SPECULATION AND PRICE INDETERMINACY IN FINANCIAL MARKETS: AN EXPERIMENTAL STUDY

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Speculation, Money Supply and Price Indeterminacy in Financial Markets: An Experimental Study*

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Abstract

To explore how speculative trading influences prices in financial markets, we conduct a laboratory market experiment with speculating investors (who do not collect dividends and trade only for capital gains) and dividend-collecting investors. Moreover, we operate markets at two different levels of money supply. We find that in phases with only speculating investors present (i) price deviations from fundamentals are larger; (ii) prices are more volatile; (iii) mispricing increases with the number of transfers until maturity; and (iv) speculative trading pushes prices upward (downward) when the supply of money is high (low). These results suggest that controlling the money supply can help to stabilize asset prices.

Keywords: Experimental finance; speculation; money supply; rational expectations; price efficiency; price bubbles; overlapping generations; backward and forward induction.

JEL-Classification: C91; G11; G12.

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1. Introduction

Speculators are short-term traders seeking capital gains. The value of a security to them depends on their future price expectations, which are sensitive to noisy information, higher-order expectations, and even recent price changes. Therefore, in a market populated by speculators, stock prices can be susceptible to excess volatility and bubbles (Keynes 1936, Shiller 2000, Stiglitz 1989). Standard finance theory, however, does not associate these phenomena with speculation. Even short-term speculators are assumed to form rational expectations of future prices; they form iterated expectations from near-to-distant future generations and conduct backward induction to arrive at the present value of the security. In the resulting rational expectation equilibrium (REE) prices are equal to fundamental values (Adam and Marcet 2011, Tirole 1982).

The REE outcomes depend on the assumption of common knowledge of rational expectations among all generations of investors (Cheung et al. 2014, Smith et al. 1988, Sutan and Willinger 2009): investors form rational expectations themselves, but also believe that the subsequent generations of investors do the same. However, common knowledge of rationality among agents is rarely achieved in practice (Aumann 1995, Geanakoplos 1992). In experimental studies, backward induction often fails due to a lack of common knowledge of rationality in the centipede game (McKelvey and Palfrey 1992), bargaining game (Johnson et al. 2002), and the beauty contest game (Nagel 1995, Camerer 2003). Given this background, the assumption of common knowledge of rational expectations across several generations of investors is unlikely to hold in practice. Without it, short-term speculators should have difficulty in backward induction and prices should no longer be anchored to the fundamental value and may wander away.

In this paper, we examine how speculation and money supply influence price indeterminacy in financial markets. We conduct a laboratory experiment because it is not possible to distinguish capital gains-seeking speculative trading from non-speculative trading in field data. Even if we can identify speculative trading and its effect on price volatility, it is difficult to determine whether it arises from investors' difficulty in forming rational expectations.[1] Furthermore, the fundamental value of the security to serve as a benchmark for measuring mispricing is rarely identifiable in the field.[2] We, therefore, choose the experimental approach where we can control the presence of speculating investors as well as money supply, focus on the feasibility of rational expectations, and define the asset's fundamental value in the laboratory.

Although there have been numerous asset market experiments (for review, see Duxbury 1995, Sunder 1995, Noussair and Tucker 2013, Palan 2013, Powell and Shestakova 2016), the question of whether speculation causes price volatility or bubbles remains unresolved. In a design introduced by Smith et al. (1988), price bubbles are observed frequently and some researchers interpret the bubbles as a consequence of speculative trading based on others' irrationality. However, in their experimental setting, it is difficult to judge whether the bubbles occur due to speculation or confusion about the fundamental value of the security. Indeed, Lei et al. (2000) repeat that experiment but prevent speculation by forbidding re-sales. They still observe bubbles, reinforcing the confusion hypothesis (see also Kirchler et al. 2012).[3]

[1] Theoretical literature suggests several possible reasons why short-term speculation could cause security prices to deviate from the fundamental values. First, the rational bubble literature shows that when securities with infinite maturity are traded in a market populated by short-term speculators, price bubbles can emerge as the REE (e.g., Blanchard and Watson 1982, Tirole 1985). In a second class of models, speculation induces prices to deviate from fundamentals due to future investors' noisy beliefs or asymmetric information (Abreu and Brunnermeier 2003, Allen et al. 2006, De Long et al. 1990a, 1990b, Dow and Gorton 1994, Froot et al. 1992, Scheinman and Xiong 2003). We should point out that both these classes of models, as well as standard finance theory, utilize the rational expectation hypothesis. Even the second class of models assume that *at least* current investors form rational expectations of future prices by considering how current and future prices are determined by future investors' beliefs.
[2] Xiong and Yu (2011) is a notable 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 which they characterize as bubbles.
[3] Akiyama et al. (2017) and Cheung et al. (2014) manipulate traders' information regarding the rationality of others in the Smith et al. (1988) setting. They find that uncertainty over the rationality of others is responsible for a substantial part of the mispricing. This result suggests that speculation on other's irrationality is a potential cause of price volatility and bubbles.

Hirota and Sunder (2007), Moinas and Pouget (2013), and Janssen et al. (2019) conducted experiments that are directly related to speculation in financial markets. In their bubble game experiment, Moinas and Pouget (2013) present evidence counter to standard finance theory on speculation. They show that subjects often buy the security above its fundamental value even when bubbles are (theoretically) ruled out by backward induction. They also find that the propensity for a subject to buy increases with the number of steps of iterated reasoning needed for backward induction. These results indicate that the lack of common knowledge of rationality might be an important driver of speculation. However, from their experiment, we cannot know whether and how speculative trading affects price formation since the security price is exogenously given by the experimenter. Janssen et al. (2019) find that overpricing is higher in markets composed of traders with a high propensity to speculate than in markets composed of traders with a low propensity to speculate. Instead of using a subject's propensity to speculate as a treatment variable, we develop an experimental design that creates investors engaged in speculative trading for capital gains and examine the effect of speculation on price formation in the laboratory. In Hirota and Sunder (2007) price bubbles emerge in a treatment where investors receive the expected next period price (predicted by a separate set of subjects) as liquidation value at the end of a market session. Their results show that when investors face the *impossibility* of backward induction, their speculation induces security prices to deviate from the fundamental value.

In the present paper, we take the ideas presented in Hirota and Sunder (2007) a step further and examine whether short-term speculation causes price deviation from the securities' fundamental value in a market where REE (through investors' backward induction) is *theoretically feasible* but calls for a controlled number of steps of expectation formation and iterated reasoning. To this end, we build on earlier designs of Hirota and Sunder (2007), Moinas and Pouget (2013), and Janssen et al. (2019) by adding two unique features. First, a single kind of simple securities is traded in the market. Each security pays only one (terminal) non-stochastic common knowledge dividend (D = 50) at the end of the final period of the session. Second, the market has an overlapping-generations structure, where only the first generation is endowed with securities (see Figure 1).[4] All subsequent generations of investors enter endowed with cash but no securities; they buy securities from the (overlapping) "older" generation, and then sell them to the next "younger" generation, before exiting the market. Only the investors of the very last generation collect the dividend at the end of the final period, and these are called "*dividend-collecting investors*". All other generations exit the market before receiving any dividend, trading the security only for capital gains; these traders are labeled "*speculating investors*".[5]

This design creates speculating investors (who trade only for capital gains without ever collecting dividends), allowing us to examine the effect of speculative trading on price formation. We compare price deviations from the securities' fundamental value in markets with dividend-collecting investors to markets with only speculating investors. We also vary the number of entering generations (and hence the number of transfers of security among generations of investors) to explore its effect on price formation. Furthermore, our choice of the single non-stochastic common knowledge dividend paid to holders of the security at the end of the final period leaves little room for doubt or confusion in the mind of any subject that the fundamental value of the security is indeed 50.[6]

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[4] Marimon and Sunder (1993) use an overlapping-generations structure for their experiment on money and inflation. Deck et al. (2014) design an overlapping generation structure for the asset market 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 speculative trading.

[5] In their models, Allen et al. (2006) call these investors "short-lived investors" and Froot et al. (1992) call them "short-horizon speculators."

[6] Also note that our experimental setting excludes two factors—infinite maturity and heterogeneity of dividend expectations—that are also supposed to cause prices to deviate from fundamentals in theoretical models (Blanchard and Watson 1982, Tirole 1985, Allen et al. 2006, De Long 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 investors' difficulty of forming common knowledge of rational expectations. Still, prices above and below 50 can be considered rational under certain conditions, as we will argue in Section 3.

Standard finance theory predicts that even in a market populated by speculating investors, the market price of this security should be close to the fundamental value of 50 throughout since 50 is the REE price at which each generation of investors arrives through backward induction. However, our experimental results show that with speculating investors in the market, transaction prices deviate substantially from 50. Specifically, we find that (i) in phases with only speculating investors present prices are more likely to depart from fundamentals, compared to prices in phases in which dividend-collecting investors are present; (ii) volatility of prices is higher when only speculating investors are present; (iii) prices are more likely to depart from fundamentals as the securities change hands among speculating investors more often over their 16-period life (i.e., the holding period of speculating investors shrinks and more steps of iterative reasoning are called for). These laboratory results document deviations from price predictions of REE, as well as greater volatility, generated by speculation.

We also explore whether money supply influences the effect of speculative trading on price formation by varying the total amount of money supply in a market by controlling the cash endowment of entering subjects by a factor of five between low- and high-liquidity treatments. We find that (iv) when the supply of money is high (low), speculative trading pushes prices above (below) the fundamental value providing evidence that the direction of price deviations from the fundamentals (positive or negative) is driven mostly by money supply. This result implies that controlling money supply is important for stabilizing asset prices when markets are dominated by speculative trading.

The paper is organized as follows: Section 2 describes the experimental design and procedures. Section 3 presents theoretical considerations and the hypotheses to be tested in the laboratory. Section 4 reports experimental results and Section 5 discusses the implications and presents concluding remarks.

2. Design of the experiment

Setup and treatments

In the experiment, the 48 market sessions consist of 16 trading periods of 120 seconds each. Each session is populated with ten investors (who buy and sell securities), and eight (with the exception of five in T1) predictors (who predict the average transactions price for the period).

We differentiate investors into two classes of five each by implementing an overlapping generations structure shown in Figure 1. At any time, there are two generations in the market. 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 only to its holders from the last-to-enter generation, referred to as "*dividend-collecting investors*". All other generations of investors are called "*speculating investors*" who collect no dividend, and who trade the security only for capital gains. Any securities these investors hold at the time of their exit are worthless (and are redistributed to the next entering generation to keep the number of securities in the market fixed).[7]

(Insert Figure 1 about here)

The experiment has a 4x2 design (see Table 1) in which the first treatment (number of entering generations until maturity of the security) takes four different values and the second treatment (money supply, henceforth also referred to as liquidity) takes two values. By varying the number of entering generations (1, 2, 4, and 8), we manipulate the number of periods with

[7] 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 the chances of subjects' confusion and to gather data from markets populated only by speculating investors. Smith et al.'s (1988) design makes it difficult to create speculating investors (who do not receive dividends and trade only for capital gains) in the overlapping-generations structure. In addition, our design of the security (a single lump sum common knowledge dividend without uncertainty) differs from previous experimental studies featuring constant fundamental values (Porter and Smith 1995, Smith et al. 2000, Noussair et al. 2001, Kirchler et al. 2012, Stöckl et al. 2015, all of which yield efficient pricing).

only speculating investors and the level of difficulty (number of iterative steps) for each generation of investors to arrive at REE through backward induction. 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 periods 1-8, 1-12, and 1-14, respectively, have only speculating investors active in the market; 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).

(Insert Table 1 about here)

The liquidity or money supply treatment varies the initial cash-to-(fundamental) asset value ratio (commonly referred to as C/A-ratio, that is the amount of cash available to trade securities in the economy divided by the sum of the fundamental value of all securities) for H (= 10) and L (= 2).[8] Treatments are denoted as Txy with x $\in$ {1, 2, 4, or 8} indicating the number of entering generations and y $\in$ {H or L} indicating high and low-liquidity treatments. In six independent replicating sessions of each treatment, the market structure (number of investors, number of securities, and cash endowment of an entering generation) remains unchanged over the 16 periods.

To keep the total number of subjects within reasonable limits we recruit 18 subjects for each session.[9] In every period, two five-subject generations (ten subjects in total) are active investors, while the other eight (five in T1) subjects are predictors. When an investor 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

[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 securities 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), Noussair and Tucker (2014), and references therein on the effects of cash endowments on mispricing.

[9] In treatment T1 we invited only 15 subjects instead of 18 since no rotation is needed. Ten subjects trade through all 16 periods and the other five act as predictors (to be explained below).

predictors. Subjects stay in this pool for one or more periods. This rotating mechanism allows each generation of investors to gain experience and an understanding of the environment without significantly interfering with the purpose of the experiment (see Lim et al. 1994, Marimon and Sunder 1993). Since subjects cannot know whether and when they will reenter the market, their current behavior is unlikely to be influenced by their anticipations of any future re-entries into the laboratory economy.

Security and cash endowments

Only the initial generation of investors (G0) is endowed with units of the security at the beginning of period 1. All other generations (G1 up to G8) are initially endowed with only cash and no securities. They can use their cash to buy securities from the 'older' generation, then sell the securities to the next 'younger' generation and exit the market, just when another generation enters (or the session ends).[10] This design ensures that even in T1, where G0 and G1 are present in all 16 periods each security needs to be traded at least once (from a member of G0 to a member of G1) to realize its dividend.

(Insert Table 2 about here)

To equalize the per period trading 'workload' across the four treatments, security and cash endowments are varied; the expected number of transactions for the entire 16-period session is kept fixed at 160, independent of the number of generations (see Table 2 for details on parameter selection in each treatment). 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 in integer numbers (to avoid fractional unit trades). This arrangement ensures that no buyer is

[10] Note, that the cash endowment of an entering generation is ten (two) times the amount needed to buy all securities at their 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.

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.[11]

Trading mechanism

The trading mechanism used is a continuous double auction with an open order book, opportunity to cancel a bid or ask until 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. Investors can buy and sell securities freely as long as neither their cash nor the security holdings become negative.[12] 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.

Investor payoff

The final earnings of each member of the last generation of investors are [number of securities in their hands at the end of Period 16]$\times$[terminal dividend of 50] + [cash holdings at the end of Period 16]. The final earnings of all other generations of investors are equal to

[11] We chose random distribution of forfeited securities in whole units because equal distribution would have resulted in fractional securities being allocated in most instances. For example, if only one security was forfeited in a given period, this would have had to be split equally among the five incoming traders of the "young" generation. To avoid trading of fractional securities, which would complicate the auction mechanism, we chose random allocation. 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, 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 has some validity, but is not a consistent explanation of all observed data.

[12] Shorting securities and cash was forbidden as it would have led to the possibility of bankruptcy, and complicated consequences at generation changes – e.g., if a trader of an exiting generation had negative securities holdings, the securities of other traders would have had to "evaporate" to keep the number of securities in the market constant.

their cash holdings at the time of exit with any unsold securities in their hands forfeited.[13] The final earnings of investors are converted to euros at a pre-announced rate and paid out.[14]

Predictors' task and payoff

Eight (five in T1) subjects assigned the predictor role in each period are required to submit a prediction of the average transaction price at the beginning of the period. The mean of all eight (five T1) individual price predictions is disclosed to the market at the end of the period to avoid predictions influencing investors' trading behavior.[15] Individual predictors earn 140 units of cash for perfect forecasts, and one unit is deducted for each unit of forecast error (subject to zero minimum earnings).[16] The amount earned is later exchanged to euros at a rate of 133:1.

Implementation

The experiment was conducted at the Innsbruck-EconLab using software written in z-tree (Fischbacher, 2007) in 2013 with a total of 828 University of Innsbruck bachelors and masters students from different fields in 48 sessions (eight treatments of six sessions each).

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[13] 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. See Appendix F1 for more information.

[14] We use different rates for the first, transition, and last generations and the low/high-liquidity treatments to equalize expected euro payouts. See Table 2 for details.

[15] We deliberately separate predictor's role from investor's role in each period to eliminate the possibility that eliciting price prediction from investors induces some bias in their trading behavior in the same period. Such strategic behavior is unlikely to motivate trades in real-world markets, but might bias our experimental results. Previous literature suggests that eliciting beliefs and forecasts in the laboratory can change the subjects' behavior (see Schotter and Treviono 2014 for a survey). In particular, Bao et al. (2013) provide experimental evidence on a cobweb economy showing that REE is less likely to be attained when subjects are asked to play the forecasting role and make decisions simultaneously. Also, Hanaki et al. (2018) show that eliciting forecasts significantly increases the magnitude of mispricing in Smith et al.'s (1988) asset market experiment when subjects are rewarded for both trading and forecasting performance. See Marimon and Sunder (1993) for further analysis.

[16] We use this linear payoff function (with a zero lower boundary) following Hirota and Sunder (2007). We usedthis instead of alternatives like a quadratic scoring rule (Bao et al. 2012, Bao et al. 2013, Evans et al. 2019, Hommes et al. 2005) or other non-linear functions (Akiyama et al. 2017, Haruvy and Noussair 2007) as we wanted to keep the incentives in the predicting task similar to those in the investor task. Moreover, we wanted to keep the payoff function easy and straightforward to understand. Hanaki et al. (2018) report that forecasting performance (the accuracy of price prediction) does not significantly differ between two functional forms in their forecasting-only experiments.

Most subjects had participated in other economics experiments, 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 common knowledge instructions (with their understanding tested through a written questionnaire to minimize the possibility of misunderstanding and experimenter bias, see Appendix B for details). Any questions from subjects were answered privately. The trading screen was explained, followed by two trial periods to allow subjects to become familiar with the environment, trading and prediction tasks, mapping from experimental actions and events to their payoffs, and to test their comprehension.[17] In both trial periods, all subjects played dual roles of investor and predictor. As an example, instructions for treatment T2L, along with screenshots, are provided in Appendix A. Each session lasted approximately 90 minutes. Calculations of period as well as cumulative earnings were shown to subjects on the history screen at the end of each period. At the end of a session earnings of each subject were calculated, converted into euros, and paid to them in private.[18]

3. Theory and Hypotheses

In this section, we present theoretical considerations raising the possibility that speculating investors may or may not induce price indeterminacy in these laboratory markets. In Section 3.1, we show that prices are equal to the fundamental value (terminal dividend) in a market with dividend-collecting investors. In Section 3.2, we argue that in a standard securities pricing model REE predicts prices equal to the fundamental value even in a market with only speculating investors. In Section 3.3, we examine the validity of REE assumptions and provide arguments for potential price deviations from the fundamental value in our laboratory markets.

[17] We implemented this procedure to minimize mispricing due to subjects' confusion or misunderstanding.
[18] There was no fixed payment for the subjects. The average and standard deviation of actual earnings of the subjects across treatments are shown in Appendix C.

In Section 3.4, we derive a set of hypotheses to be evaluated with the data generated in the experiment.

3.1 Pricing in a market with dividend-collecting investors

We start by examining price formation in periods with dividend-collecting investors in our laboratory sessions, using market T4 (see Figure 1) for illustration (similar reasoning applies to treatments T1, T2, and T8). To simplify, divide the 16 periods of T4 into four subsets: Subset 1 (periods 1-4) in which subjects from G0 and G1 trade, Subset 2 (periods 5-8) in which subjects of G1 and G2 trade, Subset 3 (periods 9-12) in which subjects of G2 and G3 trade, and Subset 4 (periods 13-16) in which subjects of G3 and G4 trade. Only G4 traders collect dividends; traders of G0 to G3 are speculating investors who exit the market before the security pays its dividend D at the end of period 16.

In Subset 4 where dividend-collecting investors (G4) are present, the equilibrium price P_4 of the security is equal to the terminal dividend D due to the G4's arbitrage transactions (assuming perfect competition among G4 traders):

$$P_4 = D = 50. \quad (1)$$

The prediction that the price is equal to the security's fundamental value holds whenever dividend-collecting investors are present (periods 1-16 in T1, period 9-16 in T2, and periods 15-16 in T8).[19]

[19] One may argue that the theoretical equilibrium price is not necessarily equal to 50 in the market with dividend-collecting investors. The argument would be as follows: dividend-collecting investors (e.g., G4 in T4) would buy the security if the price is below 50 and non-dividend-collecting investors (e.g., G3 in T4) would sell the security if the price is above 0 (because they cannot receive the dividend). Hence the equilibrium price lies in the range of [0, 50]. This argument, however, is not theoretically valid under perfect competition. In our experimental design, the total number of the securities outstanding is limited (e.g., 40 in T4) and total cash held by investors is twice (4,000 in T4L) or ten times (20,000 in T4H) as much as total fundamental value of the securities outstanding (40x50 = 2,000 in T4). The demand function being horizontal at P =50 for values of Q from 0 to 80 and the supply function being vertical at Q = 40, their intersection at P = 50, Q = 40 is the competitive equilibrium in presence of dividend-collecting investors.

3.2 Rational Expectation Equilibrium (REE) in a market with only speculating investors

Next, we examine price formation in a market with only speculating investors. The REE in the standard security pricing model predicts prices to be equal to the fundamental value. To see this, we consider Subset 3 (periods 9-12) where G2 and G3 are present. In this situation the price of the security, P_3, depends on G3's expectation of the price in Subset 4 (assuming perfect competition among G3 traders):

$$P_3 = E_3 (P_4). \tag{2}$$

Standard security pricing models claim that speculating investors form rational expectations of future prices through backward induction: G3 rationally expect P_4 to be given by (1):

$$E_3 (P_4) = 50. \tag{3}$$

Therefore,

$$P_3 = 50. \tag{4}$$

In Subset 2 (periods 5-8) where G1 and G2 are present, the price of the security, P_2, depends on G2's expectation of the price in Subset 3 (assuming perfect competition among G2):

$$P_2 = E_2 (P_3). \tag{5}$$

G2 rationally expect P_3 using (4),

$$E_2 (P_3) = 50. \tag{6}$$

Thus, $P_2 = 50$ holds. Repeating this process one more stage, we get $P_1 = 50$.

This step completes the derivation of the REE yielding $P_1 = P_2 = P_3 = P_4 = 50$. Under the stated assumptions, prices in markets with only speculating investors (P_1, P_2, and P_3) are equal to those in a market with dividend-collecting investors (P_4). This argument also applies to other treatments (T2 and T8), predicting price is 50, irrespective of the presence or absence of speculating and dividend-collecting investors in the market. Therefore, the standard security pricing model predicts that, even in a market populated by speculating investors, the price of the security with fixed maturity is determined through investors iteratively forming common knowledge rational expectations through backward induction, and prices are equal to the security's fundamental value.

3.3 Feasibility of REE

The result of the standard security pricing model presented above critically depends on two assumptions. First, speculating investors form rational expectations of future sales prices, believing that the future generation of investors exhausts arbitrage opportunities in perfect competition. In the example given above, this assumption implies that traders of G3 form rational expectations of P_4 (equation 3) since they not only have the cognitive ability to surmise the behavior of the market in Subset 4 but also believe that traders of G4 conduct perfect arbitrage in a frictionless market (i.e., "perfect competition") to realize $P_4 = 50$ (equation 1). It is not clear that this assumption holds in practice. Some traders of G3 may expect that in Subset 4 some G4 traders are not rational and willing to buy the security at $P_4 > 50$. Such G3 traders may buy the security in Subset 3 even if $P_3 > 50$, hoping for reselling it at even higher prices in Subset 4. In high-liquidity markets where each investor has plenty of cash to buy a large number of securities (each investor's cash holding is twice the total fundamental value of all securities), strong demand from these "bullish G3 traders" may push Subset 3 price P_3 above 50, and create deviations from predictions of REE. At the same time, another G3 trader may expect that in Subset 4 G4 traders may be unwilling to buy the security at P_4 slightly below 50 because a small profit is not worth the extra effort. Such G3's may not be willing to buy the security in Subset 3 even if $P_3 < 50$ if they are not confident of having the opportunity to resell it at a higher price in Subset 4.[20] In low-liquidity treatments with less cash on their hands (each

[20] We can also interpret this behavior to reflect G3's ambiguity aversion for future sales prices. That is, G3 does not have sufficient information to form beliefs on the probability distribution of P_4 and require a premium for this ambiguous situation. Easley and O'Hara (2009) show that ambiguity may induce an increase in the equilibrium

investor's cash holding is 0.4 times the total fundamental value of all securities), the buy orders of the other G3 traders may not be sufficient for prices to rise to 50 in Subset 3. $P_3 < 50$ can arise due to insufficient cash of the willing buyers if some potential buyers are, for whatever reason, do not buy.

Second, REE assumes that it is common knowledge among all generations of investors that speculating investors form rational expectations. This assumption implies that speculating investors must not only form rational expectations themselves, but also believe that all subsequent generations of speculating investors also do the same.[21] In T4, traders of G2 form rational expectations of P_3 (equation 6) by believing that traders of G3 also form rational expectations of P_4 (equation 3). Furthermore, traders of G1 form rational expectations of P_2, not only believing that traders of G2 also form rational expectations of P_3, but also believing that traders of G2 believe that traders of G3 form rational expectations of P_4. This common knowledge assumption of rational expectations among speculating investors, however, may not hold in practice. For example, traders of G2 may believe that some traders of G3 do not form rational expectations ($E_3(P_4) = 50$) and that they form the expectation, $E_3(P_4) > 50$. In high-liquidity markets, this G3's expectation could cause P_3 to rise above 50 in Subset 3. Anticipating this, traders of G2 buy the security at $P_2 > 50$ in Subset 2 by backward induction. Further, if traders of G1 expect these price realizations, we would observe $P_1 > 50$ in Subset 1 as well.

Therefore, the two abovementioned assumptions needed for REE may not hold in practice; even if traders form rational expectations, they might expect that subsequent traders will not exhaust arbitrage opportunities or their expectations will not be rational. Consequently, P_1, P_2, and P_3 may no longer be formed in line with REE predictions (50) and get unhinged from

risk premium (implying a decrease in the equilibrium price). See Guidolin and Rinaldi (2013) for a survey article on the effect of ambiguity on asset pricing. However, this theoretical work remains to be supported by methods of estimating ambiguity and risk aversion that exhibit empirical out-of-sample predictive power.

[21] In fact, the first generation (G0) need not form rational expectations because they should be willing to sell the security to G1 at all positive prices before they exit.

the fundamental value in T4. This pricing pattern may also occur in a market with only speculating investors in other treatments (periods 1-8 in T2 and period 1-14 in T8). This argument opens the possibility that price formation is different in markets with only speculating investors compared to markets with dividend-collecting investors present. Furthermore, if REE is not realized in markets with only speculating investors, the algebraic sign of pricing error may depend on the amount of money supply (liquidity). In high-liquidity markets, positive price deviations from the fundamental value are more likely to occur because each speculating investor expecting high future prices (bullish traders) could make a large number of buy orders. In contrast, in low-liquidity markets, negative price deviations are more likely because buy orders of the generation may not be sufficient for perfect arbitrage that pushes prices to 50.

3.4 Hypotheses

As discussed in Sections 3.1 and 3.2, in standard security pricing models the nature of investors (dividend-collecting vs. speculating) does not affect security prices; actions of arbitraging and competitive dividend-collectors as well as of rational expectations through backward-inducting speculators both push the prices towards the fundamental value given by the terminal dividend (50). In laboratory security markets, precise correspondence between transaction prices and fundamental values is rare.[22] The observed deviations are often attributed to noise trading arising from subjects' gradual and imperfect learning, confusion, and irrationality.[23] While some noise in transaction prices is to be expected in all treatments of our experiment, our purpose is to examine whether or not speculation and money supply affect price deviations. We pose the following null hypothesis based on REE:

[22] See e.g. Plott and Sunder (1982, 1988), and Smith et al. (1988) and the large follow-up literature reviewed in Palan (2013).
[23] 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). However, none of these papers features overlapping generations of investors.

***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 also present in the market.*

In contrast, in Section 3.3., we also considered the possibility that prices in a market with only speculating investors may become unhinged from REE. Speculating investors may not form rational expectations of future prices due to the lack of common knowledge rational expectations. In that case, prices are more likely to depart from the fundamental value in a market with only speculating investors leading us to the formulation of the alternative hypothesis:

***Hypothesis I_A**: 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 also present in the market.*

Next, we investigate whether, for a security of a given maturity, the number of security transfers across generations (and hence the length of investors' maximum holding period) influences the security's pricing. In the four treatments of our experiment, the security always has the same time to maturity (16 periods) and pays the same terminal dividend, but the number of security transfers across generations until maturity of the security differs (one in T1, two in T2, four in T4, and eight in T8).[24] According to standard security pricing models (REE), price paths should not differ across the four treatments; investors of each generation should form rational expectations through backward induction and prices at all times should be equal to the fundamental value. However, we argue that the formation of speculating investors' rational expectations may be difficult due to a lack of common knowledge of rational expectations. In particular,

[24] The maximum holding periods of the security for each generation are different among the four treatments. For example, the maximum holding periods for G1 are 16 in T1 and T2, eight in T4, and four in T8. Note that these are only the maximum and not the actual holding periods, because an investor of generation G1 in T4, for example, may choose to wait until period 3 to buy a security and sell it in period 5 and thus hold it only for two periods. Henceforth, we refer to the maximum holding periods simply as "holding periods".

as the number of generations until maturity increases, the number of periods with only speculating investors increases, and failure to form common knowledge rational expectations and departure of prices from the fundamentals become more likely. This leads to the following null and alternative hypotheses:

Hypothesis II_0: *For a security of a given maturity, the magnitude of deviation of prices from the fundamental value is not affected by the number of security transfers across generations.*

Hypothesis II_A: *For a security of a given maturity, the magnitude of deviation of prices from the fundamental value increases with the number of security transfers across generations (as the length of investors' holding periods becomes shorter).*

Prior experimental evidence suggests that higher liquidity tends to raise security prices.[25] Therefore, we additionally examine whether liquidity influences speculative trading and thus may have an effect on prices. In standard finance theory (REE), neither speculation not liquidity cause prices to deviate from the fundamental value. However, in Section 3.3, we argued that if REE does not apply, speculation may give rise to positive (negative) price deviations when liquidity is high (low). We set up the following null and alternative hypotheses:

Hypothesis III_0: *Prices are the same during periods when only speculating investors are present compared to periods when dividend-collecting investors are present, irrespective of liquidity (i.e. the C/A-ratio in the market).*

Hypothesis III_{A-1}: *In high-liquidity sessions (the C/A-ratio = 10), prices are higher during periods when only speculating investors are present compared to periods when dividend-collecting investors are present.*

[25] See, e.g., 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), and Porter and Smith (1995).

Hypothesis III$_{A-2}$: *In low-liquidity sessions (the C/A-ratio = 2), prices are lower during periods when only speculating investors are present compared to periods when dividend-collecting investors are present.*

Experimental asset market prices tend to exhibit significant within-period variation. However, we do not know if the volatility of price changes will be the same when only speculating investors or when also dividend-collecting investors are present. In our experiment, since the fundamental value is constant (50), REE predicts no effect of the kinds of traders present in the market on price variations and volatility. However, when REE assumptions do not hold, speculating investors may engage in short-term trading on the expectation of the future price changes even within a period, and prices become more volatile during periods with only speculating investors compared to periods with dividend-collecting investors. This leads to the following null and alternative hypotheses:

Hypothesis IV$_0$: *Volatility of price changes is the same during periods when only speculating investors are present compared to periods when dividend-collecting investors are also present in the market.*

Hypothesis IV$_A$: *Volatility of price changes is higher during periods when only speculating investors are present compared to periods when dividend-collecting investors are also present in the market.*

4. Results[26]

4.1 Evolution of prices

Figures 2 and 3 illustrate the dynamic evolution of transaction prices in our experiment 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.[27] Note that the fundamental value – the terminal dividend of 50 – is constant across all periods throughout our experiment. The thick blue line with hollow circular markers is the average of six sessions in each panel.

(Insert Figures 2 and 3 about here)

Figure 2 for high-liquidity sessions shows that in T1H markets (the upper left panel where the dividend-collecting generation G1 is present in all 16 periods) prices are near or above the fundamentals (50). While prices are relatively high in period 1, they tend towards fundamentals with time (except in one session), and they converge close to the fundamental value in the last period (Period 16) in four of the six replications.[28] Earlier experimental studies

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[26] In this section, we only present analyses directly related to the hypotheses formulated in Section 3.4 and the formation of price expectations. In the Appendices D, E, and F we provide additional analyses on the accuracy of price predictions (Appendix D) and regression results (Appendix E). In Appendix F, we present additional analyses on trading patterns observed in our markets (Appendix F1: Forfeiture rates of securities; Appendix F2: Concentration of security holdings among traders; Appendix F3: Trading activity between different combination of two investor types; Appendix F4: Do the last generations behave like fundamental traders?; Appendix F5: Cash constraint investors; Appenidx F6: Ratio of buy transaction value to fundamental transaction value).

[27] We dropped two transactions that occurred at prices above 800 from the analyses; one was at 999 in period 9 of a T2H market (one of 64 transactions in that period; it was probably a keyboard error made under pressure of heavy/fast trading); the second observation was a price of 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 confirm that the results remain qualitatively unchanged. Note that no session ended before period 16. The two sessions appearing to have ended early did not see any transactions in spite of several bids and asks in the final periods.

[28] Noisy convergence suggests far-from-perfect arbitrage even in the final period. In a few sessions in Figures 2 and 3, the mean prices (thin grey lines) are above 50 in Period 16 indicating that some traders bought the security at prices above 50 even in the final period. Either these traders hoped to resell the security to others at even higher prices within the 120 seconds of the last period, or they did not fully understand the rules of the market. In Appendix F4 we provide further data on whether the last generation behaves like fundamental traders.

with constant fundamental values also report that prices tend to converge to fundamentals (Porter and Smith 1995, Smith et al. 2000, Noussair et al. 2001, Kirchler et al. 2012, Stöckl et al. 2015). In contrast, in treatments T2H, T4H, T8H, where many periods with only speculating generations exist, positive deviations of prices from fundamentals are larger and more persistent.[29] In these high-liquidity treatments, prices usually converge towards fundamentals only once the dividend-collecting investors (of the last generation) enter the market. The low-liquidity sessions (Figure 3) also exhibit a similar tendency of larger deviations from fundamental prices in periods with only speculating investors, and these deviations are mostly negative.

Figures 2 and 3 point to inconsistencies with the REE predictions because (i) the absence of dividend-collecting investors influences prices, and (ii) the securities with identical dividend and maturity are priced differently in the four treatments. These data appear to reject hypotheses I_0 and II_0 in favor of I_A and II_A for high as well as low-liquidity treatments. In addition, in periods with only speculating investors, generally positive price deviations from the fundamental value in the high-liquidity treatment (Figure 2) and generally negative deviations in the low-liquidity treatment (Figure 3) favor rejecting null hypothesis III_0 in favor of alternatives III_{A-1} and III_{A-2}.

4.2 Analyses of price deviations from the fundamental value

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

$$RAD = \frac{1}{N}\sum_{t=1}^{N}|P_t - F_t|/|\bar{F}| \quad (7)$$

[29] In the transition periods when a new cohort/generation of traders enters the market, we frequently see “price jumps” that appear to be similar to the “restart effect” often observed in public good games. This is likely driven by (i) new and inexperienced traders entering the market and (ii) their initially available cash balances.

where $|P_t - F_t|$ is the deviation of the mean price from the fundamental value in period t, $|\bar{F}|$ is the absolute average fundamental value in the session, t is 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 price deviations among dividend collecting and other periods within a session, we propose *Period-RAD*, a measure of mispricing per period.

$$Period\text{-}RAD = |P_t - F_t|/F_t \quad (8)$$

Since $F_t = 50$ throughout all sessions of the experiment *Period-RAD* is

$$Period\text{-}RAD = |P_t - 50|/50. \quad (9)$$

We calculated *Period-RAD* for each of 16 periods in 24 high-liquidity sessions (six sessions × four treatments) and 24 low-liquidity sessions.[30]

(Insert 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 dividend-collecting investors (the last generation) present are shaded in grey and those with only speculating investors present are white. Subsets of periods in which the same two generations trade have a bold border. 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 when only speculating investors are present (white cells) than in presence of dividend-collecting investors (grey cells).

Table 4 summarizes 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 differences

[30] 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. 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 since they had no transactions). These deletions reduced the sample size for each liquidity treatment to 381. The resulting average of *Period-RAD* is 0.735 (with a standard deviation of 0.908) across all high-liquidity sessions and 0.333 (with a standard deviation of 0.304) for the low-liquidity sessions.

(0.623 in H and 0.362 in L) are large in absolute terms and statistically significant at the 1% level for each liquidity treatment (two-sided t-test).[31] The Null hypothesis I_0 (that the presence of dividend-collecting investors makes no difference) can be rejected in favor of the alternative I_A. The REE hypothesis does not hold in our laboratory markets, although theoretically, the REE would seem to be an obvious outcome in this simple market environment.

(Insert Table 4 about here)

When the number of future generations who will enter the market until the security matures is higher, speculating investors would need to perform the more difficult task of backward inducting over expectations of more generations to arrive at REE, causing greater mispricing.[32] To examine this proposition, we calculated averages of *Period-RAD* across periods with only speculating investors, conditional on the number of yet-to-enter generations until maturity (for example, 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).

(Insert Figure 4 about here)

The resulting average *Period-RADs* are presented in Figure 4, which 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 finding suggests that speculating investors have some difficulty in forming rational expectations even when only one future generation is left. This difficulty may arise from investors' limited cognitive ability, lack of common knowledge of rationality, or doubts about perfect

[31] Note that *Period-RAD*s are not independent across periods within a session. We dealt with this dependence by regressing *Period-RAD* on the dummy variable which takes a value of one for periods with only speculating investors and checking whether the coefficient of the dummy is statistically significant using standard error adjusted for clusters (sessions). The coefficients are significant for both H and L treatments. As an additional robustness check, we added the period number (1-16) to the above regression to control for the learning effect of the subjects within a session. We also confirmed that the dummy for periods with only speculating investors is significant for both H and L treatments.

[32] Moinas and Pouget's (2013) experiment shows that subjects are more likely to buy the security at higher prices than fundamentals as the number of steps of iterated reasoning needed for backward induction increased.

arbitrage in the future. Taken together, these observations suggest that the assumption of rational expectations used in standard finance theory to derive REE may not hold even in this simple laboratory market.

To evaluate Hypothesis II, we use the data presented in Table 5. We see that the number of security transfers across generations until the maturity of the security (inverse of the length of investors' holding periods) affects mispricing. 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 (Panel A of 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 smaller numbers. We conclude that given the maturity of the security, the higher the number of future security transfers across generations of investors, the greater the deviation of prices from fundamentals. This result rejects Hypothesis II_0 in favor of the alternative hypothesis II_A.

(Insert Table 5 about here)

4.3 Liquidity supply and mispricing

With Hypothesis III, we explore 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 periods with only speculating investors in the high-liquidity sessions, but below the fundamental value in those periods 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*):

$$\textit{Period-RD} = (P_t - 50)/50 \quad (10)$$

where P_t is the mean price in period t.[33] The average of Period-RD across all high liquidity markets is positive (0.534 or 53.4% above the fundamental value), but negative (-0.222, or 22.2% below the fundamental value) across all low-liquidity sessions; the difference (0.756) is statistically significant at the 1% level (two-sided t-test).[34]

(Insert Table 6 about here)

To test Hypotheses III, we first examine whether positive mispricing in high liquidity markets is larger when only speculating investors are present in the market. Table 6 compares average *Period-RD* in periods with dividend-collecting investors present to those with only speculating investors. In high-liquidity sessions, the average *Period-RD* across periods with dividend-collecting investors is 0.295 (significantly different from zero at the 1% level, two-sided t-test), which indicates that prices are on average 29.5% higher than the fundamental value. 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 (two-sided t-test). This result rejects Hypothesis III_0 in favor of the alternative III_{A-1}; with high liquidity, speculating investors amplify the magnitude of overpricing. As seen in Section 3.3, if speculating investors have difficulty in forming rational expectations of future prices, they (e.g., traders of G2) may buy the security at prices over 50 if they think that some future buyers (e.g., traders of G3) may purchase the securities at even higher prices with the hope of subsequent price increases. This "hot potato" game is more likely to occur when more cash is on hand in the high-liquidity (H) treatments.[35, 36] We conjecture that this game among speculating

[33] *Period-RD* is an analog of *RD* (Relative Deviation), proposed by Stöckl et al. (2010) which measures the average level of gross (not absolute) price deviations from fundamental values across all periods throughout the session.
[34] 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 dividend-collecting investors in our experiment), a larger C/A-ratio is associated with greater positive mispricing (see Palan 2013 for a survey).
[35] In H treatments, each trader (e.g., with 4,000 of cash in T4H) could buy up all the securities (e.g., 40 in T4H) even at a price of 100.
[36] Additional evidence in this regard is provided in Appendix F2 in which we report that the concentration of securities (SC) is significantly higher in H treatments than in L treatments in T1, T2, and T8. In addition, this

investors causes positive price deviations from fundamentals to persist over time in H liquidity treatments.[37, 38]

In the low-liquidity sessions, the average of *Period-RD* when dividend-collecting investors are present is -0.087, which is small but significantly different from zero at the 1% level (two-sided t-test), indicating the imperfect arbitrage by dividend-collecting investors. The average *Period-RD* when only speculating investors are present is -0.340, significantly different from -0.087 at the 1% level (two-sided t-test). This result rejects Hypothesis III_0 in favor of $III_{A\text{-}2}$ and indicates that with low liquidity, investors' short-term speculation magnifies the undervaluation.[39] We conjecture that this result might be caused by speculating investors' fear of future price drops. As reasoned in Section 3.3, some speculating investors (e.g., from G3), may fear being forced to sell below 50 because the dividend-collecting investors' (e.g., from G4) may fail to compete perfectly,[40] and transact at prices below 50. This is more likely to occur in

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concentration increases over the course of the experiment. Crockett et al. (2019) also show the experimental evidence that a small number of subjects accumulate most of the securities.

[37] This hot potato game among traders is often reported in theoretical literature on bubbles (Abreu and Brunnermeier 2003, Allen et al. 2006, De Long et al. 1990a, 1990b, Dow and Gorton 1994, Froot et al. 1992, Scheinman and Xiong 2003) and related to the "greater fool theory" (Kindleberger 2000). In addition, this hot potato interpretation is consistent with DeMarino et al. (2013) who report that subjects with high theory of mind have an increased propensity to ride bubbles.

[38] We could also argue that even dividend-collecting investors (the last generation) may participate in the hot potato game as well, which causes positive price deviations in their presence in H treatments (see positive price deviations in the upper-left cell in Table 6 and the upper-left panel (T1H) in Figure 2).

[39] For robustness checks on the results of Table 6, we regressed Period-RD on the dummy variable which takes a value of one for periods with only speculating investors and confirmed that the coefficient of the dummy is statistically significant using standard error adjusted for clusters (sessions) for both H and L treatments. We also add the period number (1-16) to the above regression to control for the learning effect of the subjects. The result shows that while the dummy for periods with only speculating investors become insignificant for H treatments, it is still significant for L treatments.

[40] 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 do, 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 crises; 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. In Figure 3, 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.

low liquidity treatment when every trader may not have enough cash to execute perfect arbitrages.[41]

Figure 5 presents *Period-RD* classified by the number of subsequent generations yet to enter the market. In the high-liquidity treatments (Panel A), when this number is two or more, *Period-RD*s are significantly different from periods with dividend-collecting investors, indicating that prices are higher than in the periods with dividend-collecting investors. This observation seems to suggest that in high-liquidity treatments, speculating investors participate in a "hot potato" game when at least two future generations enter the market (i.e., when at least one entering generation of speculating investors is left)[42]. Moreover, we find that *Period-RD* tends to increase with the number of generations left, indicating that the hot potato game is more likely to occur when traders are further away from the terminal generation. 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* in the periods with dividend-collecting investors. Note that the difference is statistically significant even when the number of entering generations is one (i.e., when the following generation is the generation of dividend-collecting investors). This supports the conjecture that speculating investors' fear of price declines in the future tends to keep the prices below the fundamentals. From these observations, it appears that overpricing in high-liquidity treatments occurs due to investors' "buy low and sell high" strategy; undervaluation in low-liquidity treatments occurs due to their anticipation of low prices in the future. These strategies arise not from REE but from the difficulty of forming rational expectations.

(Insert Figure 5 about here)

4.4 Volatility of prices

[41] In L treatments, each trader (e.g., with 800 of cash in T4L) could not buy all the securities (e.g., 40 in T4L) at prices above 20.

[42] Note that the when the remaining number of entering generations is two, the number of entering generation of speculating investors left is only one, since the final generation consists of dividend-collecting investors.

To estimate the within-period price volatility, we calculate for each period the standard deviation of log-returns (*Period-VOLA*) using (11). Here, i indexes transactions in period p; I is number of transactions in period; P_i is the price of transaction i; log returns are calculated as $RET_i = \ln(P_i/P_{i-1})$; $\overline{RET}$: mean of log returns in period p.

$$\text{Period-VOLA} = \sqrt{\frac{1}{I}\sum_{i=1}^{I}(RET_i - \overline{RET})^2} \tag{11}$$

Table 7 compares average *Period-VOLA* across all periods with dividend-collecting investors (0.135 in H and 0.091 in L) with periods populated only by speculating investors (0.222 in H and 0.266 in L). The differences (0.086 in H and 0.175 in L) are large in absolute terms and statistically significant at the 1% level for each of the two treatments (two-sided *t*-tests). These results indicate that speculating investors introduce a higher level of price volatility in the market even within a period. When dividend-collecting investors are present, volatility is significantly lower. The null hypothesis IV_0 (that the presence of speculating investors does not impact price volatility) is rejected in favor of the alternative IV_A.

(Insert Table 7 about here)

4.5. Formation of Expectations

Finally, we examine if the formation of price expectations differs between markets with dividend-collecting investors and markets with only speculating investors. Since the dividend-collecting investors would focus on the known fundamental value, their presence in the markets should tend to bring the investor expectations towards this value. In contrast, in markets with only speculating investors, investors may have to seek alternative mechanisms for forming expectations if they have difficulties in forming rational expectations of future prices through backward induction from the terminal dividend, We use the price prediction data to try to address this question.

We postulate two simple models of the price expectation formation; a fundamental model and a trend model (Hirota and Sunder 2007). In the former, investors form expectations of future prices based on backward induction from the deviation of prices from the fundamental value of the security.

$$E_t(P_{t+1}) = P_t + \alpha(F_t - P_t) \tag{12}$$

where P_t is the price of the security at time t, F_t is the fundamental value, $E_t(P_{t+1})$ is investor's expectation at time t of the price at time $t+1$, and α (> 0) is the adjustment coefficient. Investors expect future price appreciation (depreciation) if F_t is higher (lower) than 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: $E_t(P_{t+1}) = F_t$ in any period t.

The trend model assumes that investors form their expectations about future prices through forward induction or extrapolation based on recently observed price changes (it captures momentum).

$$E_t(P_{t+1}) = P_t + \beta(P_t - P_{t-1}), \tag{13}$$

where P_{t-1} is the price at t-1. If $\beta > 0$, recent price increases (decreases) cause investors to expect further price increases (decreases) in the future; if $\beta < 0$, the reverse holds. With this model, investors' expectations of the future prices are based on recent price movements; fundamentals do not influence the formation of price expectation.

We can combine (12) and (13) into a more general specification of expectation formation:

$$E_t(P_{t+1}) = P_t + \alpha(F_t - P_t) + \beta(P_t - P_{t-1}). \tag{14}$$

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

Rearranging terms, (12), (13) and (14) become

$$E_t(P_{t+1}) - P_t = \alpha(F_t - P_t), \quad (15)$$

$$E_t(P_{t+1}) - P_t = \beta(P_t - P_{t-1}), \text{ and} \quad (16)$$

$$E_t(P_{t+1}) - P_t = \alpha(F_t - P_t) + \beta(P_t - P_{t-1}), \quad (17)$$

where $F_t = 50$ (the terminal dividend) throughout all periods in all sessions in the experiment.[43]

The cross-sectional average of the predictors' price expectations (for the following period) is used for $E_t(P_{t+1})$, and the average price of the previous period and the one before that are used as P_t and P_{t-1}, respectively.[44] We estimated equations (15), (16) and (17) using the data from 360 periods (24 sessions in four treatments x 15 periods) for each of high and low-liquidity treatments.[45] We divided the sample into the periods with dividend-collecting investors and the periods with only speculating investors. We conducted the estimation using ordinary least squares regression with constant terms, treatment (T2, T4, T8) dummies and period dummies (Period 3-Period 16). Table 8 shows the estimation results.

Overall, the coefficient of $(F_t - P_t)$ in the combined model ranges from 0.051 to 0.374, which is significantly less than one (at 1% level). Even when dividend-collecting investors are present, adjustment to REE is gradual, not instantaneous.[46]

Although the data reject the instantaneous rational expectation formation, it reveals that the fundamental value of the security helps anchor the expectation of future price in markets with dividend-collecting investors. In periods with dividend-collecting investors (left half of

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[43] 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 two lags - AR (2) - 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 (9)) when $\gamma = 0$, $\beta_1 + \beta_2 = 1$, and $\beta_2 = -\beta$.

[44] In the experiment, we asked the predictor to forecast the price only for the following period. In this sense, we elicit only "short-run" price expectation. Some asset market experimental studies (e.g., Evans et al. 2019, Hanaki et al. 2018, Haruvy and Noussair 2006) elicit not only short-run but also long-run price expectations (asking subjects to forecast prices over multiple periods).

[45] Note that the actual number of observeraions is below 360 due to period with no transactions and the fact that we do not have data for Period 1 in TREND and COMBINED, because, while we have the data of the average price expectation ($E_t(P_{t+1})$) we do not have the data of the average price of the previous period (P_t).

[46] This result is consistent with the empirical results reported by Greenwood and Shleifer (2014). They show that expectations of investors captured by the surveys are not at all the expectations obtained from REE models.

Table 8), backward induction from fundamental values fits the data better than the forward induction from past prices. In high-liquidity sessions (upper left of Table 8), the coefficient of $(F_t - P_t)$ is significantly positive (0.189) 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, while both the fundamental factor $(F_t - P_t)$ and the trend factor $(P_t - P_{t-1})$ are statistically significant, the former effect (0.202) is significantly larger than the latter (0.104).[47] In low-liquidity sessions (lower-left of Table 8), the coefficient of $(F_t - P_t)$ is significantly positive in both the fundamental (FUND; 0.358) and the combined (COMBINED; 0.374) models; the coefficient of $(P_t - P_{t-1})$ is not significant in either trend and combined models. These results suggest that in the presence of dividend-collecting investors, the fundamental value of the security helps form expectations and determines transaction prices. Arbitrage transactions of dividend-collecting investors enable market participants to expect that future prices will converge to the fundamental value.

(Insert Table 8 about here)

In contrast, the results in periods with only speculating investors (right half of Table 8) support the trend model better than the fundamental model. In high liquidity sessions (upper right of Table 8), the coefficient of $(F_t - P_t)$ in the FUND model (0.121) is marginally significant, but it becomes insignificant in the combined (COMBINED) model. The coefficient of $(P_t - P_{t-1})$ is -0.285 and -0.250 in the trend (TREND) model and the combined (COMBINED) model, respectively, and both are statistically significant at the 1% level. In low liquidity sessions (lower right of Table 8), the coefficient of $(P_t - P_{t-1})$ is significantly negative in both trend (TREND; -0.187) and combined (COMBINED; -0.172) models.[48] These results suggest that

[47] The difference in two coefficients is significant at 5.6 % level (two-sided test).

[48] $(F_t - P_t)$ is also significant in the fundamental and combined models, albeit with much smaller estimated coefficients (0.067 and 0.051) as compared to the periods with dividend-collecting investors (0.358 and 0.374). We can infer that the trend model is better supported over the fundamental model in periods with only speculating investors for low as well as high-liquidity sessions.

in a market with only speculating investors, investors tend to form their expectations based on recently observed prices through forward induction, and not backward induction from fundamental values. In addition, 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 the next period price by about 0.17-0.29. [49]

Overall, the results shown in Table 8 indicate that the expectations about future prices are formed based on the fundamentals (through backward induction) in a market with dividend-collecting investors, and are based on recent price changes (through forward induction) in a market with only speculating investors. [50]

5. 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 holding periods are not relevant and therefore frequently ignored; they are replaced in trading decisions by expectations about future prices. Standard finance theory, however, assumes that even in such markets speculators form iterated rational expectations of future prices through backward induction and prices tend toward the fundamental value constituting the rational expectations equilibrium (REE). We conjecture that this assumption cannot be met in practice, causing prices to deviate from fundamentals and become indeterminate in financial markets populated by speculating investors.

[49] While this pattern of reversal in expectations has been observed in some experimental markets (Bao, et al. 2012, 2013), it is in a sharp contrast to the momentum (extrapolative) expectations reported in other experimental markets (Haruvy et al. 2007, Hirota and Sunder 2007, and Hommes et al. 2005).

[50] We also considered session-specific fixed effects estimating session-specific fixed effect models (adding period dummies). The results are very similar to the ones in Table 8. In periods with dividend-collecting investors, all coefficients of (F_t – P_t) are significantly positive but two of the coefficients of (P_t -P_{t-1}) are not significant; in periods with only speculating investors, all coefficients of (P_t -P_{t-1}) are significantly negative. These numbers support our arguments.

We conduct an asset market experiment with an overlapping-generations structure where all investors have identical common knowledge beliefs about the fundamental value of the security. Our laboratory results show 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) volatility of prices is higher when only speculating investors are present; (iii) prices are more likely to depart from fundamentals when the securities changed hands among speculating investors more often over their 16-period life (i.e., the holding period of speculating investors shrank); and (iv) speculative trading pushes prices upward (downward) when money supply is high (low). These laboratory results do not support the REE prediction made by standard finance theory for this environment; instead, they suggest that speculation leads to price indeterminacy or bubbles (positive as well as negative with the sign driven mostly by liquidity).

Given these results, it is reasonable to think that price indeterminacies and bubbles in field markets may arise in the presence of speculating investors. The mechanism for these price bubbles observed in the laboratory is unlike the mechanisms suggested in the extant theoretical literature – rational bubbles models (e.g. Blanchard and Watson 1982, Tirole 1985) and heterogeneous belief models (e.g. 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). Even in these simple laboratory markets (the security pays a single non-stochastic common knowledge terminal dividend at the end of its 16-period life), it is difficult for speculating investors to form common knowledge rational expectations of future prices. Since securities traded in real financial markets have more complex features (such as uncertainty, information asymmetries, and heterogeneous beliefs regarding future cash flows), we conjecture that common knowledge of rationality among investors is even less likely to hold in the field and investors face even greater challenges in forming rational expectations, and making such expectations common knowledge.

Building theories by relaxing the assumption underlying rational expectations is a promising way to explain the price volatility and indeterminacy in financial markets (see, e.g., Adam and Marcet 2011).

In some earlier experiments, financial markets converged to the static REE (Plott and Sunder 1982, 1988) in which traders can infer the current state of the world from the observed market phenomena. In contrast, the REE examined in our markets is *dynamic* and inter-generational; investors' expectations of future prices must be formed by iterated expectations and backward induction over generations. Arriving at this dynamic REE is implausibly difficult since it requires investors to have not only extraordinary cognitive abilities but also common knowledge to be established within and across generations of investors.

Several implications emerge from this study. First, greater inefficiency, pricing anomalies, and so-called "behavioral" phenomena, which cause security prices to depart from fundamentals, are more likely to be observed when markets are populated with mostly speculating 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 observation 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 trading generations that exchange and hold the security between the present and the maturity date increases, and it becomes more difficult for investors to form rational expectations by backward inducting through multiple iterations, magnifying the impact of backward induction errors on prices. This suggests that common stocks are more susceptible to (positive or negative) price bubbles compared to other securities, because the stock typically has no maturity date.

Fourth, the securities with longer durations[51] are more likely to deviate from fundamentals. 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 more-difficult-to-anticipate capital gains (future prices). This explains the informal observation that bubbles are more likely to occur for high-growth stocks with long durations.

Fifth, prudent monetary policy would matter for the stabilization of security prices. Our laboratory data show that in markets with speculating investors, the high level of money supply enlarges positive price bubbles from fundamentals, whereas the low level of money supply causes negative price bubbles. This finding implies that controlling the supply of money and credit is important for stabilizing not only the real economy but also security prices when markets are dominated by speculating investors.[52] Sixth, 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, the effectiveness of policies for suppressing price bubbles and indeterminacy is a subject for future exploration.

[51] Duration is the weighted average time of a security's cash flows.
[52] Some recent laboratory experiments explore the effectiveness of monetary policy in reducing asset market bubbles (Fischbacher et al. 2013, Giusti et al. 2016, Fenig et al. 2018, Hennequin and Hommes 2018, Bao and Zong 2019). These experiments focus on whether interest rate policy (controlling interest rates) deflates asset market bubbles. In contrast, our laboratory result has an implication on monetary policy by suggesting that controlling money supply would be effective in reducing (both positive and negative) bubbles.

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Table 1: Treatment Overview

		Liquidity	
		HIGH (C/A-ratio=10)	LOW (C/A-ratio=2)
Number 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/investor G0	32	32	16	16	8	8	4	4
Initial no. of securities/G1-G8	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/investor G0	0	0	0	0	0	0	0	0
Initial cash/investor G1-G8	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-to-asset value 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: The number of investors/generation (5); the number of active generations (2); active investors (10 investors); period length (120 sec.); the total number of periods (16); the number of markets per treatment (6); the 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

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 Sessions

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 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

	(1) Periods with dividend-collecting investors present	(2) Periods with only speculating 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: The sample size is in parentheses. *** indicates that the difference is statistically significant at the 1% level determined by a two-sided t-test.

Table 5: Comparison of Average *Period-RAD* between Treatments with High and Low Liquidity

Panel A: Average *Period-RAD* by Treatments

Treatment	T1	T2	T4	T8
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: The 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 Dividend-Collecting Investors and Periods with only Speculating Investors

	(1) Periods with dividend-collecting investors present	(2) Periods with only speculating 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 determined by a two-sided t-test.

Table 7: Comparison of Average *Period-VOLA* between Periods with Dividend-Collecting Investorsvs and Periods with only Speculating Investors

	(1) Periods with dividend-collecting investors present	(2) Periods with only speculating investors	Difference (2)−(1)
High-liquidity session (Treatment H)	0.135 (172)	0.222 (203)	0.086***
Low-liquidity session (Treatment L)	0.091 (176)	0.266 (201)	0.175***

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

Table 8: Price Expectations Model Estimates

High-liquidity Session	**Periods with dividend-collecting investors**			**Periods with only speculating investors**		
	FUND	TREND	COMBINED	FUND	TREND	COMBINED
$(F_t - P_t)$	0.189***		0.202***	0.121*		0.100
	(0.048)		(0.055)	(0.065)		(0.062)
$(P_t - P_{t-1})$		0.030	0.104**		-0.285***	-0.250***
		(0.032)	(0.044)		(0.045)	(0.039)
N	173	167	167	186	168	168
R-squared	0.47	0.18	0.49	0.34	0.44	0.52

Low-liquidity Session	**Periods with dividend-collecting investors**			**Periods with only speculating investors**		
	FUND	TREND	COMBINED	FUND	TREND	COMBINED
$(F_t - P_t)$	0.358***		0.374***	0.067***		0.051**
	(0.079)		(0.088)	(0.021)		(0.019)
$(P_t - P_{t-1})$		-0.112	0.029		-0.187***	-0.172**
		(0.066)	(0.047)		(0.064)	(0.062)
N	171	162	162	186	168	168
R-squared	0.59	0.41	0.59	0.34	0.40	0.42

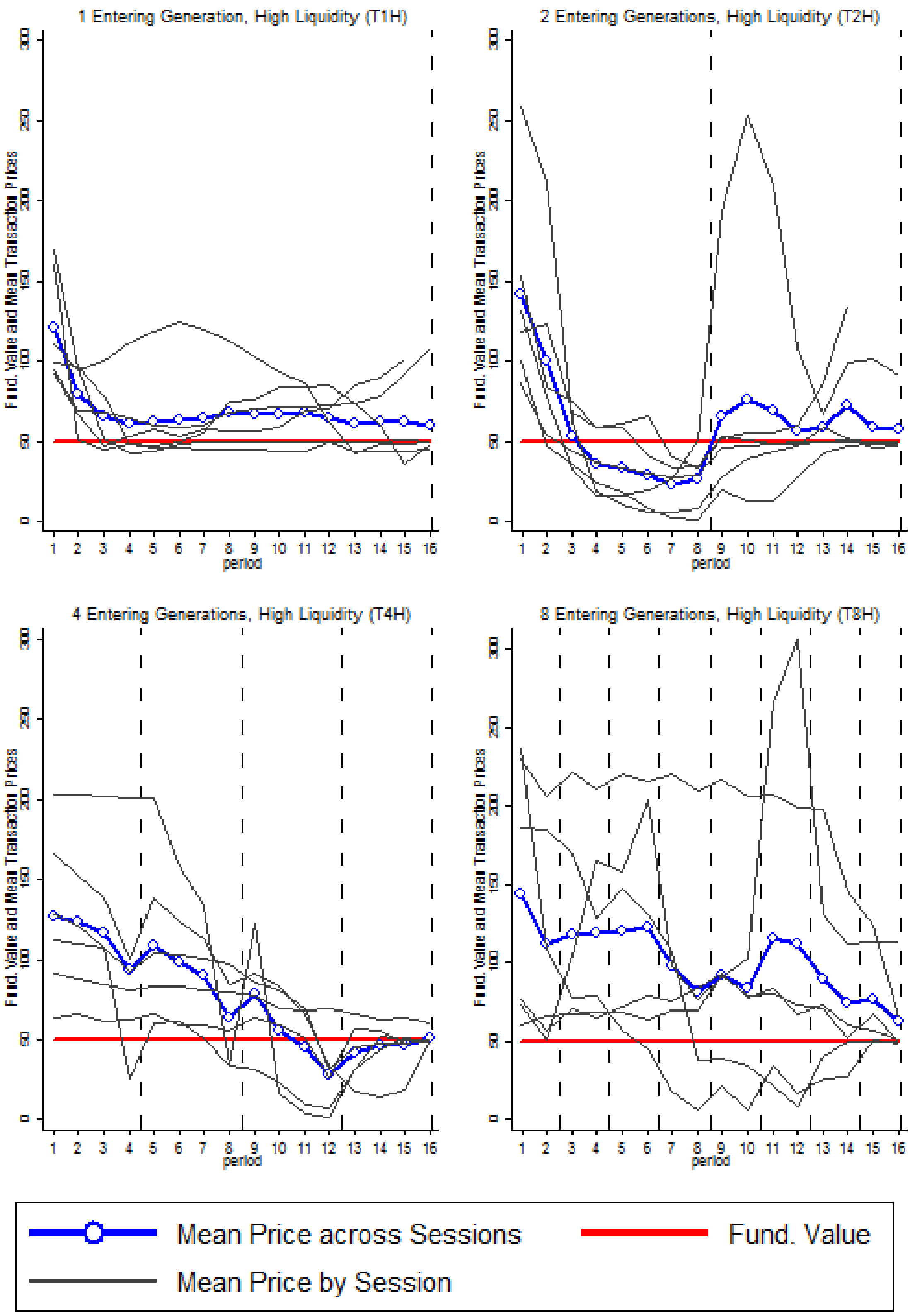
Notes: Constant terms, treatment dummies (T2, T4, T8), and period dummies (Period 3 to Period 16) are included in all regressions but not reported. Standard errors clustered by session in parenthesis. Significance levels: * (10%), ** (5%) and *** (1%).

Figure 1: Overlapping Generations Design

Treat-ment	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

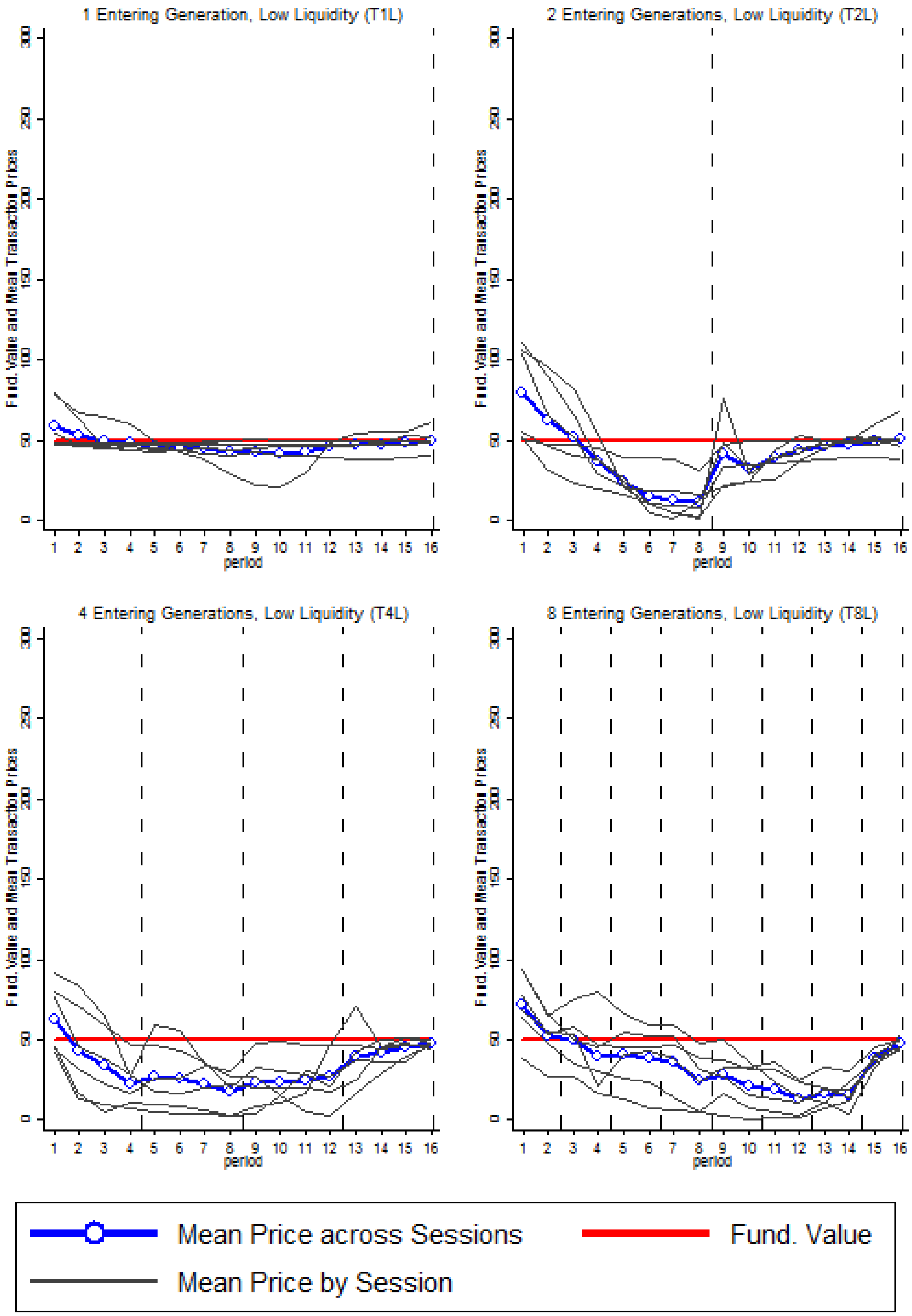
Notes: D means that the last generation of investors receives terminal dividends (50) at the end of Period 16.

Figure 2: Period-wise Average Transaction Prices in High-liquidity Treatments.



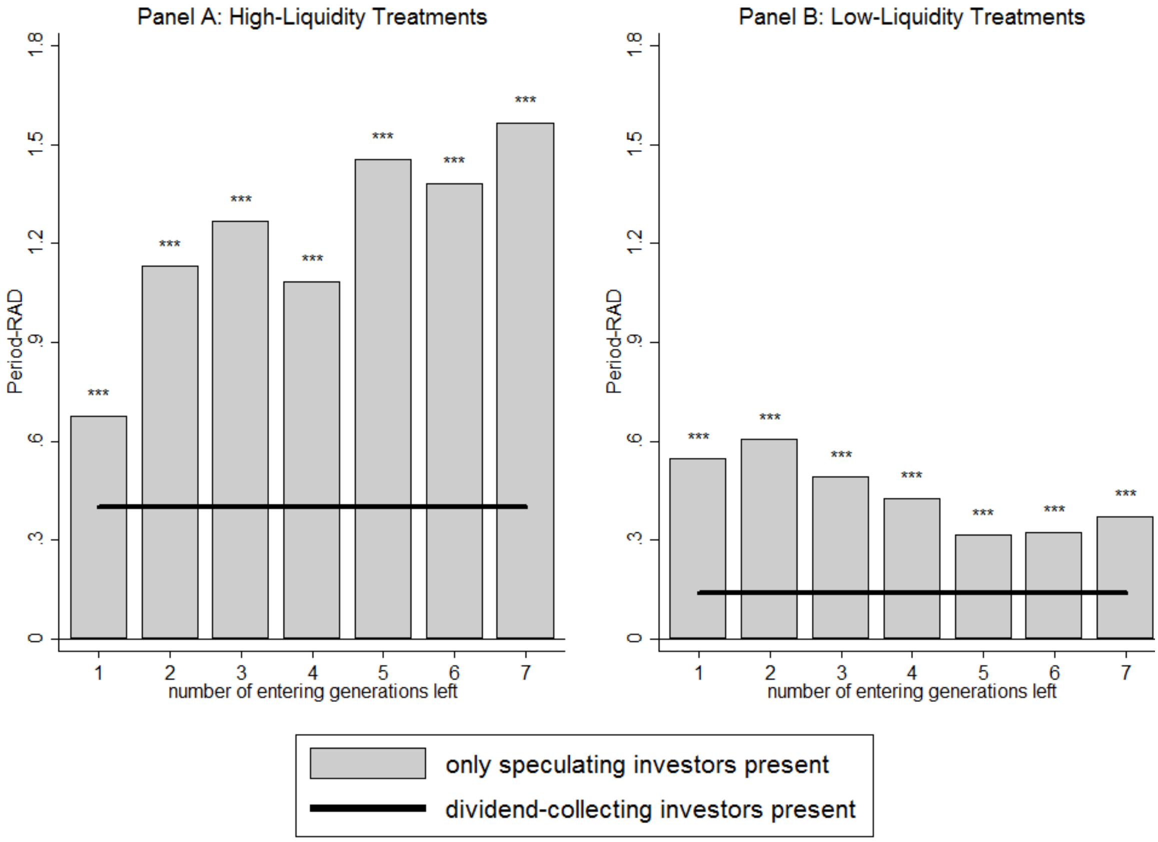
Notes: Volume-weighted mean prices from six individual sessions (thin grey lines), mean prices across the six individual sessions (blue bold line with hollow circles) and Fundamental Value (red bold straight line) by period. Broken vertical lines mark the entry/exit points of overlapping generations of investors. Each panel shows data for one of the four treatments: T1H, T2H, T4H, and T8H.

Figure 3: Period-wise Average Transaction Prices in Low-liquidity Treatments.



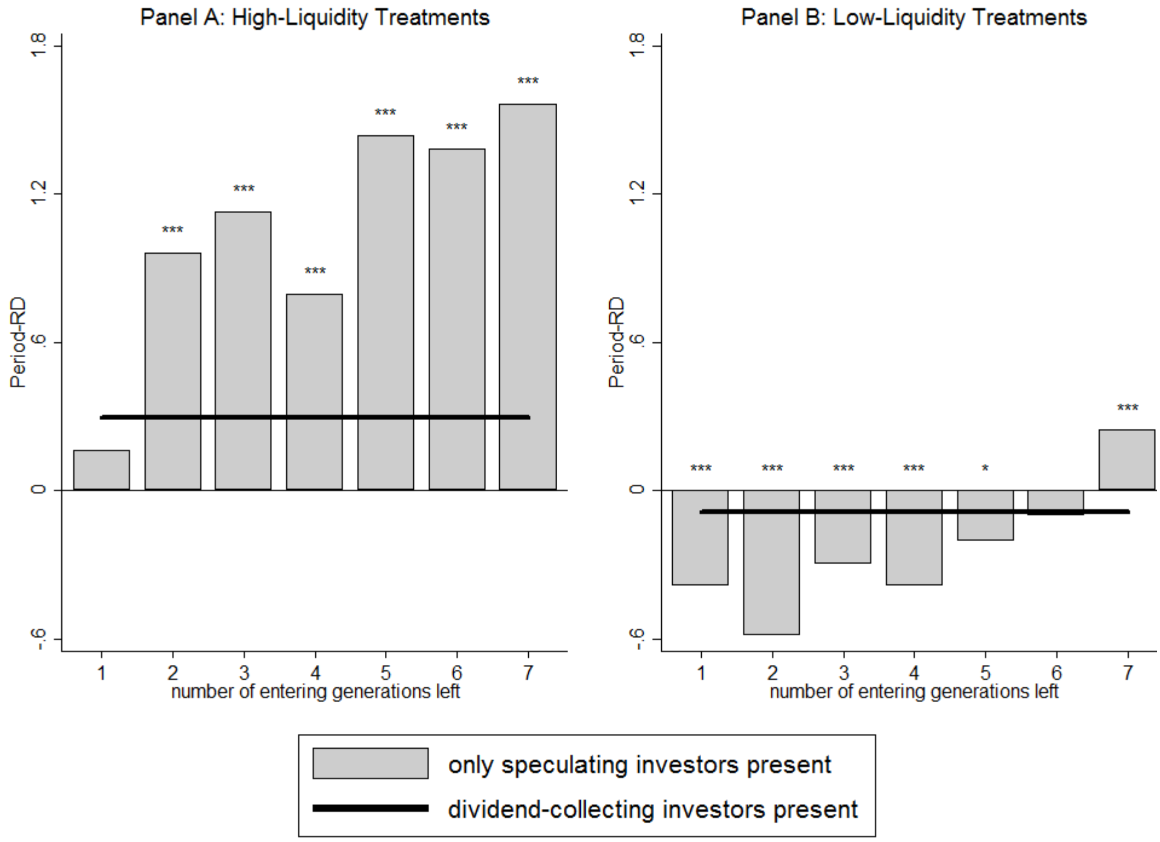
Notes: Mean prices from six individual sessions (thin grey lines), mean prices across the six individual sessions (blue bold line with hollow circles) and Fundamental Value (red bold straight line) by period. Broken vertical lines mark the entry/exit points of overlapping generations of investors. Each panel shows data for one of the four treatments: T1L, T2L, T4L, and T8L.

Figure 4: Average *Period-RAD* Conditional on the Number of Future Entering Generations



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 5: Average *Period-RD* Conditional on the Number of Entering Generations



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-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-collecting investors (two-sided t-test).

Appendix

Appendix A: Instructions of the experiment[58]

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 securities 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 an investor and from the prediction task, denoted in taler throughout the experiment, will be converted into euros and paid to you in cash at the end of the session. The more taler you earn, the more euros you will take home.

The course of the experimental session

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

[58] Instructions are for T2L. Instructions for other treatments and German translations used in the Innsbruck Econlab are available from the authors upon request. Trading screens are identical across treatments (except parameter values (given in Table 2).

Active market participants

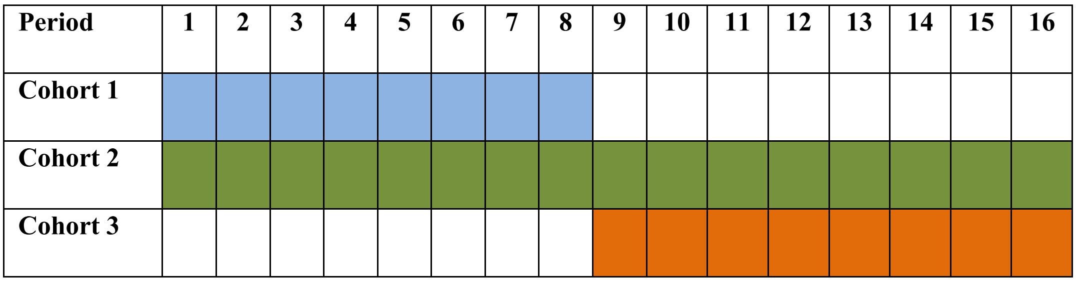
Assignment process

Figure A1 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 A1



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.

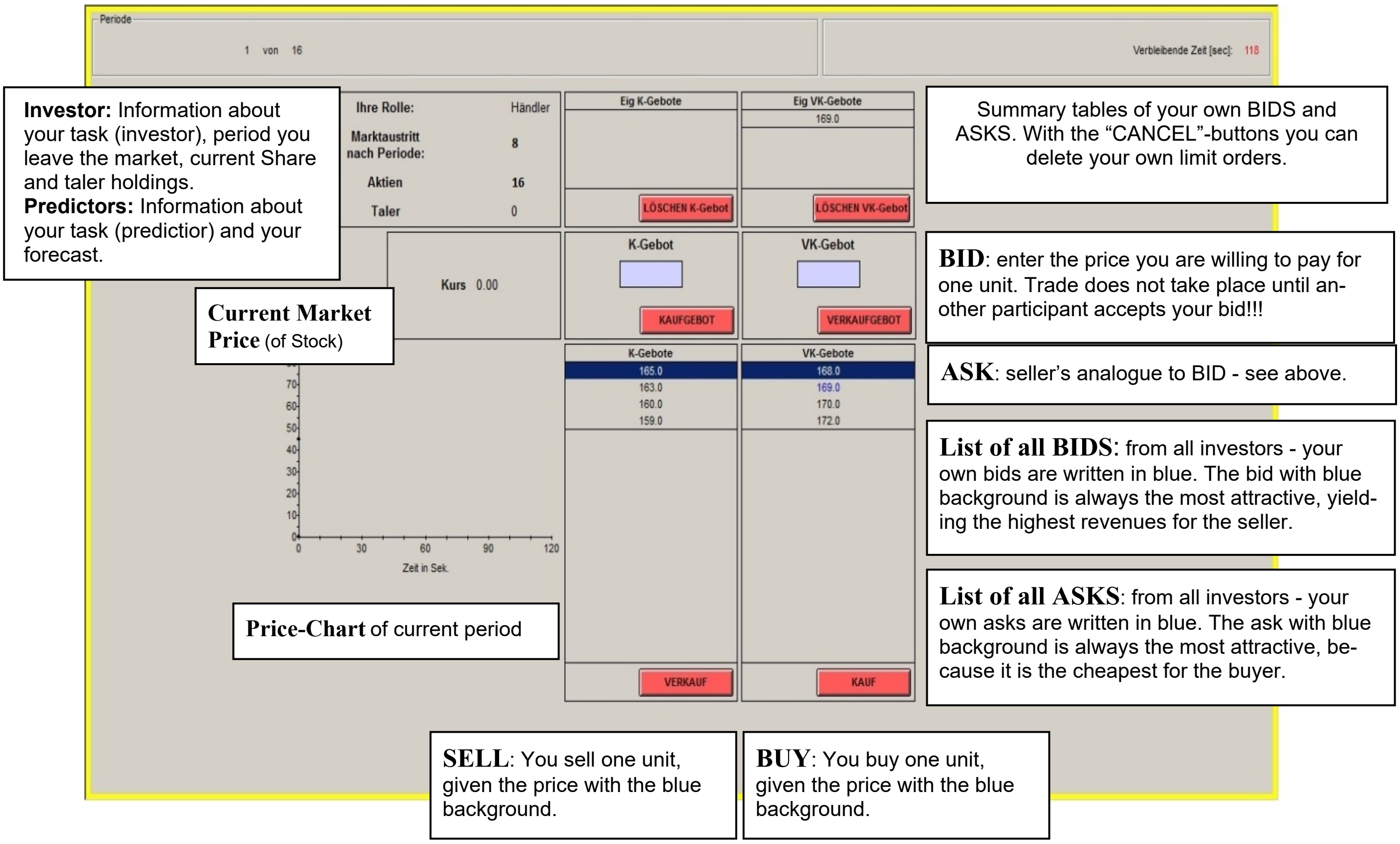
Cohort 3 also enters the market with 1.600 talers each and will be able to use these talers to buy any shares they wish to during periods 9-16. At the end of Period 16, any shares remaining in their hands pay a dividend of 50 taler each, which is added to their taler holdings.

When Cohort 1 and 2 leave the market their taler holdings will be converted into euros 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 A2), 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 canceled at the end of a period.

Figure A2: 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 taler you will 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 A3) for 15 seconds providing you with cumulative information.

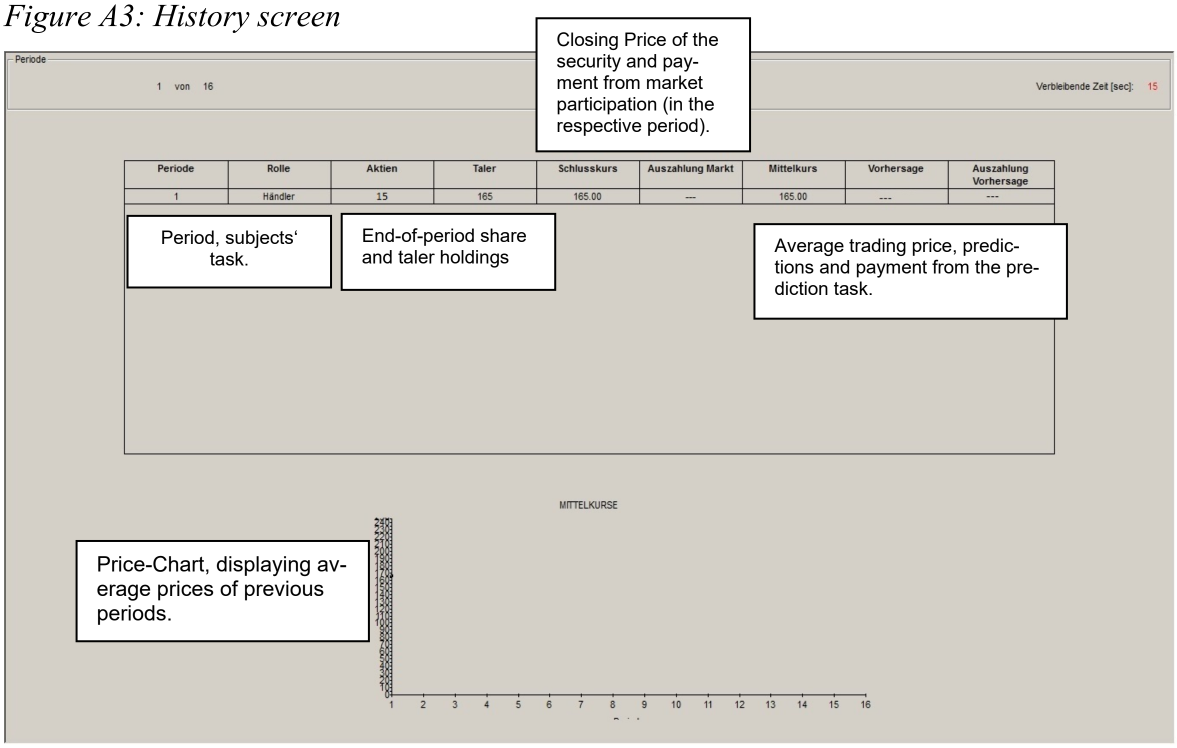
Important information

- No interest is paid for taler holdings.
- Each trading period lasts for 120 seconds.
- You have 30 seconds 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 do not influence your euro earnings!

Figure A3: 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 checking the comprehension of the instructions (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.

Appendix C: Analysis of subjects' earnings

In Table C1, we provide information on subjects' average earnings in each treatment (column total earnings). We furthermore split earnings into parts originating from the investor task (column investor earnings) and parts originating from the predictor task (column predictor earnings). To put these numbers into perspective, we report the average number of periods in which subjects had that role in the corresponding treatment in parenthesis.

Table C1: Subjects' average euro earnings by treatment and role

	Total earnings		**Investor earnings**		**Predictor earnings**	
Treatment	average	s.d.	average	s.d.	average	s.d.
T1L	16.04	1.60	15.85 (16.00)	1.93	16.42 (16.00)	0.32
T2L	15.40	3.38	10.17 (10.67)	5.29	9.58 (9.85)	3.34
T4L	15.39	2.64	8.49 (8.89)	3.11	6.90 (7.11)	1.62
T8L	15.75	1.72	8.79 (8.89)	1.90	6.95 (7.11)	0.96
T1H	17.63	4.57	18.75 (16.00)	5.24	15.39 (16.00)	0.57
T2H	15.46	3.38	10.96 (10.67)	5.19	8.76 (9.85)	3.16
T4H	16.57	3.22	9.87 (8.89)	3.97	6.70 (7.11)	1.71
T8H	15.52	2.33	9.36 (8.89)	2.37	6.16 (7.11)	1.35

Notes: The numbers in parenthesis indicate the average number of periods subjects had that role in the corresponding treatment.

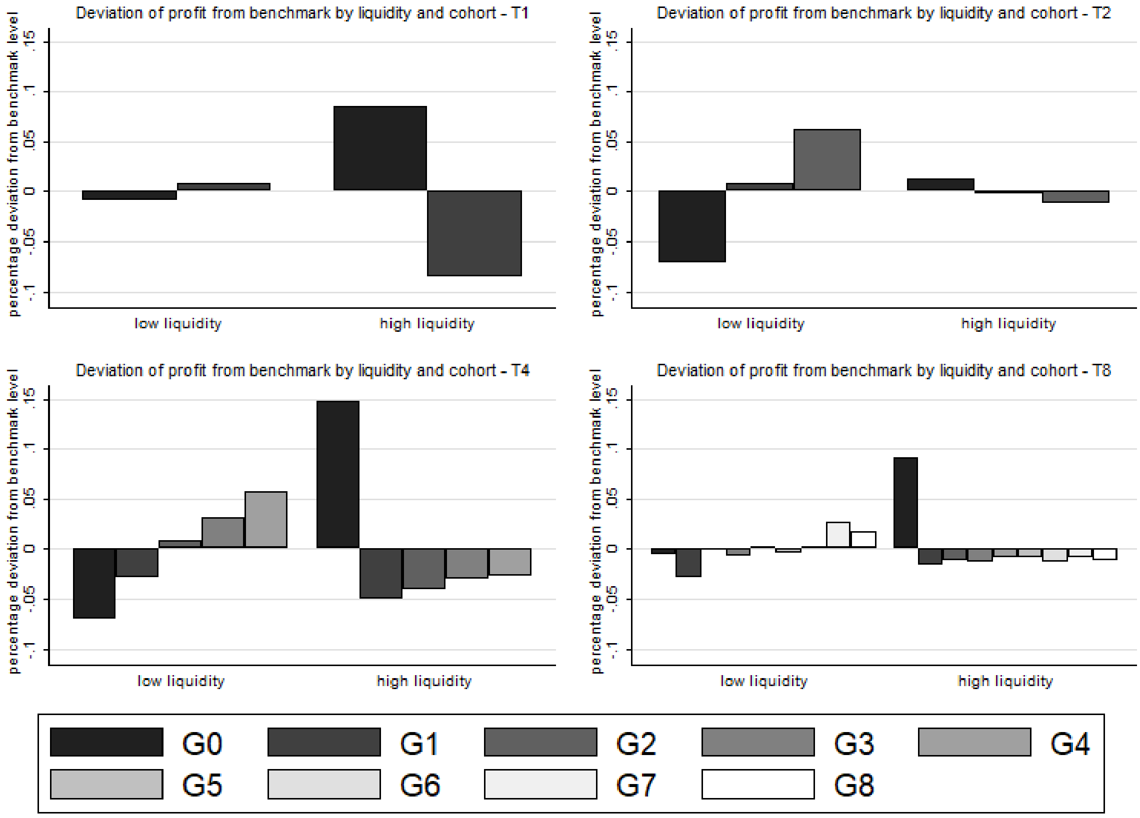
In Table C2, we show the relative average profits of dividend-collecting and speculating generations for the 4x2 treatments. Dividend-collecting generations earn more under low liquidity, and speculators earn more under high liquidity.

Table C2: Share of profits by the combination of two types of investors

LOW LIQUIDITY	T1	T2	T4	T8
Speculating	49.1%	44.4%	42.9%	45.9%
Dividend-coll.	50.9%	55.6%	57.1%	54.1%
HIGH LIQUIDITY	T1	T2	T4	T8
Speculating	58.6%	51.4%	52.0%	51.8%
Dividend-coll.	41.4%	48.6%	48.0%	48.2%

Figure C1 gives the percentage deviation of average generation profits from the equal-earnings benchmark for the 4x2 treatments. An interesting pattern emerges: in low liquidity markets, generations active in the market in an early stage, on average, exhibit profits below the benchmark, while in high liquidity markets, the first generation earns above-average returns.

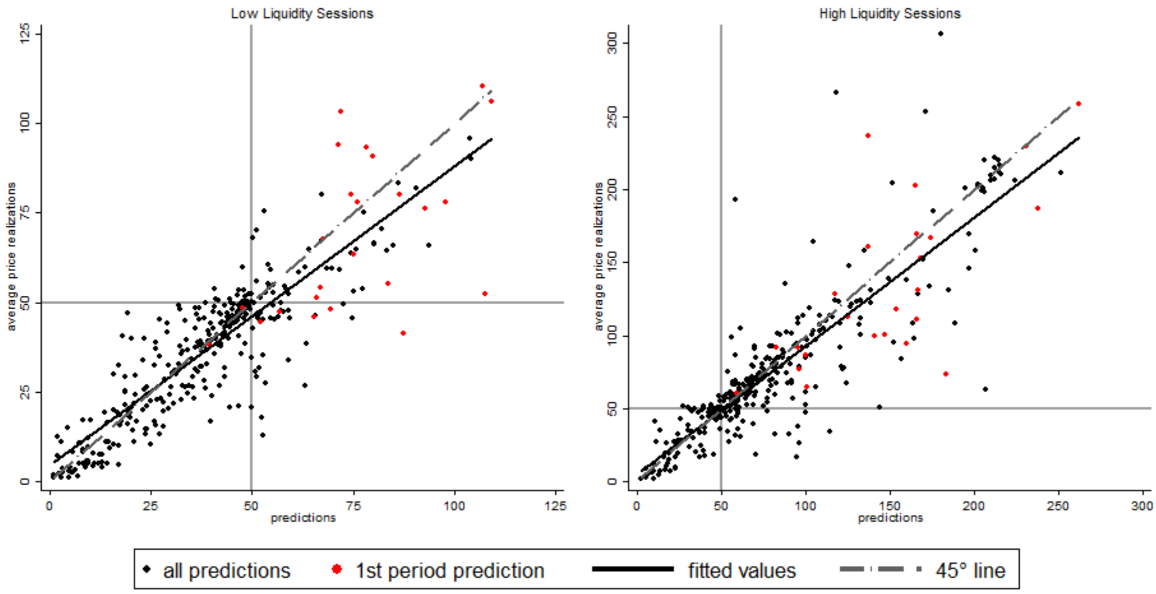
Figure C1: Deviation of profit of each generation from the average separated by treatment



Appendix D: The accuracy of price predictions

We turn to the price predictions submitted by the predictors. The five (in T1) or eight (in all other treatments) predictor subjects were not active in the market in the periods they made predictions for. We first chart and calculate how price predictions relate to observed prices. The two panels of Figure D1 show the relation between price predictions and the average price realizations for H (left panel) and L (right panel) treatments. We see that there is a strong relationship in both treatments and the correlation coefficient is 0.87 in each treatment. The average absolute deviation between price predictions and realized prices is 5.2 or 11.4 percent of the average price, which we consider fairly accurate.

Figure D1: Average period price predictions and average period price realizations



Notes: Average period price predictions and average period price realizations in low (left panel) and high (right panel) liquidity sessions. Solid grey lines indicate the fundamental value (50); black dots show predictions vs. average price realizations; red dots show predictions vs. average price realizations for period 1; the solid black line indicates the fitted values of a simple linear regression (with or without a constant?); the dash-dotted grey line is the 45° line.

The most difficult prediction is arguably the one in the first period, as no price history is available at that time. We already saw in Figure 2 that prices in the first period were usually above 50, with an average around 140 in H and 70 in L. Remarkably, these levels were also predicted: in high liquidity treatments first period prices (P_1) are above 50 in all (24) sessions. The predicted first-period prices are also above 50 in all (24) sessions. Similarly, in low liquidity sessions, first-period prices were above 50 in 17 of 24 sessions. Predictions for all 17 of these markets were also above 50 (of the remaining seven sessions with $P_1 < 50$ predictions are > 50 in five and <50 in two sessions). These results show that subjects correctly predict $P_1 > 50$ irrespective of the liquidity level.

In Table D1, we saw that price predictions are less accurate in periods with only speculating investors than periods with dividend-collecting investors. To explore whether prices are easier or harder to predict when the number of future generations increases, we regress the measure of prediction error (abs(EP-P)/P) on the "Number of entering generations left". The resulting coefficients of "Number of entering generations left" are always positive (see Table D5), showing that predictions are less accurate (and prices thus harder to predict) with a higher number of generations left. Furthermore, the regression results on "Number of periods left" show that the coefficients are always positive, which means that prices are harder to predict at the beginning of the session compared to later periods.

Finally, we analyze if subjects correctly predict that prices will drop in high-liquidity treatments when the 3rd-to-last generation is trading with the penultimate generation. In high liquidity treatments, of 78 periods when the 3rd-to-last generation is trading with the penultimate generation, 58 periods experienced a price drop (compared to the period before). Of the 58 periods with price drops in 39 periods (67.2% of cases) subjects correctly expected a price drop. In low liquidity treatments, in 43 (74.1%) of 58 periods that experienced a price drop, the subjects correctly expected the price drop. We thus conclude that subjects are mostly able to predict the price drop once the penultimate generation enters the market.

Table D1: Prediction Accuracy (regression analysis)

Panel A: High Liquidity Sessions

Dependent variables	*Abs(EP-P)/P*		*Abs(EP-P)/50*	
Intercept	0.250 *** (0.048)	0.197 ** (0.011)	0.230 *** (0.037)	0.130 ** (0.051)
Number of Entering generations Left	0.016 (0.018)		0.046 * (0.026)	
Number of Periods Left		0.010 (0.007)		0.021 *** (0.005)
R^2	0.004	0.008	0.038	0.050
N	381	381	381	381

Panel B: Low Liquidity Sessions

dependent variables	*Abs(EP-P)/P*		*Abs(EP-P)/50*	
Intercept	0.224 *** (0.045)	0.184 *** (0.051)	0.106 *** (0.015)	0.060 *** (0.014)
Number of Entering generations Left	0.041 ** (0.017)		0.020 *** (0.006)	
Number of Periods Left		0.013 * (0.006)		0.010 *** (0.002)
R^2	0.028	0.017	0.060	0.084
N	381	381	381	381

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

Appendix E: Regression results with *Period-RAD* as the dependent variable

We estimated the following two regressions as an alternative to the univariate tests we present in the main paper. In particular, we estimated random-effects models (standard errors clustered by session) with *Period-RAD* as the dependent variable separately for high and low-liquidity sessions. As independent variables, we use the interaction between an indicator for generations (values: 1, 2, 4, 8) and a dummy separating the sample into periods where only speculating investors are present and periods where also dividend collecting investors are present. The result is given in Table E1 below and demonstrates that our results reported with univariate tests also hold in the regression.

Table E1: Random effects panel regression for Period-RAD

Period-RAD	Low-liquidity sessions	High-liquidity sessions
α	0.115***	0.420***
	-0.032	-0.083
T2-dividend	0.058	0.047
	-0.047	-0.28
T4-dividend	0.052	-0.234**
	-0.051	-0.105
T8 dividend	0.034	-0.008
	-0.041	-0.222
T2-speculating	0.422***	0.277
	-0.086	-0.17
T4-speculating	0.402***	0.503**
	-0.074	-0.243
T8-speculating	0.356***	0.877**
	-0.076	-0.407
N	381	381
p	0.0000	0.0000

Notes: Random effects panel regression with standard errors clustered by session in parenthesis. Significance levels: * (10%), ** (5%) and *** (1%).

Appendix F: Additional analyses of trading patterns

F1: Analysis of forfeiture rates of securities by exiting generations

In designing the experiment, we decided that unsold securities in the hands of the exiting generation were to be forfeited to become worthless, and allocated in whole units randomly at no cost to the entering traders. To measure the share of the forfeited securities for each exiting generation of each treatment, we provide two calculations and sets of figures: first, we calculate the exiting generation's holdings as a fraction of initial security endowment (which would be zero under REE). Four panels of Figure F1 chart this data for the 4X2 treatments. With each entering generation, the measure returns to the value after one period of trading and then falls further as more securities are sold. There is no marked difference between H and L treatments, and on the whole, generations exit with fewer securities if they have more periods to trade.

Figure F1: Exiting generations' share of initial security holdings by period

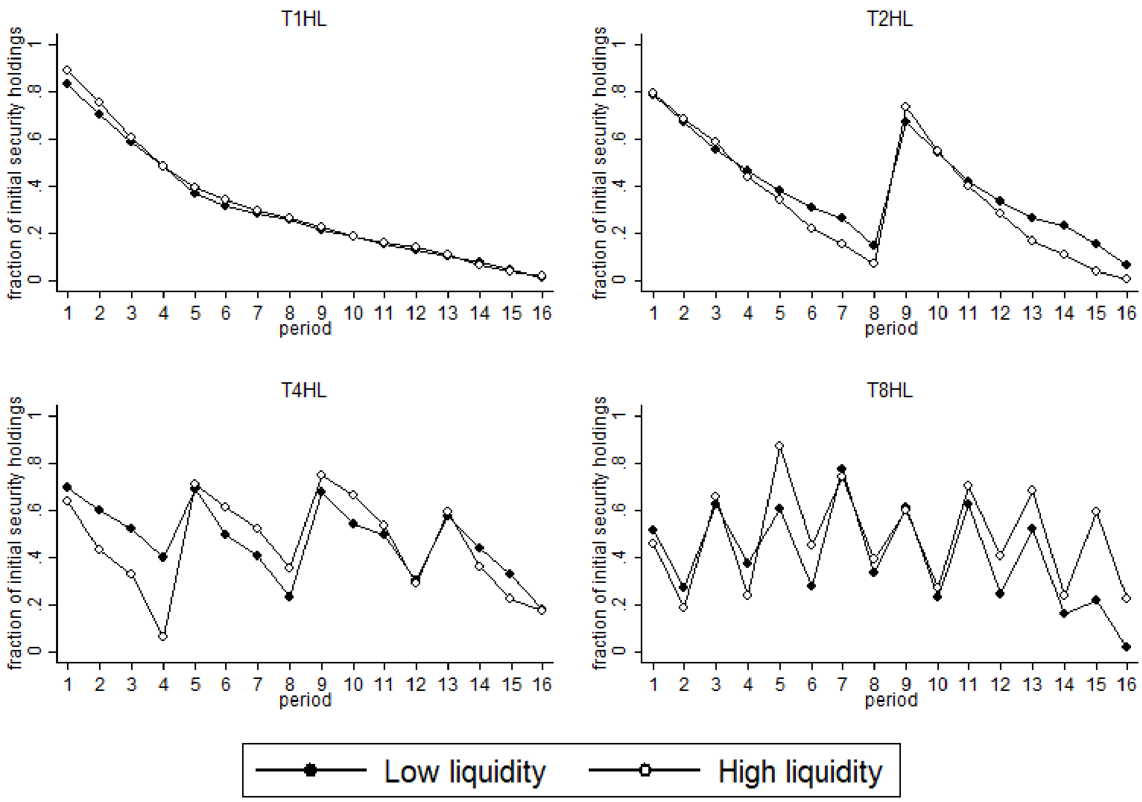


Table F1 provides comparisons of securities in the hands of speculating vs. dividend-collecting traders at the time of their exit. Although the averages are always lower for the dividend-collecting traders, the overall evidence is mixed: one comparison is significant at the 1% level, three at the 10% level, and two are not significant.

Table F1: Forfeiture rates (fractions of all securities not sold by exiting generation to entering generation) across treatments

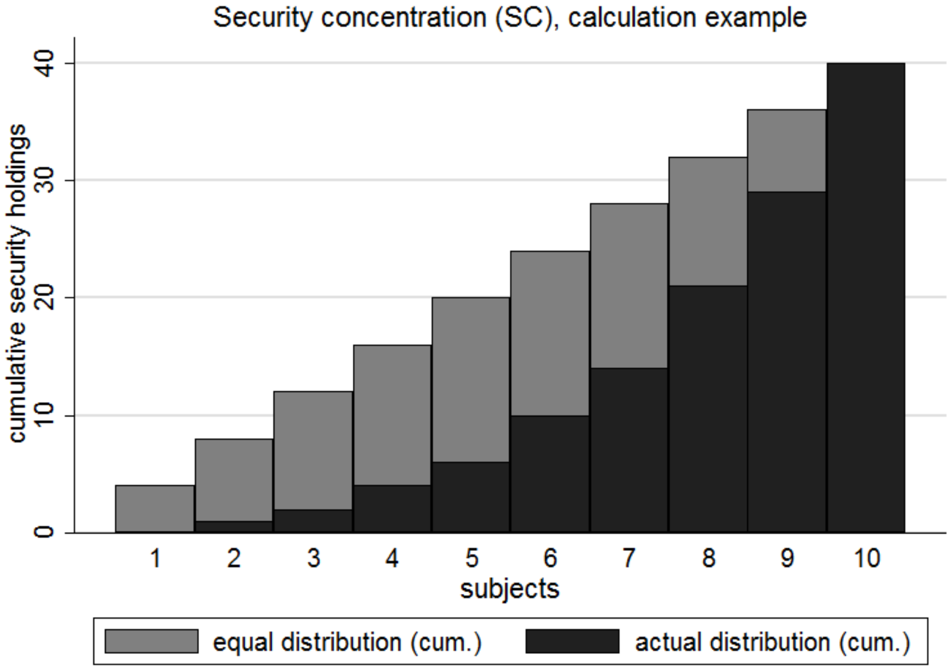
	LOW LIQUIDITY				**HIGH LIQUIDITY**			
Period	T1	T2	T4	T8	T1	T2	T4	T8
2				0.27				0.18
4			0.40	0.37			0.06	0.24
6				0.27				0.45
8		0.15	0.23	0.33		0.07	0.35	0.39
10				0.23				0.27
12			0.30	0.24			0.29	0.41
14				0.16				0.24
16	0.01	0.06	0.18	0.02	0.02	0.01	0.18	0.23
mean all	0.01	0.11	0.28	0.24	0.02	0.04	0.22	0.30
mean spec.	--	0.15	0.31	0.27	--	0.07	0.23	0.31
mean non spec.	0.01	0.06	0.18	0.02	0.02	0.01	0.18	0.23
significance		n.s.	10%	1%		10%	10%	n.s.
obs.		6/6	18/6	42/6		6/6	18/6	42/6

Significance is determined by Mann-Whitney U-tests. n.s. = not significant.

F2: Concentration of security holdings among traders

We explore the concentration of security holdings among each generations' traders by period in each treatment. Calculation of security concentration (SC) measure, analogous to Gini Coefficient and comparable across treatments, is illustrated in the example in Figure F2. SC = 0 is even distribution, and SC = 0.82 is distribution completely concentrated in the hands of a single trader.

Figure F2: Security concentration (SC), calculation example



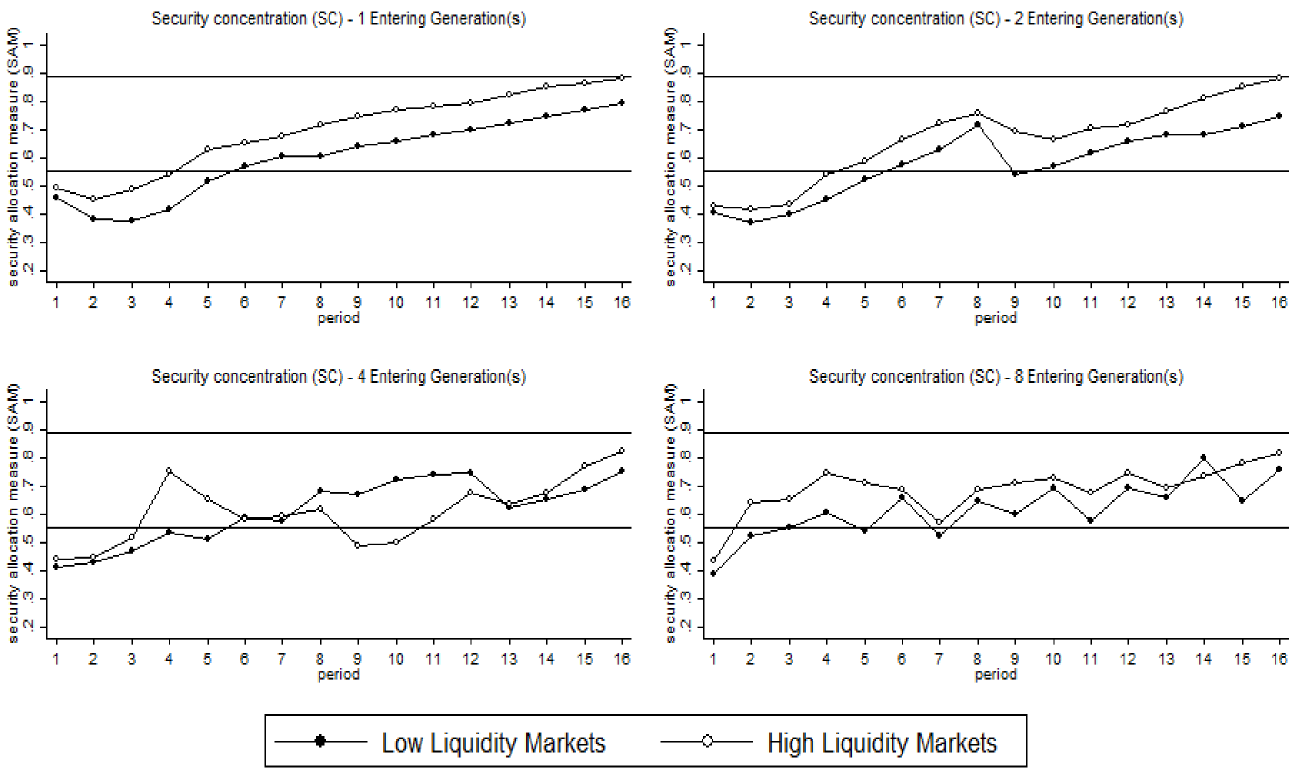
Notes: Data for the example is taken from market 6 (period 4) of a four-generation session with low liquidity. Grey bars show the cumulative distribution of security holdings assuming that shares are equally spread among the 10 subjects in the market. Black bars show the actual cumulative distribution of security holdings among the 10 subjects in that period. The sum of cumulative security holding for equal (actual) distribution equals 220 (127) and SC equals (220-127)/220 = 0.42. The maximum value of SC = (220-40)/220 = 0.82.

There are three extreme point realizations of SC: under the uniform distribution of securities among subjects, SC = 0; at the initial securities distribution (G0) SC = 0.55; and if all securities are held by a single trader SC = 0.82. This value serves as a benchmark to evaluate subjects' purchasing behavior when entering the market. If all subjects of a given generation trade equally, we should expect SC = 0.55. Higher values indicate concentration in the hands of individual members of a generation. In a final step, we normalize values by this upper bound so that all values range between 0 and 1 and become percentages of the maximum.

High liquidity markets have greater concentration than low liquidity markets, their difference being statistically significant at the 1%-level (*t*-test, t= -5.3314, df=766, p = 0.0000).

Low liquidity average SC = 0.60 (384 observations, min = 0.23, max = 0.94, s.d.= 0.15), and high liquidity average SC = 0.67 (384 observations, min = 0.22, max=1, s.d.=0.17). Perhaps it is easier for willing traders to buy as many securities as they wish in high liquidity treatments. Evolution of SC for 4X2 treatments over the 16 periods is charted in Figure F3.

Figure F3: Security concentration (SC) over time in the four treatments



SC tends to increase over 16 periods of the experimental sessions. The horizontal lines in each panel indicate the value of SC when securities are evenly distributed among five (lower) and two (upper) traders. By the end of each session, most securities are in the hands of two or three traders. especially in high liquidity markets.

Comparison of concentrations in periods with and without dividend-collecting investors in Table F2 reveals higher concentration in the former (0.725 vs. 0.613 in high liquidity and 0.633 vs. 0.577 in low liquidity) are present vs. absent. These differences are large in absolute terms and statistically significant at the 1% level for H as well as L liquidity treatments (two-sided t-test).

Table F2: Comparison of Average Period-SC between Periods with Dividend-Collecting Investors and Periods with only Speculating Investors

	(1) Periods with dividend-collecting investors	(2) Periods with only speculating investors	Difference (2)−(1)
High liquidity Session (Treatment H)	0.725 (180)	0.613 (204)	-0.112***
Low liquidity Session (Treatment L)	0.633 (180)	0.577 (204)	-0.055***

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

Table F3: Comparison of Average Period-SPEC with and without Dividend-Collecting Investors

	(1) Periods with dividend-collecting investors	(2) Periods with only speculating investors	Difference (2)−(1)
High liquidity sessions (Treatment H)	0.289 (178)	0.301 (204)	0.012
Low liquidity sessions (Treatment L)	0.232 (178)	0.322 (203)	0.091***

Note: The sample size is in parentheses. *** indicates that the difference is statistically significant at 1% level determined by a two-sided *t*-test.

Table F3 summarizes the analysis of speculative trading measured for each period by SPEC (=[total trading volume – the sum of absolute values of net changes in holdings of individual traders]/total trading volume). SPEC = 0 in absence of speculative trading and 1 if all trading is speculative, i.e., every transaction by every trader is reversed within the same period. Average Period-SPEC across all periods in presence of dividend-collecting investors is 0.289 in H and 0.232 in L; in the absence of dividend-collecting traders, the averages are 0.301 in H and 0.322 in L. The difference is statistically significant at the 1% level in the low liquidity treatment (two-sided t-test) but is not significant in the high liquidity treatment.

F3: Trading activity between different combinations of two investor types

In this section of the Appendix, we analyze which share of transactions is conducted between investors of the old (exiting) and young (entering) generations. Here the first result is that about two-thirds of total transactions are conducted between old and young generations and the other third of transactions is done within the generations; this proportion does not differ significantly between the high- and low-liquidity sessions.

Next, Table F4 shows that when dividend collecting traders ("Div") are present in high-liquidity sessions, 22.8%, 67.0%, and 10.2% of all transactions, take place between Div-Div, Div-Spec, and Spec-Spec pairs respectively ("Spec" standing for speculating investors). These proportions remain essentially unchanged under low-liquidity. Dividend-collectors are involved in nearly 90% of all transactions (as compared to nearly 80% for speculating investors) indicating that they play a slightly more active role in trading.

Table F4: The number of trades by the combination of two types of investors

Panel A: High-liquidity session

	Periods with dividend-collecting investors present	Periods with only speculating investors
Div - Div	728 (22.8%)	—
Div - Spec	2,141 (67.0%)	—
Spec - Spec	326 (10.2%)	2,801 (100.0%)
Total	3,195 (100.0%)	2,801 (100.0%)

Panel B: Low-liquidity session

	Periods with dividend-collecting investors present	Periods with only speculating investors
Div - Div	622 (21.5%)	—
Div - Spec	1,978 (68.5%)	—
Spec - Spec	287 (9.9%)	2,775 (100.0%)
Total	2,887 (100.0%)	2,775 (100.0%)

F4: Does the last generation behave like fundamental traders?

We examined if the last generation in each session (i.e., dividend-collecting investors) traded like fundamental traders – buy (sell) when the price is below (above) the fundamental value of 50. Table F5 (all periods) and Table F6 (periods 15 and 16 only) below (included as Tables F5 and F6) show the number and percentage of buy and sell transactions conducted by dividend-collecting investors when prices are above, at, or below 50. Across all periods, 48.2% of buy and 69.2% of the sell transactions in high liquidity (84.6% and 30.1% respectively in low liquidity) are consistent with fundamental trading. When we restrict attention to trades executed in periods 15 and 16 of each session (Table 9B), these four percentages change to 61.5 %, 59.5%, 82.4%, and 63.7% respectively.

Table F5: Number of trades by dividend-collecting investors (pooled for all periods)

Panel A: High-liquidity sessions

	Buy transaction	Sell transaction
Price > 50	1,352 (51.8%)	617 (62.4%)
Price = 50	200 (7.7%)	67 (6.8%)
Price < 50	1,056 (40.5%)	305 (30.8%)
Total	**2,608 (100.0%)**	**989 (100.0%)**

Note: Percentages of total buy (sell) transactions are in parentheses.

Panel B: Low-liquidity sessions

	Buy transaction	Sell transaction
Price > 50	369 (15.4%)	221 (26.9%)
Price = 50	115 (4.8%)	26 (3.2%)
Price < 50	1,915 (79.8%)	576 (70.0%)
Total	**2,399 (100.0%)**	**823 (100.0%)**

Note: Percentages of total buy (sell) transactions are in parentheses.

Table F6: Number of trades by dividend-collecting investors (periods 15 and 16 only)

Panel A: High-liquidity sessions

	Buy transaction	Sell transaction
Price > 50	147 (38.5%)	86 (48.3%)
Price = 50	42 (11.0%)	20 (11.2%)
Price < 50	193 (50.5%)	72 (40.5%)
Total	**382 (100.0%)**	**178 (100.0%)**

Panel B: Low-liquidity sessions

	Buy transaction	Sell transaction
Price > 50	82 (17.7%)	116 (61.1%)
Price = 50	36 (7.8%)	5 (2.6%)
Price < 50	346 (74.6%)	69 (36.3%)
Total	**464 (100.0%)**	**190 (100.0%)**

F5: Cash-constraint investors

Table F7 shows the fraction of cash-constrained traders according to three definitions: CC1 is cash below the fundamental value of 50, CC2 is cash below 25% of the fundamental value of all securities in the market, and CC3 is cash below 50% of the fundamental value of all securities in the market. The numbers in the table is the percentage share of traders being cash-constraint in the respective way. Table F7 shows that while relatively few traders satisfy CC1, the fraction of traders satisfying the broader definitions of cash constraint, CC2, and CC3, is markedly higher; CC3 is reaching 100% in the low liquidity sessions.

Table F7: Percentage of Cash Constrained Traders

Treatment	T1 CC1/CC2/CC3	T2 CC1/CC2/CC3	T4 CC1/CC2/CC3	T8 CC1/CC2/CC3
High-liquidity session (H)	0.2/30.7/50.0	1.9/20.6/25.1	0.6/5.8/10.9	0.6/4.0/5.8
Low-liquidity session (L)	3.4/67.5/100	2.0/45.5/97.5	4.2/23.5/97.6	3.1/18.9/97.0

F6: Ratio of buy transaction value to fundamental transaction value

In Table F7, we report the ratio between buy transaction value and fundamental transaction value, defined as the value of buy transactions required to move assets across all generations. For all of our markets and independent of treatment, this value equals 8,000. The resulting ratio can be interpreted as an indication of the speculative activity in markets. A value of one is the benchmark level for which the value of buy transactions equals the required volume for moving assets between generations. We can see that the fraction is consistently above two in high-liquidity sessions with no particular trend observable. In contrast, the fraction is below two in low-liquidity markets and we can see that with the number of generation changes the value decreases linearly. Comparing these values to the C/A-ratio (see numbers in parentheses), we can see that more of the liquidity endowment is used in low-liquidity sessions.

Table F7: Ratio of buy transaction value and the fundamental transaction value

Treatment	T1	T2	T4	T8
High-liquidity session (H)	2.75 (27.5%)	2.18 (21.8%)	2.42 (24.2%)	2.35 (23.5%)
Low-liquidity session (L)	1.56 (78.0%)	1.42 (71.0%)	1.04 (52.0%)	0.74 (37.0%)