of traders are calculated by [the number of securities in their hands at the end of Period 16]×[terminal dividend 50] + [cash holdings at the end of Period 16]. The final earnings of all other generations of traders are equal to [their cash holdings at time of exit]. Any unsold securities in the hands of these traders are forfeited, and randomly distributed in integer units among the members of the incoming generation at zero cost.[9] The final earnings of traders are converted to euros at a pre-announced rate and paid out.[10]

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

[9] 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.
[10] 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.

unit of error (subject to zero minimum).[11] 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.

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 trader 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 eliminate 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, trader and prediction tasks, and mapping from experimental actions and events to their payoffs, and to test their comprehension. In both the trial periods, all sub-

[11] The amount earned was later exchanged to Euros at a rate of 133:1. Hence, roughly one euro could be earned per prediction round.

jects played dual roles of trader 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 investment horizons of traders do not enter the formation of security prices. In a market populated with long-horizon investors, arbitrage induces prices toward the fundamental values; even in a market populated with short-horizon investors, recursive formation of rational expectations of future prices and resulting rational expectation equilibrium (REE) keeps prices near the fundamental values. Following this argument, market prices in our experimental markets should be equal to the value of terminal dividend (50), irrespective of the market being populated with short or long-horizon investors.

On the other hand, in laboratory experiment, 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 long-horizon investors (the last generation) in our model and experiment.[12] Even in those experiments security prices are rarely exactly equal to the fundamental values (Plott and Sunder 1982); such deviations are often attributed to noise trading arising from subjects' gradual and imperfect learning, confusion and irrationality.[13] 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 rational expectation equilibrium (REE) in standard security pricing models:

[12] See e.g. Smith et al. (1988) and the huge literature following it, reviewed in Palan (2013).
[13] This is true even when the security traded has a simple dividend structure (e.g. Smithet al. 2000, Lei, Noussair and Plott 2001, Kirchler et al. 2012).

Hypothesis $\boldsymbol{I_0}$*: Deviations of prices from the fundamental value do not differ during periods when only short-horizon traders are present compared to periods when long-horizon traders are present in the market.*

As shown in Figure 1, periods with only short-horizon traders (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 short and long-horizon traders are periods 1-16 (all periods) 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 to 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 short-horizon investors may not achieve rational expectations equilibrium (REE) and unhinge from their fundamental values. Short-horizon investors may not recursively form rational expectations of future prices due to the difficulty in forming their own rational expectations and/or believing subsequent generations' rational expectation formations. This possibility leads us to the following alternative hypothesis:

Hypothesis $\boldsymbol{I_A}$*: Deviations of prices from the fundamental value are larger during periods when only short-horizon traders are present compared to periods when long-horizon traders are present in the market.*

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

Next, we will examine whether, for a security of a given maturity, the length of investors' trading horizons 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 investment horizons/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 investment horizon of traders is 16 periods). In T2, G0 stay for eight periods, G1 stay for 16 periods, and G2 stay for eight periods (the average investment horizon 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 investment horizon 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 investment horizon 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 (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 investment horizons 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' trading horizons.*

Hypothesis II_A: *For a security of a given maturity, the deviation of prices from the fundamental value increases as the length of investors' trading horizons 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-security-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, ample experimental evidence 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 III$_0$*: Prices will be the same irrespective of the total amount of cash in the market.*

Hypothesis III$_A$*: 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 (volume-weighted 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.[14] Note that the funda-

[14] 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 two outliers and confirmed that the results were qualitatively

mental 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).

Figures 2 and 3 about here

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 generally close to fundamentals (50) throughout the session. While prices are relatively high in Period 1, they tend towards the 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. Noise in prices, especially transactions near 100 in one market in Period 16, 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 last generation enters. The visual inspection suggests that (i) the price formation is different between periods in which long-horizon investors (who collect the cash dividend) are present and periods in which only short-horizon 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 I_0 and II_0 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 long-horizon investors (with the last generation) present, they deviate from fundamentals in periods with only short-horizon investors. In all periods in T1L, Periods 9-16 in T2L, Periods 13-16 in T4L, and Periods 15-16 in T8L

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unchanged.

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 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).

$$RAD = \frac{1}{N}\sum_{t=1}^{N}|P_t - F_t|/|\bar{F}| \qquad (16)$$

where $|P_t - F_t|$ is 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 throughout the session.

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

$$Period\text{-}RAD = |P_t - F_t|/F_t \qquad (17)$$

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

$$Period\text{-}RAD = |P_t - 50|/50. \qquad (18)$$

We calculated *Period-RAD* for each of 16 periods in 24 high-liquidity sessions (six sessions × four treatments) and 24 low-liquidity sessions. [15]

Table 3 about here

The two panels of Table 3 show the six-session average of *Period-RAD* for each period of the high and low-liquidity treatments. Periods with long-horizon investors (the last generation) present are shaded in grey and those with only short-horizon 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) *Period-RAD* is almost always larger in markets with only short-horizon investors (white cells) than in periods with long-horizon investors (grey-shaded cells). Figure 4 show the average *Period-RAD* for each period sequence number, comparing the markets with long-horizon investors (e.g. Period 1 in T1) with those with only short-horizon 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 *Period-RAD* across markets with only short-horizon investors is larger than the one across markets with long-horizon investors. These results show that for any given period sequence number, the price deviation from the fundamentals is larger in markets with only short-horizon investors compared to that in markets with long-horizon investors. On average, this price deviation exceeds by a factor of 2.45 (4.06) under high (low) liquidity.

Figure 4 about here

[15] 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 *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 long-horizon investors (0.401 in H and 0.140 in L) with periods populated only by short-horizon 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 I_0 (that the presence of short-horizon investors makes no difference in price deviations) can be rejected in favor of the alternative I_A (that the presence of short-horizon traders increases mispricing). Apparently, short-horizon 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 short-horizon 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 short-horizon investors, conditional on the number of entering generations left until maturity. The number of entering generations left is one in Periods 1-8 in T2, Periods 9-12 in T4, and Periods 13-14 in T8. It is 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 long-horizon investors. This suggests that short-horizon 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. As we mentioned in Section 2.3, 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' trading horizons 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 generally 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 investment horizon, 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 II_0 in favor of alternative II_A.

Table 5 about here

One may argue that our experimental results are consistent with the theoretical predictions of previous literature, showing that investors' short trading horizons give 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 trading horizons 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 to form rational expectations, whereas the above literature (explicitly or implicitly) 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*):

$$\textit{Period-RD} = (P_t - 50)/50 \quad (18)$$

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),[16] but negative (−0.222) across all low-liquidity sessions; the difference (0.756) is statistically significant at 1% level This result rejects hypothesis III_0 in favor of alternative III_A. This 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 short-horizon investors in the market. Analyzing the data in more detail, Table 6 compares average *Period-RD* in periods with long-horizon investors present to those with only short-horizon investors. In high-liquidity treatments (C/A ratio = 10), the average *Period-RD* across periods with long-horizon investors is 0.295 (significantly different from zero at 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 short-horizon investors is much higher (0.741) and the difference (0.446) is statistically significant at the 1% level. This suggests that with high-liquidity, short-horizon investors amplify the magnitude of overpricing in financial markets. Usually, in a market dominated by long-horizon investors, prices above the fundamentals should be more or less driven towards fundamentals by the arbitrage transactions of long-horizon investors. However, in a market dominated by short-horizon 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 long-horizon investors are present is −0.087, which is small and negative but significantly different

[16] This overpricing is consistent with the findings of the previous literature on security market experiments: in a market with investors who can receive dividends (corresponding to long-horizon investors in our experiment), a larger cash-to-security ratio is associated with greater positive mispricing (see, Palan's (2013) survey article).

from zero at the 1% level. This indicates that the security prices under the fundamentals are not completely driven to fundamentals by the purchases of the long-horizon investors in our experiment. This imperfect arbitrage may be due to investors not having sufficient cash to buy securities under this level of liquidity.[17] In the absence of long-horizon investors, the average *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 trading horizons magnify the undervaluation in financial markets. Figure 6 presents *Period-RD* classified by the number of generations left to enter the market. In the high-liquidity treatments (Panel A) *Period-RD*s generally increase with the number of generations left to enter the market, with all but one of the *Period-RD*s being significantly larger than in the periods when the dividend-collecting last generation is present. In low-liquidity treatments (Panel B) five out of seven values of the *Period-RD*s are significantly smaller (more negative) than the *Period-RD* when the dividend-collecting last generation is present.

Figure 6 about here

We conjecture that large price declines in low-liquidity treatments could be caused by short-horizon investors' fear of future market illiquidity.[18] Suppose that short-horizon 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 under 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 short-horizon 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 short-horizon investors selling securities expecting future

[17] Note that a borrowing constraint is imposed in our experiment.
[18] In the high-liquidity treatments this is less likely as each individual trader has enough money to "buy the whole market", i.e., buy all the assets in the market at their fundamental value.

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-horizon investors sell more than long-horizon investors, and stocks held mostly by short-horizon investors experience larger price drops than stocks held mostly by long-horizon 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-horizon investors' arbitrage transactions. Cella et al. (2013) also report that stocks held mostly by short-horizon investors experience large price reversals after 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 short-horizon investors, but they generally recover and converge to fundamentals once long-horizon investors (the last generation) enter the market.

5.4 Formation of Expectations

If short-horizon 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.[19]

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.

$$E_t(P_{t+k}) = P_t + \alpha(F_t - P_t) \tag{19}$$

where α (>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

[19] We rely on predictors' estimations in the analysis of expectation formation as these estimations do not bias the price formation process in the market. Since the market information sets of the traders and predictors are identical, there is no *a priori* reason to believe that the predictions of the two sets of subjects would be different.

price, P_t. In this model any $\alpha > 0$ is consistent with the fundamental model, with $\alpha = 1$ corresponding 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.

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

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 the expectation formation:

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

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

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

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

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

where $F_t = 50$ (the terminal dividend) throughout all periods in all sessions in the experiment.[20]

[20] Hommes, et al. (2005) investigate the price expectation formation in asset market experiments. They report

The cross-sectional average of the predictors' price expectations (for the incoming period) is used as $E_t(P_{t+1})$, and the average price of the previous period and the average price of the period just ended 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 conducted the estimations on the periods with long-horizon investors as well as the periods with only short-horizon 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). This shows that the perfect rational expectation formation ($E_t(P_{t+1}) = F_t$) is not supported not only in periods with only short-horizon investors but also in periods with long-horizon investors.[21]

Although the data rejected the 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 long-horizon investors. If we first look at the results of high-liquidity sessions (upper half of Table 7), we find that in the presence of long-horizon 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 the periods with long-horizon investors, the fundamental

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 $\beta_2 = -\beta$.

[21] 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.

value of the security not only determines the transaction prices but also affects the future price expectations. Arbitrage transactions of long-horizon investors enable market participants to expect that future prices will converge to the fundamentals.

In contrast, the data from periods in which only short-horizon 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 short-horizon 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 observed reversal expectations are in a sharp contrast to the momentum (extrapolative) expectations of investors reported by previous studies in the field (Greenwood and Shleifer 2014, Vissing-Jorgensen 2003) and laboratory (Hirota and Sunder 2007, 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 long-horizon 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 short-horizon investors, the coefficient of (P_t -P_{t-1}) is significantly negative in both trend (TREND; -0.162) and combined (COMBINED; -0.180) models.[22] These results confirm that the expectations about future prices are formed based on

[22] (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 long-horizon investors (0.401 and 0.419). We can infer

the fundamentals in a market with long-horizon investors, and are based on recent price changes in a market with only short-horizon 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 traders who have short investment horizons (relative to maturity of the security). In such markets, investors' expectations about the future cash flows beyond their own personal investment horizon are not relevant for valuation, because cash flows beyond the horizon are replaced in trading decisions by expectations about 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 argued that this well-known proposition critically depends on implausibly strong assumptions about the rational expectation formation of all generations of investors and their common knowledge. We conjectured that these assumptions cannot be met in practice and that prices may deviate from fundamentals and tend to become indeterminate in financial markets populated by short-horizon investors.

We conducted security market experiments 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 short-horizon investors are present in the market. This result is consistent with our proposition that short-horizon investors fail to form rational expectations to bring prices into the proximity of fundamental values. (ii) We further found that the shorter the investment horizon (the larger the number of remaining security transfers across generations till maturity of the security), the larger the absolute mispricing in the market. (iii) We varied liquidity supply across our treat-

that the trend model is better supported over the fundamental model in periods with short-horizon investors for low as well as high-liquidity sessions.

ments and found that higher liquidity led to overpricing of the security, while low-liquidity on average led to underpricing of the security, and these over- and under-pricing are amplified by the presence of short-horizon investors. (iv) When short-horizon investors are present, price expectations are formed based not on backward induction from the fundamentals, but on forward induction from recent price changes.

These laboratory results do not support the REE prediction made by standard finance theory, which ignores the effect of the investment horizon on security prices. Given our results, it is reasonable to consider that frequently observed price indeterminacies and bubbles in markets outside the laboratory may arise from the presence of short-horizon investors (relative to the maturity of the security they are trading, e.g., gold, real estate, and corporate equity). The mechanism we test in the laboratory (in which short-trading horizons imply more transfers of the security between consecutive holders till its maturity) cause price bubbles; it is different from the ones suggested by 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 showed that even in a market with a very simple environment, it is a difficult task for short-horizon investors to form rational expectations of future prices. This was further confirmed by the analyses of the price prediction data gathered in the laboratory. These findings doubt on the validity of investors' ability to form rational expectation – a commonly applied assumption in finance literature. Since securities traded in real financial markets have far more complex features (uncertainty, information asymmetries, heterogeneous beliefs regarding future cash flows), we conjecture that investors face greater challenges in rational expectation formation. 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).

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 dominated by short-horizon 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 short-horizon investors. This raises the empirical question of whether stock price volatility is larger in periods and markets which are populated by a greater number of short-horizon investors. Third, we conjecture that securities with longer maturities are more prone to price indeterminacy. Given investors' trading horizons, 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.[23] As the duration of a security increases, investors receive a smaller portion of its value from cash flow within their horizons and their valuation is determined more significantly by capital gains (future sales prices) for which they face a difficulty in forming expectation. This 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. 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 prices. Our laboratory data showed that excess or shortage of liquidity causes prices to deviate significantly from fundamentals in markets with short-horizon investors. This implies that control-

[23] Duration is the weighted average time of a security's cash flows.

ling money stock and credit availability is important for stabilizing not only the real economy but also security prices when markets are dominated by short-horizon investors.

A future experiment may explore how, and to what degree, the presence of long-horizon traders alongside short-horizon traders may moderate the tendency of prices to deviate from fundamental values. Similar to Hirota and Sunder (2007), we presented evidence that the future dividends tend to anchor prices to fundamentals in markets with long-horizon investors. In a future experiment we plan to extend the present results to markets with mixtures of short and long-horizon traders in varying proportions.

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Table 1: Treatment overview

		Liquidity	
		HIGH (C/A-ratio=10)	LOW (C/A-ratio=2)
# of entering generations	1	T1H	T1L
	2	T2H	T2L
	4	T4H	T4L
	8	T8H	T8L

Table 2: Treatment parameterization

Treatment	T1H	T1L	T2H	T2L	T4H	T4L	T8H	T8L
Market setup								
Number of generations	2	2	3	3	5	5	9	9
Terminal dividend *D*	50	50	50	50	50	50	50	50
Initial no. securities/trader G0	32	32	16	16	8	8	4	4
Initial no. of securities G(i)	0	0	0	0	0	0	0	0
Total securities outstanding	160	160	80	80	40	40	20	20
Total value of securities	8,000	8,000	4,000	4,000	2,000	2,000	1,000	1,000
Initial cash/trader G0	0	0	0	0	0	0	0	0
Initial cash/trader G(i)	16,000	3,200	8,000	1,600	4,000	800	2,000	400
Total cash	80,000	16,000	40,000	8,000	20,000	4,000	10,000	2,000
Cash-security-ratio (C/A-ratio)	10	2	10	2	10	2	10	2
Invited subjects (3n+3)	15[a]	15[a]	18	18	18	18	18	18
Participating subjects	90	90	108	108	108	108	108	108
Exchange rates (Taler/€)								
Generation 0 (G0)	100	100	100	100	100	100	100	100
Transition generations			500	100	500	100	500	100
Last generation	1,000	200	1,000	200	1,000	200	1,000	200
Predictors	133	133	133	133	133	133	133	133
Expected payout/subject (€)	16	16	16	16	16	16	16	16

Notes: The following parameters are identical across all treatments: Number of traders/generation (5); number of active generations (2); active traders (10 traders); 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 traders, and five served as predictors.

Table 3: Average *Period-RAD* for each period

Panel A: High-liquidity session

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1	1.423	0.582	0.354	0.293	0.329	0.301	0.321	0.390	0.374	0.382	0.396	0.303	0.323	0.286	0.387	0.259
T2	1.825	1.016	0.310	0.406	0.467	0.536	0.541	0.477	0.676	0.865	0.705	0.313	0.232	0.468	0.232	0.179
T4	1.552	1.471	1.342	1.038	1.182	0.960	0.798	0.499	0.697	0.509	0.470	0.559	0.325	0.210	0.167	0.040
T8	1.879	1.249	1.373	1.392	1.409	1.498	1.177	0.991	1.108	1.082	1.607	1.733	1.019	0.647	0.550	0.273

Panel B: Low-liquidity session

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1	0.226	0.139	0.106	0.098	0.077	0.101	0.103	0.138	0.152	0.158	0.147	0.070	0.084	0.083	0.085	0.085
T2	0.596	0.425	0.299	0.278	0.503	0.685	0.743	0.760	0.342	0.352	0.222	0.146	0.071	0.053	0.085	0.115
T4	0.385	0.489	0.495	0.543	0.517	0.527	0.556	0.653	0.535	0.530	0.511	0.459	0.341	0.163	0.110	0.052
T8	0.527	0.214	0.249	0.398	0.315	0.313	0.355	0.499	0.446	0.584	0.628	0.741	0.663	0.679	0.230	0.066

Notes: Cells shaded grey are periods where the last, dividend-collecting generation of traders is present. In the other periods (no shading) only short-term investors are present.

Table 4: Comparison of average *Period-RAD* between periods with long-horizon investors and periods with only short-horizon investors

	(1) Periods with long-horizon investors	(2) Periods with only short-horizon investors	Difference (2)−(1)
High liquidity Session (Treatment H)	0.401 (177)	1.024 (204)	0.623***
Low liquidity Session (Treatment L)	0.140 (178)	0.502 (203)	0.362***

Notes: Sample size is in parentheses.*** indicates that the difference is statistically significant at 1% level by two-sided t-test.

Table 5: Investment horizons and average *Period-RAD*

Panel A: Average *Period-RAD* for each treatment

Treatment (Average investment horizon)	T1 (16.0 periods)	T2 (10.7 periods)	T4 (6.4 periods)	T8 (3.6 periods)
High-liquidity session (H)	0.421 (95)	0.586 (94)	0.739 (96)	1.187 (96)
Low-liquidity session (L)	0.116 (94)	0.355 (96)	0.429 (96)	0.429 (95)

Notes: Sample size is in parentheses.

Panel B: Differences between average *Period-RAD* across treatments

High-liquidity Session (H)			
	T2	T4	T8
T1	0.165*	0.318***	0.766***
T2		0.153	0.601***
T4			0.448***
Low-liquidity Session (L)			
	T2	T4	T8
T1	0.239***	0.313***	0.313***
T2		0.075	0.074
T4			0.000

Notes: Two-sided t-test significance levels * (10%), ** (5%) and *** (1%).

Table 6: Comparison of average *Period-RD* between periods with long-horizon investors and periods with only short-horizon investors

	(1) Periods with long-horizon investors	(2) Periods with only short-horizon investors	Difference (2)−(1)
High-liquidity session (Treatment H)	0.295 (177)	0.741 (204)	0.446***
Low-liquidity session (Treatment L)	−0.087 (178)	−0.340 (203)	−0.253***

Notes: *** indicates that the difference is statistically significant at 1% level by two-sided t-test.

Table 7: Price expectations model estimates

High-liquidity Session	**Periods with long-horizon investors**			**Periods with short-horizon investors**		
	FUND	TREND	COMBINED	FUND	TREND	COMBINED
Const.	1.672**	-0.709	1.733**	4.159**	-2.611*	0.515
	(0.622)	(1.595)	(0.620)	(1.895)	(1.310)	(1.449)
$(F_t - P_t)$	0.197***		0.211***	0.109*		0.078
	(0.043)		(0.053)	(0.061)		(0.057)
$(P_t - P_{t-1})$		0.020	0.067		-0.301***	-0.270***
		(0.031)	(0.044)		(0.049)	(0.043)
N	173	167	167	186	168	168
F	20.96	0.42	8.09	3.19	37.71	25.16
p	0.000	0.522	0.002	0.092	0.000	0.000
adj. R2	0.38	0.00	0.39	0.14	0.30	0.36

Low-liquidity Session	**Periods with long-horizon investors**			**Periods with short-horizon investors**		
	FUND	TREND	COMBINED	FUND	TREND	COMBINED
Const.	-2.275***	1.054	-2.543**	-0.804	-0.248	-1.636**
	(0.684)	(0.737)	(0.742)	(0.524)	(0.399)	(0.671)
$(F_t - P_t)$	0.401***		0.419***	0.070***		0.065**
	(0.092)		(0.096)	(0.017)		(0.024)
$(P_t - P_{t-1})$		-0.088	-0.016		-0.162*	-0.180**
		(0.079)	(0.031)		(0.081)	(0.074)
N	171	162	162	186	168	168
F	19.36	1.26	10.10	16.25	3.95	5.82
p	0.000	0.274	0.001	0.001	0.063	0.012
adj. R2	0.43	0.01	0.43	0.08	0.08	0.13

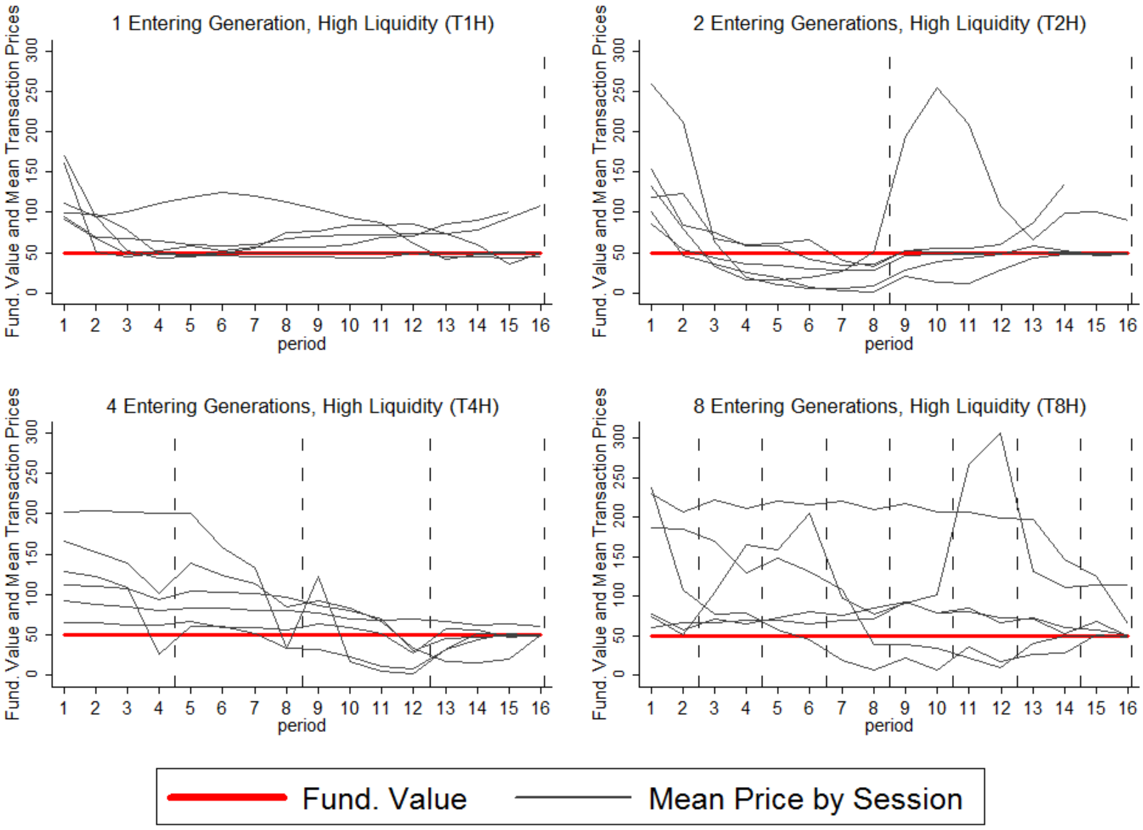
Notes: Standard errors clustered by session in parenthesis. Significance levels: * (10%), ** (5%) and *** (1%).

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																
	5	G1																D
T2	5	G0																
	5	G1																
	5									G2								D
T4	5	G0																
	5	G1																
	5					G2												
	5									G3								
	5													G4				D
T8	5	G0																
	5	G1																
	5			G2														
	5					G3												
	5							G4										
	5									G5								
	5											G6						
	5													G7				
	5															G8		D

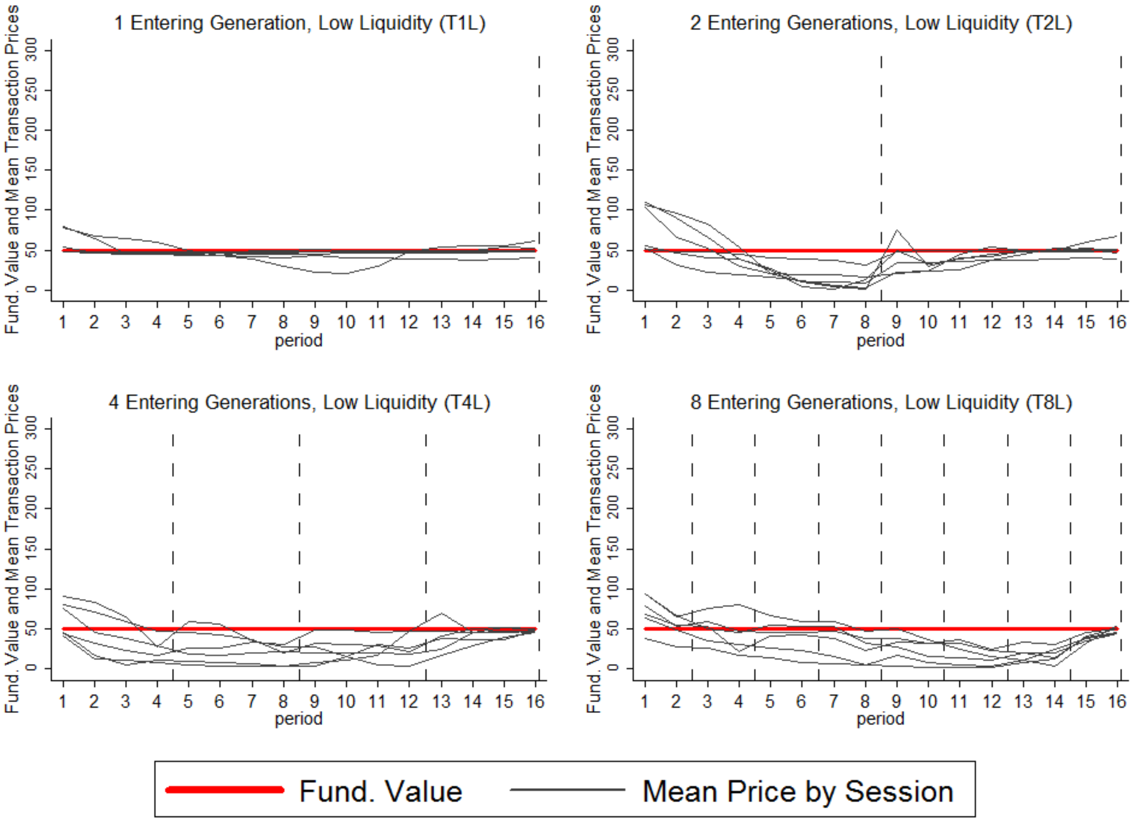
Notes: D means that the last generation of investors receives terminal dividends (50) at the end of Period 16.

Figure 2: Period-wise average transaction prices in high-liquidity treatments.



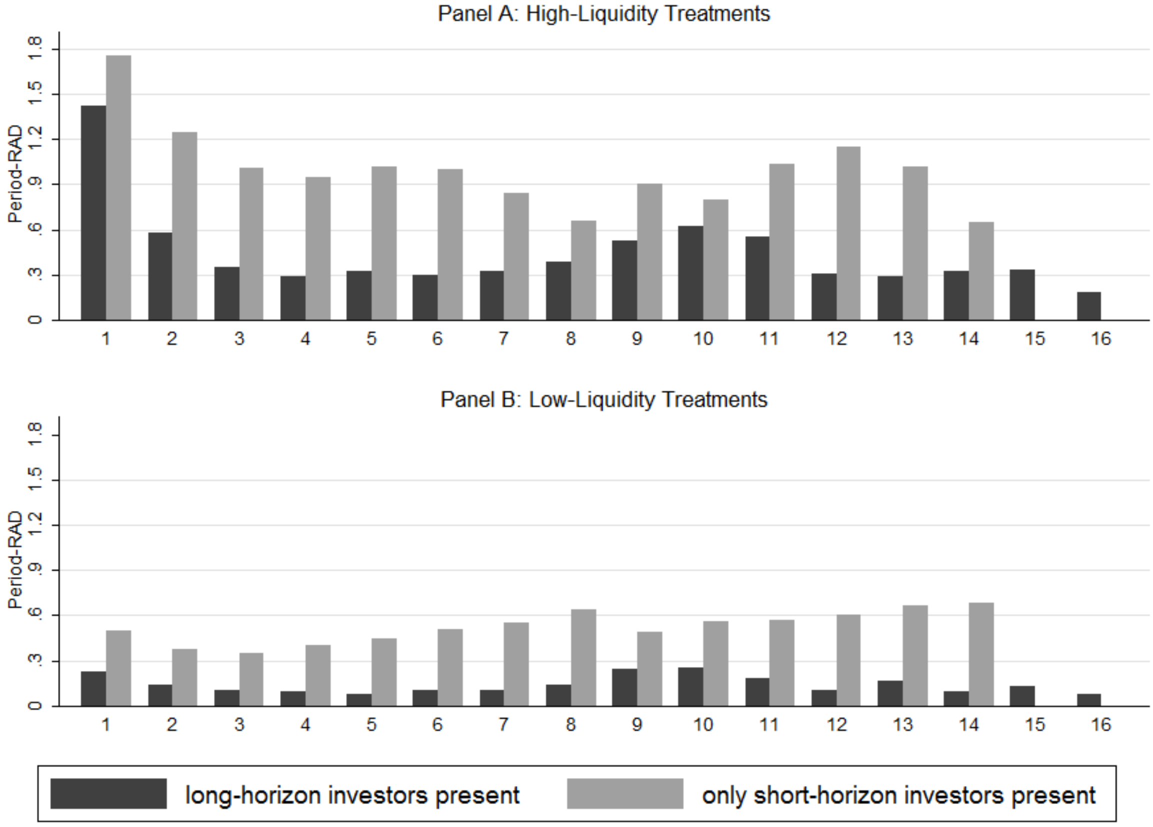
Notes: Volume-weighted mean prices from six individual sessions (grey lines) and Fundamental Value (FV, red bold straight line) by period on vertical axis. Each panel is identified by treatment: T1H, T2H, T4H, and T8H.

Figure 3: Period-wise average transaction prices in low-liquidity treatments.



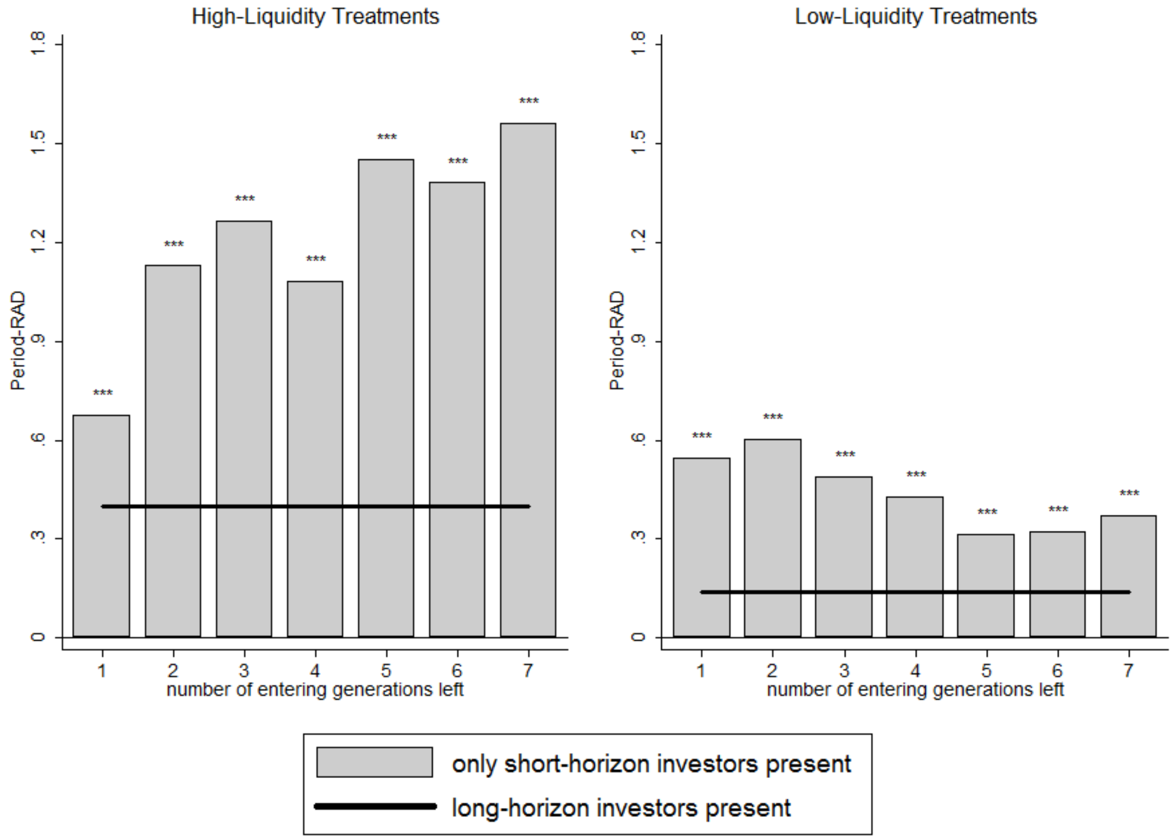
Notes: Volume-weighted mean prices from six individual sessions (grey lines) and Fundamental Value (FV, red bold straight line) by period on vertical axis. Each panel is identified by treatment: T1L, T2L, T4L, and T8L.

Figure 4: Average *Period-RAD* for each period number: Comparison between the markets with long-horizon investors and those with only short-horizon investors. Panel A: high-liquidity treatments; Panel B: low-liquidity treatments.



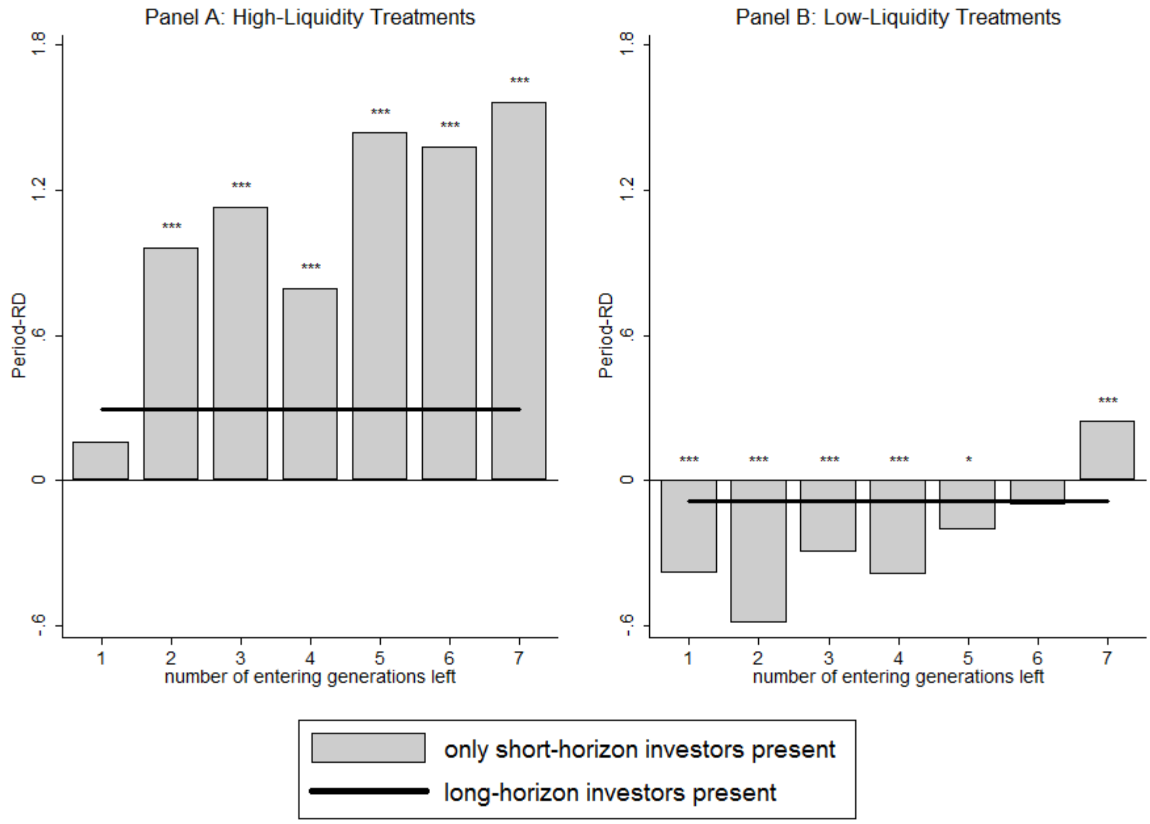
Notes: In periods 15 and 16 long-horizon investors are present in all treatments (see, Table 3). Therefore only black bars are shown for these two periods.

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 short-horizon investors were present. The black bold line represents periods where long-horizon investors were present. ***, **, or * indicates that the average Period-RAD across periods where only short-horizon investors were present is significantly different at 1%, 5%, or 10% level, respectively, from the average Period-RAD across periods with long-horizon 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 short-horizon investors were present. The black bold line represents periods where long-horizon investors were present. ***, **, or * indicates that the average Period-RD across periods where only short-horizon investors were present is significantly different at 1%, 5%, or 10% level, respectively, from the average Period-RD across periods with long-horizon investors (two-sided t-test).

Appendix A: Instructions of the experiment[24]

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 trader ("trader") 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 trader 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

[24] 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

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Cohort 1																
Cohort 2																
Cohort 3																

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.

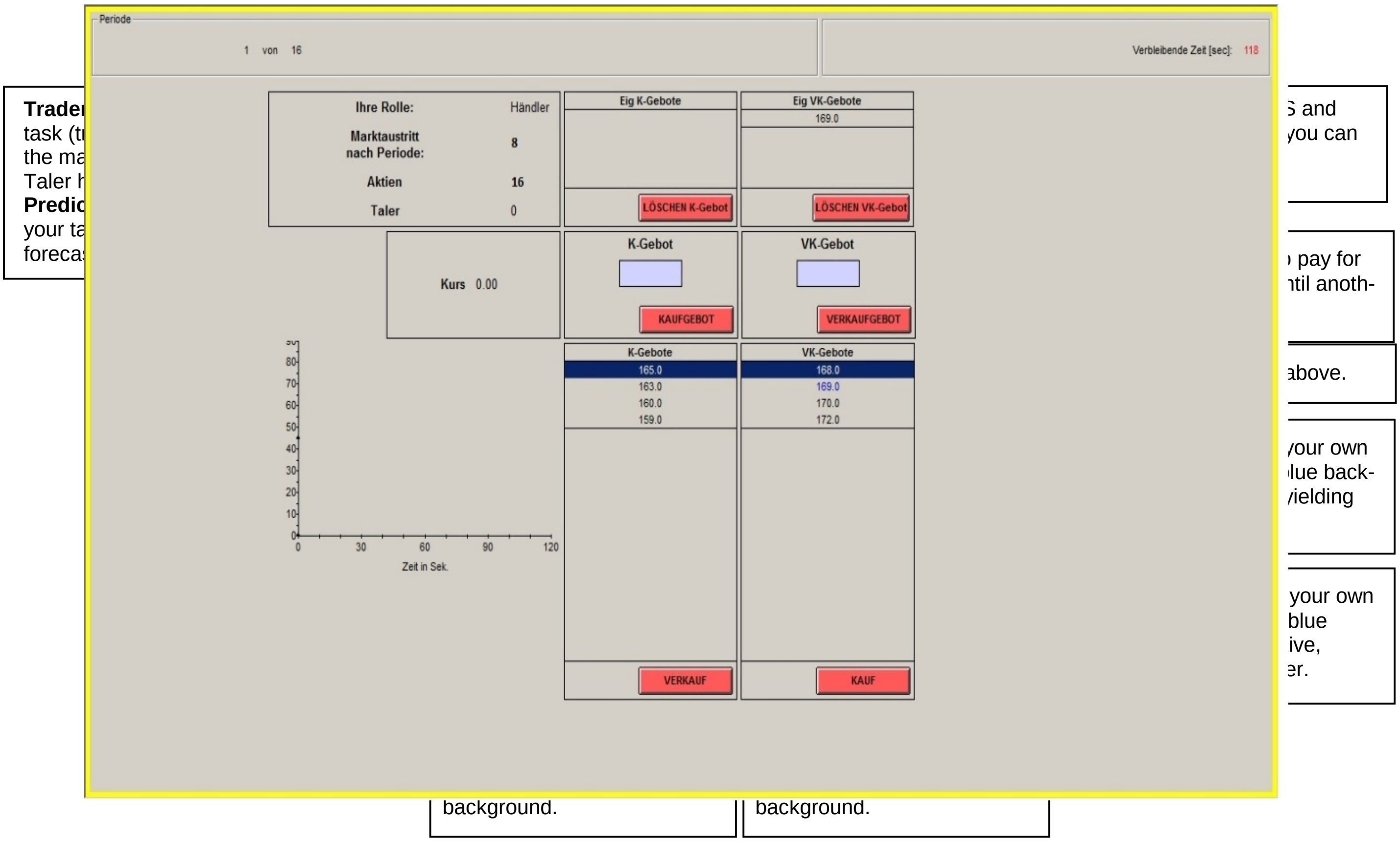
Cohort 3 also enters the market with 1.600 Talers each and will be able to use these Talers to buy any shares they wish to during periods 9-16. At the end of Period 16, any shares remaining in their hands pay a dividend of 50 Taler each, which is added to their Taler holdings.

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 traders 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



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.

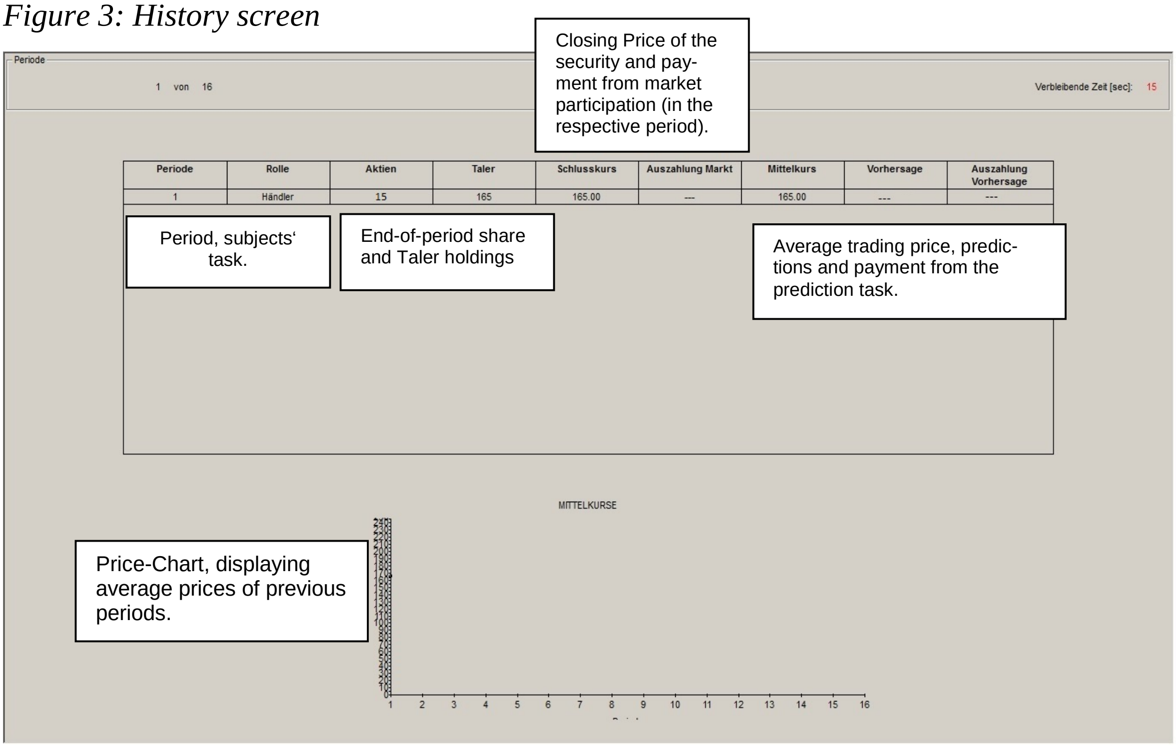
Important information

- 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 trader 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



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.

Your payment = Sum of earnings from market experiment +
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*
3. If you buy a share for 350 Taler, what happens to your cash balance? (i) *My cash balance decreases by 350*. (ii) My cash balance increases by 350. (iii) Nothing happens to my cash balance.
4. If you sell a share for 350, what happens on your cash balance? (i) My cash balance decreases by 350. (ii) *My cash balance increases by 350*. (iii) Nothing happens to my cash balance.
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.