Short Investment Horizons, Higher Order Beliefs, and Difficulty of Backward Induction: Price Bubbles and Indeterminacy in Financial Markets*

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Abstract

This paper examines if markets populated by short-horizon investors tend to have the prices come unhooked from their fundamental values or cash flows. For prices to be near the fundamental value in a market populated with short-horizon investors, the investors must induct backward from future cash flows to the present values. We argue that investors' ability to backward induct depends critically on strong and unrealistic assumptions about their first and higher order expectations about future cash flows and presence of common knowledge. Since these assumptions are rarely met, prices tend to deviate from fundamentals and become indeterminate. We examine this proposition by conducting laboratory asset markets with overlapping generations of short-horizon traders and comparing observed transaction prices to the fundamental values. Our results show that transaction prices are close to the fundamental values when traders have long horizons. They deviate significantly as investment horizons shrink (and backward induction to present values becomes more difficult).

Keywords: Experimental finance; backward induction; price efficiency; short-horizon investors; overlapping generations.

JEL-Classification: G11; G12; C91.

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1. Introduction

According to finance theory, prices of securities are close to, or tend towards, their fundamental value – the sum of discounted present value of expected future cash flows. Variations in decision horizons of investors do not enter the theory. Even if a market is dominated by short-horizon investors, their backward induction from cash flows in distant future to the present leads to prices being close to the fundamental values (FV).

We should note, however, that the feasibility of investors succeeding in backward induction depends critically on whether two strong assumptions hold: (1) all generations of investors form rational expectations, and (2) these expectations, as well as the ability of all present and future investors to form such expectations, are common knowledge. We argue that these assumptions are so strong that they cannot be expected to hold in practice. Some generations of investors may not form rational expectations, and even if all generations of investors do, rational expectations may not be common knowledge across or even within the generations. Under such conditions, investors cannot be expected to backward induct from first and higher order expectations to the present value of securities (i.e., the fundamental value based on the first order expectations of all future cash flows of the current generation of investors); prices are no longer anchored to the fundamental values, may be dominated by other factors, and become indeterminate. For a security with a given maturity, the number of generations that will hold the security between present and maturity increases as the investment horizon of investors gets shorter and the likelihood and magnitude of failures in backward induction should be expected to get amplified.

We examine this proposition by designing and conducting 48 (four sets of six each) independent sessions of laboratory asset markets, each consisting of 16 periods. A single kind of simple assets (each paying a single, certain, common knowledge terminal dividend of 50 at the end of Period 16) is traded in these markets. This simplest of designs leaves little room for doubt in any subject that the fundamental value of the asset is 50. The asset market has an overlapping generations structure (Tirole, 1985). In any given period, two generations of five investors each are in the market. In all but the first set of market sessions, members of a generation participate in the market for some periods before exiting, and/or enter the market some time after the first period. That is, they do not participate in all 16 periods of trading. Members of entering generations are endowed with cash, so they can buy assets from the overlapping generation which will leave the market. They can sell those assets to members of the following overlapping generation, before exiting the market. Since only the members of the very last generation collect the dividends, all others are short-horizon investors trading in the hope for capital gains. If subjects can backward induct from the future cash flows to the present value, finance theory would strongly suggest that at least in this simplest of securities—single certain common knowledge homogeneous dividend—it is feasible for investors to backward induct, and therefore for the market price should be equal to the fundamental value of 50. Rational calculation is essential trivial; the only challenge is backward induction through higher order expectations. We designed the experiment so any systematic deviations between observed transaction prices for the fundamental value would be difficult to explain except being reasonably attributed to the short investment horizons of subjects in three of the four treatments as explained above. This is the sense the experiment is designed to test the proposition that short investment horizons tend to generate price indeterminacy and bubbles.

The results show that with the introduction of short horizon traders in markets, in spite of the evident ease of "rational" calculation for this simple security, transaction prices deviate consistently from the fundamental value of 50 to become indeteriminate. Following the argument given above (developed more formally in the following section), we attribute this market behavior to the infeasibility of backward induction in such settings. Specifically, (i) likelihood and magnitude of deviation of prices from FV tends to increase as investment horizons shrink (i.e., more generation of investors over the 16 period life of the security); (ii) prices tend toward fundamentals only when long term investors (who are the last generation of investors who are the only ones to collect the dividend cash flow of 50 in each session) are present in the markets; and (iii) increase in liquidity (the ratio of total cash to total of the fundamental value of all securities in the market) raises transaction prices.

The following sections present the model, experimental design and procedures, results, and discussion.

2. Model

Consider a security that matures at time $t+m$. For simplicity, the security pays only a terminal dividend D at time $t+m$. D is non-stochastic and common knowledge among the investors. Assuming a zero discount rate[1], the fundamental value of the security at time t is:

$$F_t = D \tag{1}$$

2.1. Long-horizon investors and security prices

We define long-horizon investors as those whose investment horizon are longer than or equal to m. They hold the security to its maturity to collect its cash dividends, which consist of the single terminal dividend D at $t+m$. The value of the security to such an investor at time t, F_t (and its price P_t in a market populated by such homogenous investors) is equal to the fundamental value of the security (without loss of generality, setting discount rate to zero):

$$P_t = F_t = D \tag{2}$$

[1] This assumption is standard in most experimental settings and reduces the level of complexity. It allows us to clearly identify the effects of failures in backward induction. See the discussion in Stöckl et al. (2014) on the effects of discounting mechanisms on asset pricing.

When only one generation of subjects is present and D is common knowledge, this proposition is well-supported by data from laboratory markets (e.g., Smith et al. 2000, Noussair et al. 2001, Kirchler et al., 2012; Noussair et al., 2012).[2]

2.2. Short-horizon investors and security prices

Following Hirota and Sunder (2006), consider short-horizon investors with investment horizon $k < m$, who buys the security at time t, holds it for k periods, and sells it at $t+k$ to exit the market before it matures. The value of the security to this investor and its price P_t in a market populated by such homogenous investors is:

$$P_t = F_t = E_t\,(P_{t+k}) \qquad (3)$$

where P_{t+k} is the stock price at $t + k$ and $E_t\,(.)$ is investors' homogeneous expectation at time t. In equation (3) price P_t depends on the investor's expectation of the future sales price, $E_t\,(P_{t+k})$. Therefore, determining P_t in (3) requires further specification of how investors form expectation $E_t\,(P_{t+k})$.

Assumption 1: Investors form rational expectations, i.e., they use all available information to form their expectations, and know that the price equation (3) holds at all times from t to t+m-2k.

From assumption 1, investors at time t expect that equation (3) holds for the subsequent generation of investors at time $t+k$.

$$P_{t+\mathrm{k}} = F_{t+k} = E_{t+k}\,(P_{t+2k}) \qquad (4)$$

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

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

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

[2] However subjects fail to backward induct when multiple dividend payments occur over a predetermined horizon (Smith et al. (1988); see Palan (2013) for a review.)

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

The price of the security at time t depends on the investor's expectations at time t of the subsequent generation's expectations at time $t+k$ of price at $t+2k$ (second-order expectations). This means that to determine P_t, we must specify how investors form their expectations of other investors' expectations in order to form their own price expectations. Expectation formation is private, and the investors of one "generation" do not necessarily know how investors of subsequent generations form their expectations.[3] A common knowledge assumption is needed to render this problem analytically tractable.

Assumption 2: Assumption 1 (that investors can form rational expectations) is common knowledge.

Under this assumption, an investor at time t knows that another investor at time $t+k$ also forms rational expectations and second-order expectations as

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

Then, investors at time t form second-order expectations as

$$E_t\,(E_{t+k}\,(P_{t+2k})) = E_t\,(E_{t+k}\,(E_{t+2k}\,(P_{t+3k}))) \tag{8}$$

where $E_t\,(E_{t+k}\,(E_{t+2k}\,(\cdot)\,))$ is the third-order expectation of investors at time t. Substituting into (6), we get

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

Repeating this substitution yields the price equation including higher order expectations of subsequent prices.

$$P_t = E_t\,(E_{t+k}\,(E_{t+2k}\,(\ldots E_{t+m-2k}(P_{t+m-k})))\ldots). \qquad (10).$$

[3] We use the term "generation" for each consecutive cohort of investors who buy from the preceding cohort and sell to the succeeding cohort. The idea of cohort simplifies the exposition of a market consisting of short-horizon investors by assuming that all members of a cohort buy and sell at the same time interval. The "generations" label links our model to the well-known overlapping-generations-models of which ours is a special case. Of course, it is an abstraction from markets with individual traders having varied investment horizons entering and leaving at various times, which renders the challenge of backward induction to fundamental values even more difficult than in the simplification considered here. See Marimon and Sunder (1993) and Lim, Prescott and Sunder (1994) for introduction of experimental examination of overlapping generations economies.

At time $t+m-k$, the price should be equal to the terminal dividend D that the last (m/k th) generation of investors receive from the security:

$$P_{t+m-k} = D. \quad (11)$$

Then investors at time $t+m-2k$ use equation (11) to form their expectation of P_{t+m-k}:

$$E_{t+m-2k}\,(P_{t+m-k}) = D. \quad (12)$$

This means that

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

Repeating this process, we get

$$P_t = D = F_t\,. \quad (14)$$

This completes the derivation of the fundamental value of the security being its price when assumptions 1 and 2 hold, and the stock price is determined through the investor recursively forming a series of rational expectations and doing the corresponding backward inductions. This valuation process yields the standard textbook case of the price P_t being equal to the fundamental value of the security, F_t at any time.

2.3. Investment horizon and feasibility of backward induction

When assumptions 1 and 2 hold, price should be equal to fundamental value irrespective of investment horizon being long or short. With shorter investment horizon k, the number of transfers of the security across generations of investors until maturity increases. As long as we assume that all investors form rational expectations and that these expectations are common knowledge, equilibrium prices are solely determined by the fundamental value; they are not affected by the number of times a security changes hands until its maturity.

However, assumptions 1 (rational expectations) and 2 (common knowledge) are strong, and cannot be expected to hold in practice. Some generations of investors may not form rational expectations, and even if they do, rational expectations may not be common knowledge across or even within the generations. Suppose that one generation (i^{th} generation) of investors do not form rational expectations, or even if they do, they do not believe that the subsequent generation of investors form rational expectations. Then repeated substitution process in equation (9) stops at $t+ik$ and consequently the price is not linked to the terminal dividend by backward induction. In this case prices are no longer anchored to the fundamental values and may become indeterminate.

We conjecture that, in a market for a security with a given date of maturity, as investment horizon k becomes shorter, the number of intergenerational transfers till maturity (m/k) increases, it becomes increasingly difficult to satisfy assumptions 1 and 2. Since formation of rational expectations calls for formation of first and higher order beliefs about the future, and utilization of all available information, arriving at such expectations becomes increasingly challenging, even implausible, with the increase in the number of generations. Each additional generation adds another order of expectations which must become common knowledge, which is even more difficult to ensure. With an increase in the number of generations of investors until maturity, it is more likely that (1) one or more generations do not form rational expectations and/or (2) investors do not believe that all subsequent generations form rational expectations. Therefore, we hypothesize that a shorter investment horizon is associated with lower probability that backward induction from beliefs about the future will yield market prices in proxity of the fundamental value of the security. We test this hypothesis with laboratory experiment described in the following section.

3. Design of the experiment

Market sessions. Each market session consists of 16 periods of 120 seconds each.[4] At the beginning of Period 1, the initial generation of traders (G0) is endowed with units of the

[4] We chose 16 periods to (1) be the lowest number divisible by 2, 4, and 8; (2) ensure that each generation is in the market for at least two periods (one to buy, one to sell assets); and (3) to complete each session in

asset and no cash. There are also ‘entering generations’ in a market. ‘Entering generation’ means that the cohort of traders enters the market with cash but no assets. They participate in the market for a prespecified number of period, may enter into purchase and sale transactions during this time, and exit the market, when another generation enters (or the session ends).

Asset characteristics. The asset traded always lasts for 16 periods, and pays a single, common knowledge dividend, $D = 50$, at maturity to its holders at the time (who are members of the last entering generation). Any assets held at the time of their exit by the members of all earlier generations are worthless.

Treatments. The experiment has a 4x2 design in which the first treatment (number of entering generations) takes four different values and the second treatment (liquidity) takes two values (see Table 1). The number of entering generations varies between 1, 2, 4, and 8 inducing investment horizons that vary across treatments to be 16, 8, 4, or 2 periods. The liquidity treatment varies the initial C/A-ratio (amount of cash available to trade securities in the economy/the total fundamental value of all assets) between low (= 2) and high (= 10). Treatments are denoted as Txy with x [1,2,4, or 8] indicating the number of entering generation changes and y [L or H] indicating low and high C/A-ratios.

Table 1: Treatment Overview

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

approximately 90 minutes.

Overlapping generations. Within each treatment the market structure (number of traders, number of assets and the amount of cash) remains unchanged over periods but individuals enter and exit the market (except in T1-sessions). There are two overlapping generations of five traders each in the market at any time (for a total of ten active traders). For example, in treatment T4, each entering generation of five subjects trades for eight periods before exiting. It enters the market with cash endowment it can use to buy assets from one overlapping generation, and then usually sells those assets to the next overlapping generation for cash before exiting. Boundary condition adjustments are made at the beginning and end of the session (see Table 2). Given this setup, all generations, except the last, are short term investors who collect a market price, not dividend *D,* as their payoff. Only the very last generation consists of long term investors because they hold the asset until maturity and collect dividend *D*.

Table 2: Overlapping generations

	Period / Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1	5	**G0**															
	5	**G1**															
T2	5	**G0**															
	5	**G1**															
	5									**G2**							
T4	5	**G0**															
	5	**G1**															
	5					**G2**											
	5									**G3**							
	5													**G4**			
T8	5	**G0**															
	5	**G1**															
	5			**G2**													
	5					**G3**											
	5							**G4**									
	5									**G5**							
	5											**G6**					

	5													G7			
	5															G8	

Participation and subject circulation. In order to keep the total number of subjects for a session within reasonable limits we recruit 3*n*+3 subjects for a session with *n* subjects per generation (in treatments T1 we only recruited 15, in all other treatment 18 subjects).[5] At any time two generations (ten subjects in total) are active traders, while the other eight (five in T1) subjects are "predictors" who are rewarded on the basis of how accurately they predict, before trading starts, the average trading price of the asset during the period. Traders can buy and sell assets freely as long as neither their cash nor the asset holdings can become negative. When a generation exits the market, *n* subjects are randomly chosen from the pool of *n*+3 predictors to form the newly entering generation for the next period, and the exiting generation joins the pool of predictors. Subjects stay in this pool for one or more (but unpredictable number of) periods. This rotating mechanism allows each generation of traders to gain experience and understanding of the environment without significantly interfering with the purpose of the experiment (see Lim, Prescott and Sunder, 1995 and Marimon and Sunder, 1993). Since the subjects cannot know whether and when they will reenter the economy, it is virtually impossible for their anticipations about any future reentry into the market to influence their current behavior.

Asset endowments. Only the initial generation of subjects (G0) is endowed with units of the asset. All subjects who enter the game subsequently are endowed only with cash when they enter the market. To equalize the trading "workload" per period, asset and cash endowments are varied across treatments so as to keep the number of expected transactions per session (160) independent of the number of generations (see Table 3 for details). Furthermore, to ensure that the total number of assets in the experimental economy stays

[5] In T1 we invited 15 subjects instead of 18 as no subject pool for future generations is needed. However we invited five subjects to serve as predictors.

constant throughout the session, any assets in the hands of exiting traders are distributed at zero cost to randomly chosen members of the entering generation. This arrangement ensures that no buyer is forced to buy an asset at a price unacceptable to him/her, and the sellers have an incentive to sell their assets before exiting the market.[6]

Table 3: Treatment parameterization

Treatment	T1L	T1H	T2L	T2H	T4L	T4H	T8L	T8H
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. assets/trader G0	32	32	16	16	8	8	4	4
Initial no. of assets G(i)	0	0	0	0	0	0	0	0
Total assets outstanding	160	160	80	80	40	40	20	20
Total value of assets	8,000	8,000	4,000	4,000	2,000	2,000	1,000	1,000
Initial cash/trader G0	0	0	0	0	0	0	0	0
Initial cash/trader G(i)	3,200	16,000	1,600	8,000	800	4,000	400	2,000
Total cash	16,000	80,000	8,000	40,000	4,000	20,000	2,000	10,000
Cash-asset-ratio (C/A-ratio)	2	10	2	10	2	10	2	10
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			100	500	100	500	100	500
Last generation	200	1,000	200	1,000	200	1,000	200	1,000
Predictors	133	133	133	133	133	133	133	133
Expected payout/subject (€)	16	16	16	16	16	16	16	16

NOTES: The following parameters are identical across all treatments: Number of traders/generation (5); number of active generations (2); active traders (10 traders); period length (120 sec.); total number of periods (16); number of markets per treatment (6); number of expected transactions (160).
[a] In treatments T1L and T1H we invited 15 subjects instead of 18 as no subject pool for future generations is needed. Ten subjects were traders, and five served as predictors.

Cash endowment. Except for the initial generation of traders (G0), all others enter the economy with a cash endowment that varies across treatments (see Table 3). The cash

[6]One may argue that the pressure on the exiting generation to sell its assets at the risk of forfeiture, without corresponding pressure on the entering generation to use up all its cash endowment to buy assets, may create a downward pressure on market prices. As shown in the results section, this indeed happens in the low liquidity treatments but not in the high liquidity treatments.

endowment of an entering generation is two (ten) times the amount needed to buy all assets at its terminal value in L (H) treatments. The amount of cash going out of the economy with the exiting subjects will, of course, vary each period and will be equal to the cash endowments of the entering subjects only by chance.

Trading mechanism. The trading mechanism used is a continuous double auction with open order book, the opportunity to cancel a bid or ask before it is accepted, single-unit trades, and shorting constraint (no negative holdings of cash or assets at any time). The single unit trades helps homogenize the amount of trading "work" per period across treatments. All cash and asset balances are carried over to the following period until the trader exits. Each trading period lasts for 120 seconds with a digital wind-down clock on the trading screen.

Trader payoffs. Only the last generation receives asset dividend; all others' cash holdings at the time of exit are converted to euros at a pre-announced rate and paid out.[7] Any unsold assets in the hands of these traders are forfeited, and randomly distributed among the members of the incoming generation at zero cost. Earnings accounts are shown on a history screen at the end of each period (see Appendix E for details).

Prediction task. Of the $3n$+3 subjects, n+3 act as observer/predictors in each period. They are required to submit a prediction of the average transaction price of the period before trading starts. Subjects' earnings depend on the precision of their forecast: 140 units of cash for a perfect forecast with a one unit penalty for each unit of error (subject to zero minimum). Calculations of period as well as cumulative earnings are shown on the history screen at the end of each period (see Appendix E for details).

Session termination. Subjects are informed through common knowledge instructions (with their understanding tested through a written questionnaire, see Appendix F for details) that the session ends with period 16, when each unit of asset pays a dividend D = 50 to its

[7] The conversion is done at a predetermined rate announced at the outset. We use different rates for the first, transition, and last generations and the low/high liquidity treatments to ensure identical average euro payouts. See Table 3 for details.

holders from the last entering generation. Earnings of each trader and predictor are calculated as described above, converted into euros, and are paid to subjects in private.

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

4. Hypotheses

In treatment T1 the only entering generation (G1) is the last generation, thus receiving a terminal dividend of 50 for each asset which they hold at the end of Period 16. G1 in T1 therefore corresponds to the long-horizon investors. Section 2.1 model predicts transaction price close to the fundamental value of the asset (50) in this treatment. In other treatments (T2, T4, T8), all except the last entering generations, receive a market price, not the terminal dividend, and they are short-horizon investors as described in Section 2.2. While we hypothesize that the short-horizon investors may have difficulty backward inducting from terminal dividend *D* to generate market prices in proximity of 50, we cannot know this ex ante. Observed prices should depend on whether each entering generation of traders can form rational expectations and whether it is common knowledge among traders within and across generations. As discussed in Section 2.3, as the investment horizon of traders gets shorter (the number of the entering generations increases), it is more likely that traders fail in backward induction and that prices deviate from fundamentals. This argument yields hypotheses H1 and H2:

> ***H1****: Prices tend toward fundamentals in the presence of long-term investors (when the last generation is present).*
>
> ***H2****: Prices become indeterminate in the presence of short-term investors. The degree of indeterminacy increases in the number of short-horizon generations.*

Hypothesis 3 (H3) is concerned with the effect of short-horizon investors on spreads and volatility. If prices are indeterminate there is a lack of (common) knowledge about the pricing strategies of other subjects. This increase in uncertainty forces subjects to coordinate on unknown pricing strategies and we expect spreads and volatility to increase.

> ***H3****: Spread and volatility are higher in the presence of short-term investors.*

Hypothesis 4 (H4) is concerned with the effects of liquidity (cash/ asset endowment ratio) on market outcomes. Theoretically more liquidity should not affect prices, as the asset's fundamentals do not change. However, ample experimental evidence suggests, that prices can be higher when liquidity is higher either through initial cash endowments or conditions that influence the C/A-ratio (see e.g. Caginalp et al. 1998, Caginalp et al. 2001, Haruvy and Noussair 2006, Caginalp and Ilieva 2008, Kirchler et al. 2012, King et al. 1993, Porter and Smith 1995, Ackert et al. 2006, Deck et al. 2012, Noussair et al. 2012, Breaban and Noussair 2014).

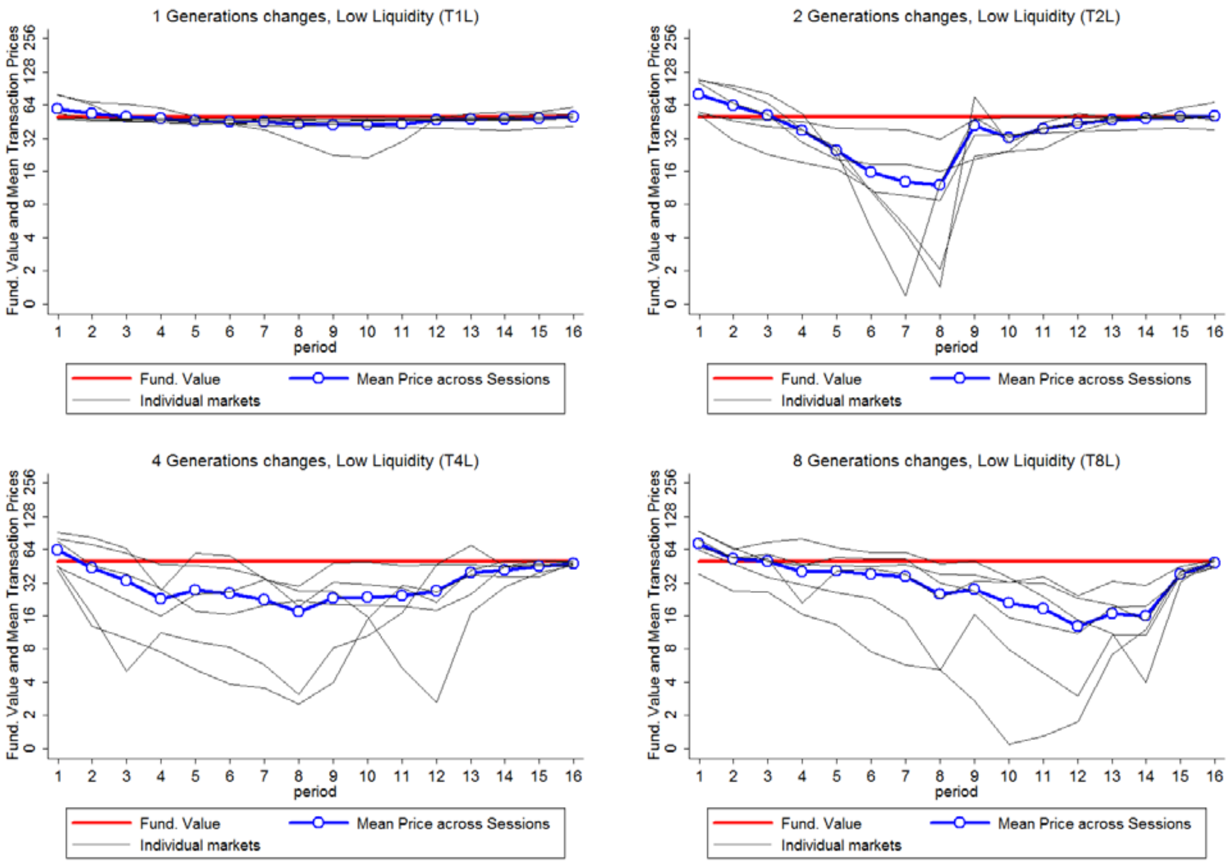
H4: *Prices levels are higher in treatments with high initial cash/asset value ratios.*

We examine these hypotheses in light of the experimental data in the following section.

5. Results

Figures 1 and 2 show the evolution of individual market prices (grey lines), of mean prices across sessions (blue bold line with circles), and of FV (red bold line) for low liquidity treatments (T1L, T2L, T4L, and T8L) and high liquidity treatments (T1H, T2H, T4H, and T8H), respectively.[8]

Figure 1: Period-wise average transaction prices in low liquidity treatments.



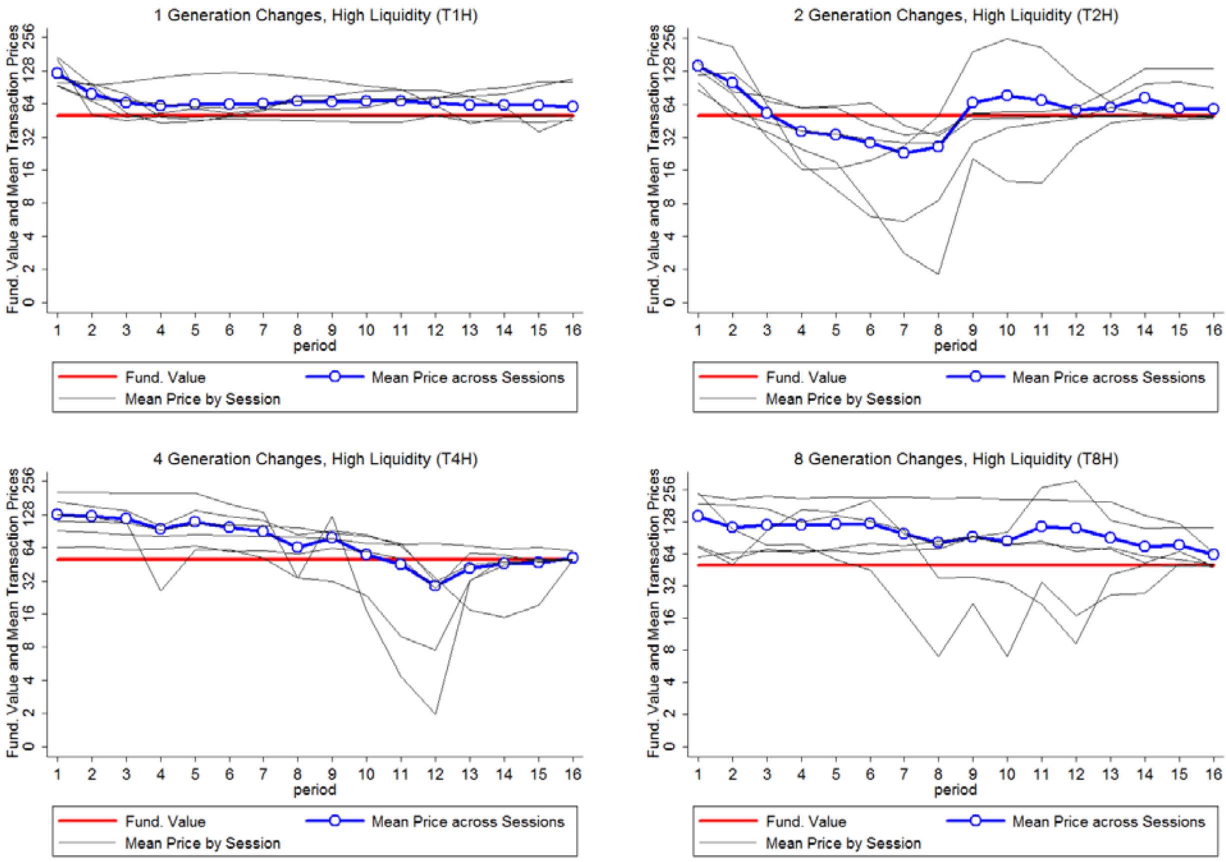
Notes: Fundamental Value (FV, bold straight line), mean prices (bold line with circle markers),

[8] We dropped two transactions that occurred above 800 from the analyses.

and volume-weighted mean prices from six individual markets (grey lines) by period against log scale on vertical axis. Each panel is identified by treatment: T1L, T2L, T4L; and T8L.

We calculate and present relative absolute deviation (RAD) and relative deviation (RD) as an inverse measure of proximity of transaction prices to the fundamental value *D* (see Stöckl et al. 2010). Additionally, average bid-ask-spread/*D* (SPREAD), the standard deviation of transaction-to-transaction log returns (VOLA), and share turnover (ST) are presented in tables 4 (definitions) and 5 (treatment averages).

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



Notes: Fundamental Value (FV, bold straight line), mean prices (bold line with circle markers), and volume-weighted mean prices from six individual markets (grey lines) by period against log scale on vertical axis. Each panel is identified by treatment: T1L, T2L, T4L; and T8L.

Individual market results and figures detailing the sequence of individual transaction prices for each market are reported in Appendix D. Table A1 (A2) in the Appendix shows the differences between averages across treatments with identical (different) liquidity for the price performance measures and provides results of pairwise two-sided Mann-Whitney U-tests.

Table 4: Formulae for price performance measures

Measure	**calculation**
Relative absolute deviation (RAD)	$RAD = \frac{1}{N}\sum_{p=1}^{N}\left\|\overline{P}_p - D\right\|/\|\overline{D}\|$
Relative deviation (RD)	$RD = \frac{1}{N}\sum_{p=1}^{N}\left(\overline{P}_p - D\right)/\|\overline{D}\|$
Bid-ask spread	$SPREAD = \frac{1}{N}\sum_{p=1}^{N} SPREAD_p/D$
Standard deviation of log returns	$VOLA = \frac{1}{N}\sum_{p=1}^{N}\sqrt{\frac{1}{T}\sum_{t=1}^{T}(RET_t - \overline{RET})^2}$
Share turnover	$ST = \sum_{p=1}^{N} VOL/TSO$

Notes: *p* indexes period; *t* indexes transaction sequence number within a period; *N* = total number of periods; $\overline{P}_p$ = (volume-weighted) mean transaction price in period *p*; *D* = dividend; $\overline{DV}$ = average fundamental value of the market; P_t = price of transaction *t*; $SPREAD_p$ = (volume-weighted) average bid-ask spread evaluated at each transaction in period *p*; RET_t = $\ln(P_t/P_{t-1})$; $\overline{RET}$ = mean of log-returns in period *p*; *T* = number of transactions in period *p*; *VOL* = number of shared trades; *TSO* = total shares outstanding.

First, we find that in T1L markets, where traders of the entering generation (G1) receive the terminal dividend, prices are mostly close to fundamentals (50) throughout the session. However, in sessions where the entering generations (except the last one) do not receive dividends, we observe that prices significantly deviate from fundamentals throughout the session, except in the periods close to the end. For example, in T2L, although prices gradually converge to the fundamentals after Period 10, they are higher than 50 in periods 1 and 2, but lower than 50 in periods 4 to 11. This suggests that generation G1 failed to backward induct in the first half of the session (in periods before the last generation, G2, enters). In T4L and T8L we observe the same tendency: before the last generation enters the market (before period 13 in T4L, before period 15 in T8L) prices are mostly deviating strongly from fundamentals. Backward induction obviously breaks down and it does usually not work for intermediate generations.

Table 5: Treatment averages for price performance measures

	RAD	RD	SPREAD	VOLA	ST
T1L	11.43%	-5.24%	8.79%	4.70%	1.60
T2L	35.47%	-18.95%	19.92%	17.56%	1.69
T4L	42.92%	-34.07%	22.52%	25.16%	1.56
T8L	43.03%	-30.48%	21.69%	26.24%	1.05
T1H	41.99%	37.39%	29.61%	14.08%	2.01
T2H	77.02%	38.81%	55.04%	22.70%	1.59
T4H	73.86%	52.11%	23.37%	17.72%	1.57
T8H	118.67%	103.48%	65.95%	18.17%	1.07

As seen in Table 5 (first two columns) and tested statistically in Table A1 (top two panels in Appendix A), by both RAD as well RD measures, prices are closer to the fundamental value in long-horizon investor treatment T1H than in treatments in T2H, T4H, and T8H in which short-horizon investors are present. This characterization holds strongly in low liquidity, but weaker in high liquidity treatments. Only one out of 12 differences is of wrong sign.

Among the four low liquidity treatments the measure for mispricing (OR indeterminacy), relative absolute deviation (RAD), is highest in T8L and lowest in T1L. Among the four high liquidity treatments, RAD is again highest in T8H and lowest in T1H with a general upward trend as the investment horizons shrink. The differences between RAD in T1 and T8 is significant in both liquidity treatments (on the 1% level in treatment L and on the 10%-level in treatment H, see Table 6). These results suggest that as the investment horizon of traders gets shorter (the number of the entering generations increases), increasing difficulty of backward induction causes prices to deviate more from fundamentals.

Deviation of prices from the fundamental value is uniformly small across all treatments during the periods in which the last entering generation is present in the economy. These deviations in earlier periods (before period 9 in T2H, before period 13 in T4H, and before period 15 in T8H) are larger. This suggests that traders have difficulty in backward inducting to fundamental value even if it involves only one future generation's valuation into the current price of the asset. When higher order beliefs of multiple future generations are to be considered, prices exhibit greater indeterminacy. Backward induction from higher order beliefs appears to be far more difficult than often assumed. In addition, we notice that prices in high liquidity treatments (Figure 2) are usually higher and deviate more from fundamentals than those in low liquidity treatments (Figure 1).

Table 5 shows averages for each treatment for all five price performance measures. RD detects underpricing in each L-treatment and overpricing in each H-treatment, suggesting that the cash available clearly influenced price levels. In both liquidity treatments prices in T1 are closest to fundamentals and the magnitude of under-/overpricing increases as investment horizons shrink.

Underpricing of securities on average raises the possibility of a hold-up problem in the market design: members of the exiting ("old") generations must liquidate their asset holding before the end of the period at the risk of forfeiture of the unsold units, while members of the entering ('young") generation are not under a corresponding pressure to use up their cash holdings (because unused cash is carried over across periods), and the unsold units of the exited generation are distributed free of cost to the next entering generation.

There are three counter-arguments to this suggestion. First, underpricing in low liquidity treatments are accompanied by overpricing under high liquidity. Second, although the presumed selling pressure is present equally in all periods, the under- overpricing tends to diminish to only a small magnitude the last period of all sessions in which traders do not need to depend on their higher order beliefs to make trading decisions. Thus, the only difference is that in the middle periods of a session, the backward induction has to be done through many more generations, and as we get closer to the end of the session, fewer layers of backward induction are necessary, and the susceptibility to indeterminacy decreases as we near the end of the session. Third, members of the young generation cannot be the beneficiaries of the strategy to holding back on buying assets in the hope of the getting the assets for free, because such free distribution goes the next entering generation whose members are not in the market at the time of trading. Thus, the current period's "young" generation does not have an incentive to refuse to buy from the "old" in the hope of getting the unsold units for free.

The results on SPREAD and VOLA point into the same direction as those on RAD: markets T1 are those with lowest SPREAD and VOLA, T8 are usually those with the highest values.

As seen in the last column of Table 5, stock turnover ST reveals almost monotonic decrease in turnover as the number of periods for which a generation of traders stays in the economy, starting from 2.01 or 1.6 for T1 to the proximity of 1 (which is the minimum number of transactions—160—needed to ensure that all units can be handed from exiting generation to the next generation) in T8 (1.05 and 1.07).

6. Concluding Remarks

This paper proposes, and empirically tests, the idea that security prices tend to deviate from the fundamental values when market is populated with traders who have short investment horizons (relative to maturity of the security). In such markets, the first order beliefs of investors about the future cash flows beyond their own personal investment horizon are not relevant to valuation, because cash flows beyond the horizon are replaced by expectations about future prices. For prices to be near the fundamental values in investors in such markets would have to conduct backward induction from their higher order beliefs about the expectations held by the future generations to present. We argue that investors' ability to backward induct critically depends on strong assumptions about the process of expectation formation, and their common knowledge about both the higher order expectations as well as the process of backward induction employed by those generations. We claim that when these assumptions are not met, prices may deviate from fundamentals and tend to become indeterminate.

Laboratory data show that deviation of transaction prices from fundamental values increases significantly when investment horizons end before the security being traded matures. This result is consistent with our proposition that, in such situations, investors fail to backward induct to bring prices to the proximity of fundamental values. In particular, we found that the shorter the investment horizon (the larger number of generations), the more difficult the backward induction.

Given these results from our laboratory experiment, there is additional reason to think that frequently observed price indeterminacies and bubbles in other markets outside the laboratory may also arise from the fact that they are populated with agents whose investment horizons are shorter than the maturity of the asset they are trading, e.g., gold, real estate, and corporate equity. Investors in such markets face an insurmountable difficulty of backward induction from higher order beliefs about future cash flows to the fundamental value. Note that this difficulty exists independent of any cognitive limitations, because the common knowledge needed to complete the task is simply unavailable to them.

Several implications emerge from this study. (i) *Markets prone to price indeterminacy*. Bubbles are known to occur more often in markets for assets with longer maturity and duration and higher uncertainty. That is consistent with the lab data. (ii) *New Role of dividends in security valuation.* Standard finance theory approaches dividend policy through the lens of Modigliani-Miller's irrelevance theorem. Our model and the results point to another role of dividends as inputs/bases on which investors can form their first order expectations of future cash flows, from which induction of present value is easier to do. The result points to a possibility that dividend policy matters since the presence and expectation of dividends in the future, renders valuation less dependent on increasingly amorphous higher order expectations about the future cash flows. We should expect that firms with larger payout ratios have more stable prices than firms with smaller or zero payouts.

(iii) Hirota and Sunder's (2007) analysis of their trading data revealed that when traders are unable to conduct backward induction, they reverse the logic of valuation, and resort to forward induction (infer current value from past observations).

(iv) More generally, we should expect that markets dominated by short-horizon investors should exhibit greater inefficiency, pricing anomalies, and the so-called "behavioral" phenomena. Ceteris paribus, the same should be true of firms whose securities have a longer duration as calculated from their expected dividend policy.

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

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Appendix A: Significance tests

Table A1: Differences between averages across treatments with identical liquidity (column minus row) in percentage points for RAD, RD, SPREAD, VOLA, and ST (not in percentage points). Mann-Whitney two-sided U-Test significance levels * (10%), ** (5%) and * (1%).**

RAD	T2L	T4L	T8L		T2H	T4H	T8H
T1L	24.03**	31.48***	31.60***	T1H	35.03	31.87	76.67*
T2L		7.45	7.56	T2H		-3.16	41.64
T4L			0.11	T4H			35.03

RD	T2L	T4L	T8L		T2H	T4H	T8H
T1L	-13.70**	-28.83***	-25.23**	T1H	1.42	14.71	66.09
T2L		-15.13	-11.53	T2H		13.29	64.67
T4L			3.60	T4H			51.38

SPREAD	T2L	T4L	T8L		T2H	T4H	T8H
T1L	11.13*	13.73**	12.90**	T1H	25.43	-6.24	36.34
T2L		2.59	1.76	T2H		-31.67	10.91
T4L			-0.83	T4H			42.58**

VOLA	T2L	T4L	T8L		T2H	T4H	T8H
T1L	12.86**	20.46***	21.54***	T1H	8.61	3.64	4.09
T2L		7.60	8.68*	T2H		-4.98	-4.53
T4L			1.08	T4H			0.45

ST	T2L	T4L	T8L		T2H	T4H	T8H
T1L	0.09	-0.03	-0.55**	T1H	-0.43	-0.44	-0.94**
T2L		-0.12	-0.64***	T2H		-0.02	-0.52**
T4L			-0.51	T4H			-0.50**

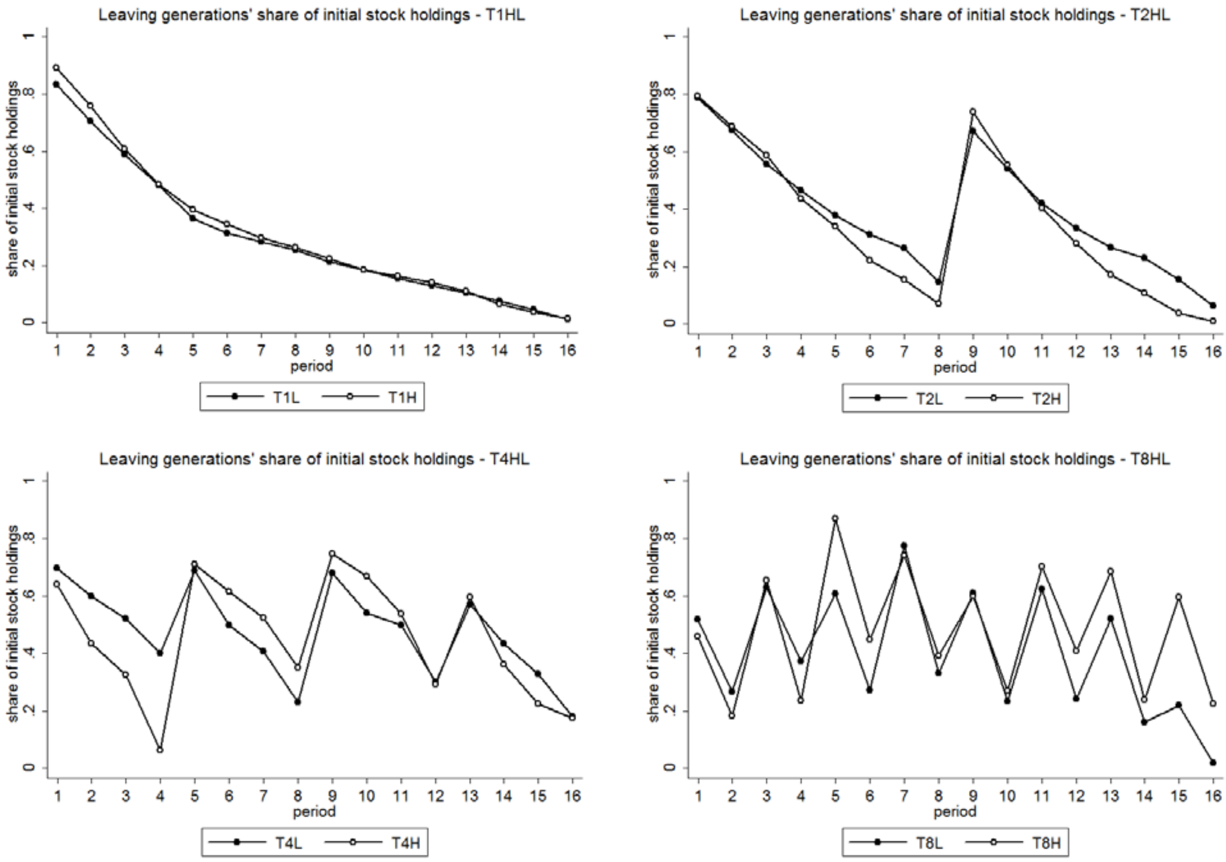
Table A2: Differences between averages across treatments with different liquidity (column minus row) in percentage points for RAD, RD, SPREAD, VOLA, and ST (not in percentage points). Mann-Whitney two-sided U-Test significance levels * (10%), ** (5%) and * (1%)**

H minus L	RAD	RD	SPREAD	VOLA	ST
T1	30.56**	42.64***	20.82***	9.39*	0.42
T2	41.56	57.76**	35.12*	5.14	-0.10
T4	30.95	86.18***	0.86	-7.44	0.01
T8	75.64*	133.96***	44.26**	-8.07	0.02

Appendix B: Unsold Shares and Price Prediction Errors

Figure A1 shows the leaving generations' share of initial stock holdings. We found that the larger number of entering generations, the more units remain unsold (though trading time/unit is the same across treatments).

Figure A1: Leaving generations' share of initial stock holdings.



Notes: Share of all assets in the market held by the next leaving generation as a function of period. Upper left panel: treatment T1LH; upper right panel: treatment T2LH; lower left panel: treatment T4LH; lower right panel: treatment T8LH.

We asked the subjects who held unsold units at the end of their leaving period why they had not sold all their units when they left the market. Table A3 summarizes the answers to the questionnaire.

At some point in the experiment you left the market while still in possession of shares. What was/were the reasons you did not sell your stock holdings before leaving the market?
A1) I did not want to sell cheaper than for what I bought;
A2) there were no remaining buy-offers;

A3) my sell-offers were not accepted;
A4) I did not want to give away my shares at the prices offered;
A5) I was not aware I still had shares;
A6) I was not aware it was the last period before I left.
A7) other reasons.

Table A3: Answers to the unsold shares questionnaire.

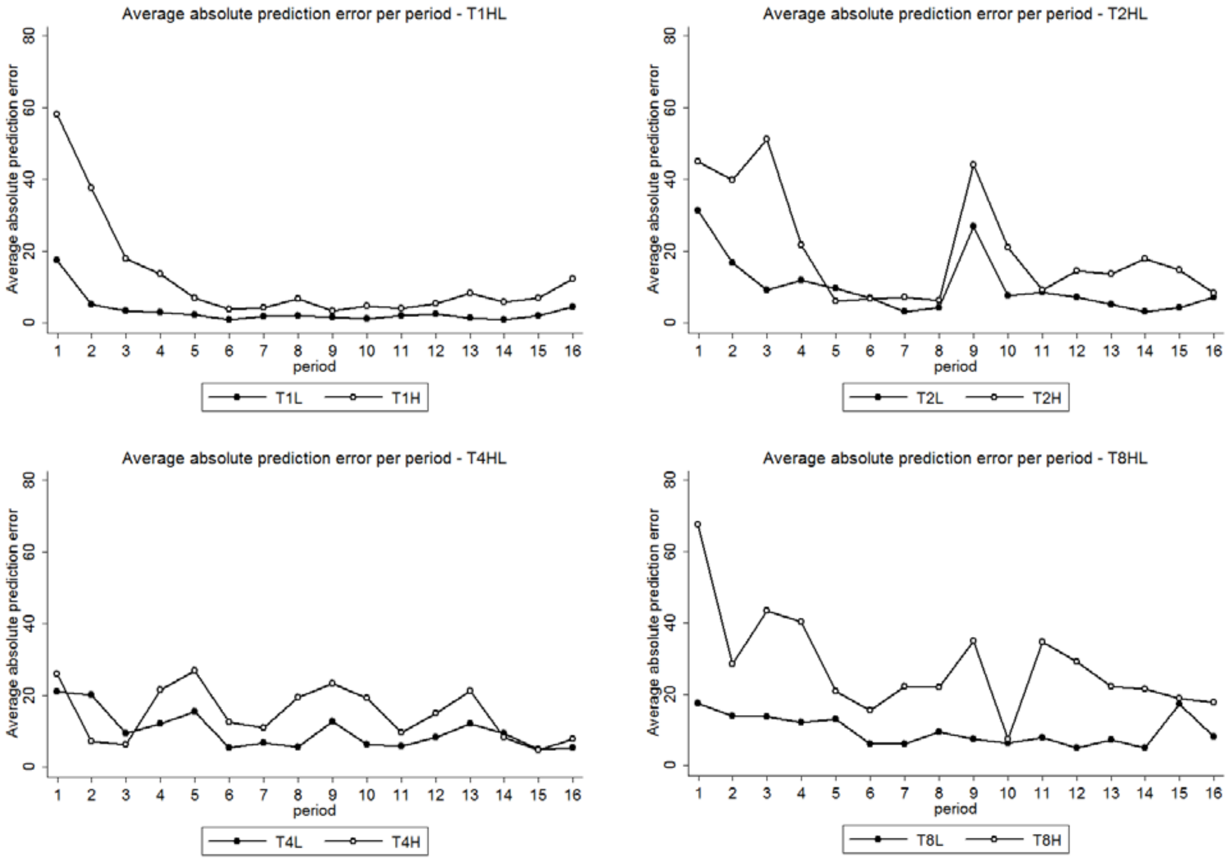
Gen	Liqu	A1		A2		A3		A4		A5		A6		A7		Not applicab	
1	low	21	21%	0	0%	9	10%	15	15%	0	0%	1	8%	8	23%	58	27
2	low	18	18%	2	15%	22	24%	23	23%	2	40%	0	0%	5	14%	63	30
4	low	30	30%	2	15%	22	24%	26	26%	2	40%	8	67%	10	29%	52	25
8	low	32	32%	9	69%	38	42%	35	35%	1	20%	3	25%	12	34%	38	18
1	high	13	14%	2	7%	7	8%	6	9%	0	0%	0	0%	6	13%	69	30
2	high	19	21%	3	11%	12	13%	15	22%	1	14%	0	0%	11	23%	72	31
4	high	27	29%	9	32%	34	37%	26	39%	0	0%	0	0%	17	35%	49	21
8	high	33	36%	14	50%	39	42%	20	30%	6	86%	4	100%	14	29%	39	17
sum	high	101	52%	13	32%	91	50%	99	60%	5	42%	12	75%	35	42%	211	48
sum	low	92	48%	28	68%	92	50%	67	40%	7	58%	4	25%	48	58%	229	52
sum overall		193		41		183		166		12		16		83		440	

Notes: multiple answers allowed (A1-A7).

Appendix C: Unsold Shares and Price Prediction Errors

Lastly Figure A2 shows the average absolute prediction errors for each treatment.

Figure A2: Average absolute prediction error.



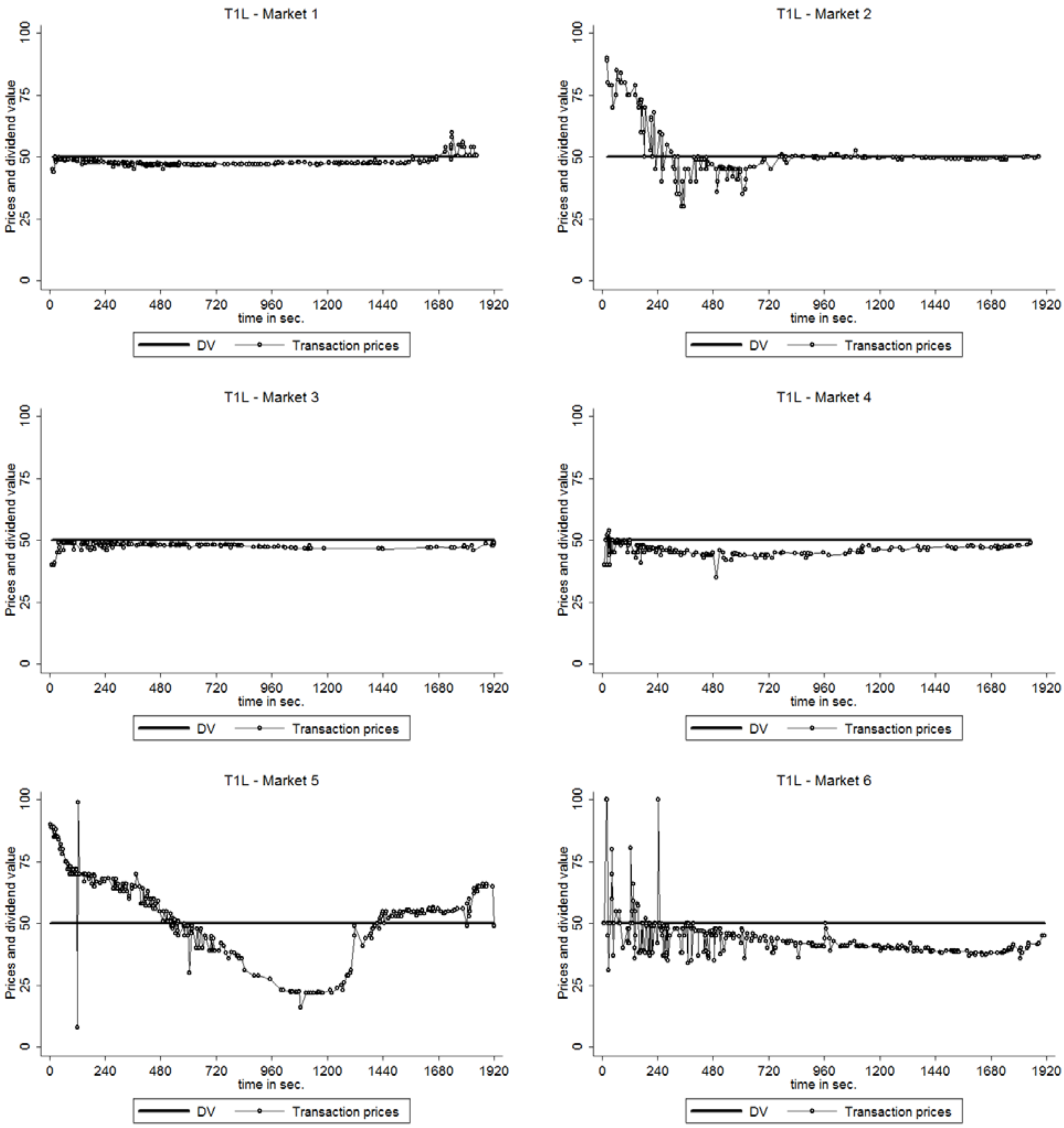
Notes: Average absolute prediction error as a function of period. Upper left panel: treatment T1LH; upper right panel: treatment T2LH; lower left panel: treatment T4LH; lower right panel: treatment T8LH.

Appendix D: Individual market results

Table A4 Individual market results for RAD, RD, SPREAD, VOLA and ST for all treatments.

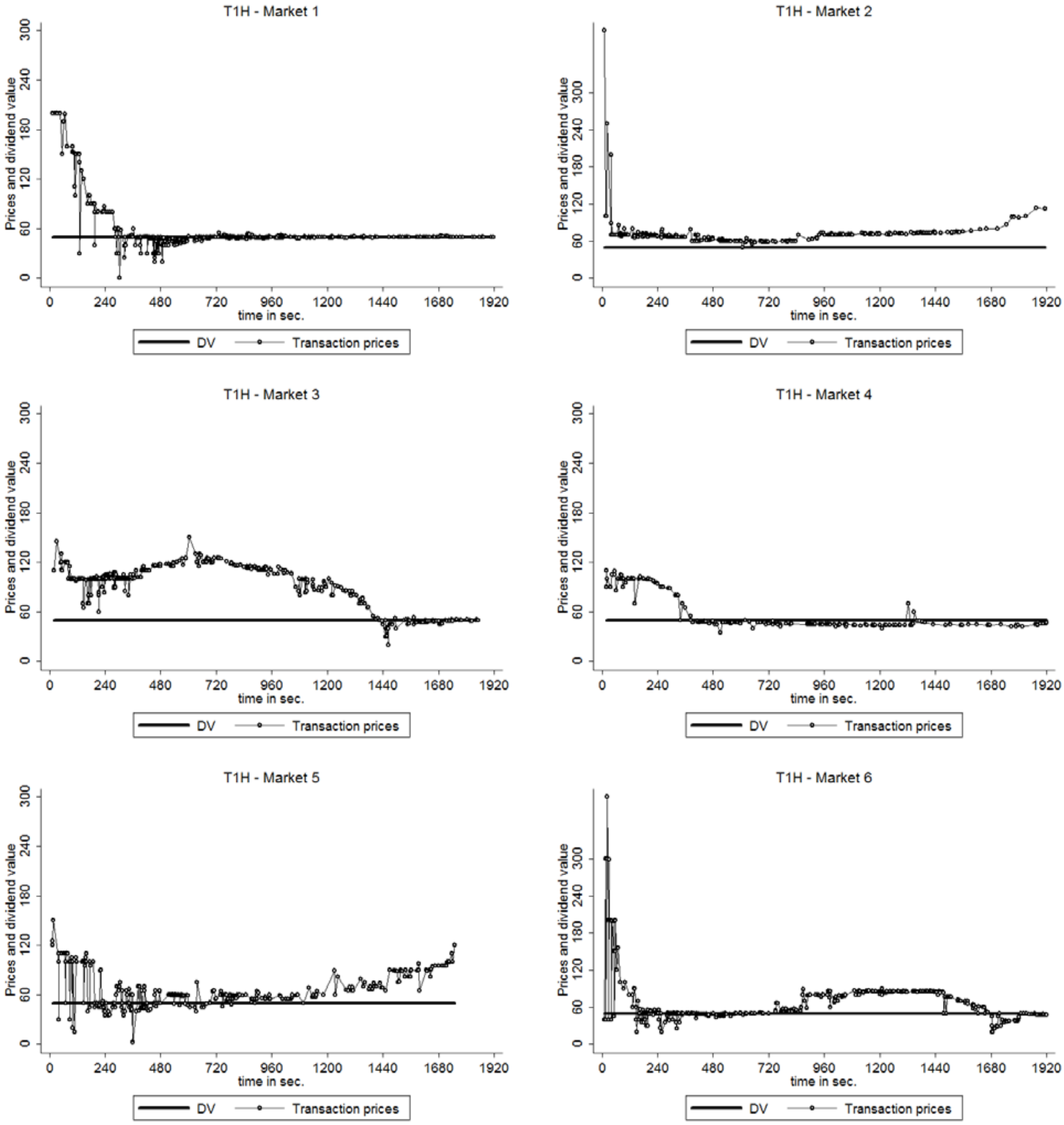
		RAD		RD		SPREAD		VOLA	
treat	market	C/A=2	C/A=10	C/A=2	C/A=10	C/A=2	C/A=10	C/A=2	C/A=10
T(1,HL)	1	5.08%	22.68%	-3.60%	19.03%	3.60%	25.64%	1.51%	18.98%
	2	8.51%	47.79%	2.60%	47.79%	10.10%	20.90%	5.48%	6.65%
	3	4.73%	80.90%	-4.73%	78.32%	2.90%	30.27%	1.18%	7.56%
	4	8.12%	23.05%	-8.12%	8.23%	7.89%	23.78%	2.90%	6.81%
	5	26.46%	36.16%	-2.93%	35.60%	12.57%	51.31%	8.26%	25.75%
	6	15.69%	41.37%	-14.69%	35.40%	15.69%	25.78%	8.83%	18.75%
	mean	11.43%	41.99%	-5.24%	37.39%	8.79%	29.61%	4.70%	14.08%
T(2,HL)	1	8.74%	18.37%	-8.40%	-8.08%	6.90%	21.44%	3.54%	5.06%
	2	43.28%	50.10%	-42.07%	-37.54%	14.41%	20.19%	19.60%	46.07%
	3	44.36%	80.37%	-8.61%	18.16%	34.28%	65.40%	45.52%	14.89%
	4	35.85%	28.80%	-16.68%	21.06%	21.46%	50.47%	10.14%	24.06%
	5	48.99%	161.47%	-14.64%	151.00%	14.67%	39.35%	10.42%	19.66%
	6	31.57%	123.02%	-23.30%	88.28%	27.82%	133.39%	16.12%	26.45%
	mean	35.47%	77.02%	-18.95%	38.81%	19.92%	55.04%	17.56%	22.70%
T(4,HL)	1	26.65%	19.46%	-21.59%	13.15%	24.84%	24.19%	20.79%	11.28%
	2	59.80%	67.97%	-59.80%	60.76%	13.79%	15.54%	28.32%	16.23%
	3	27.00%	148.48%	-11.72%	108.14%	20.53%	29.82%	14.62%	24.65%
	4	42.82%	103.06%	-36.09%	74.34%	31.17%	31.37%	24.97%	13.32%
	5	47.81%	52.95%	-21.83%	4.98%	36.22%	22.15%	36.68%	32.92%
	6	53.43%	51.26%	-53.43%	51.26%	8.57%	17.17%	25.56%	7.93%
	mean	42.92%	73.86%	-34.07%	52.11%	22.52%	23.37%	25.16%	17.72%
T(8,HL)	1	67.95%	37.88%	-67.95%	37.76%	12.72%	26.84%	39.79%	12.81%
	2	28.19%	43.15%	-21.75%	43.15%	17.94%	20.92%	19.02%	5.45%
	3	54.07%	171.28%	-50.53%	171.28%	14.60%	187.35%	26.19%	31.13%
	4	41.76%	102.93%	-3.48%	73.58%	30.01%	50.90%	29.72%	23.87%
	5	38.47%	287.14%	-21.24%	287.14%	24.52%	68.09%	22.08%	6.39%
	6	27.73%	69.61%	-17.89%	7.98%	30.34%	41.60%	20.63%	29.38%
	mean	43.03%	118.67%	-30.48%	103.48%	21.69%	65.95%	26.24%	18.17%

Figure A3: Individual market results for T1L.



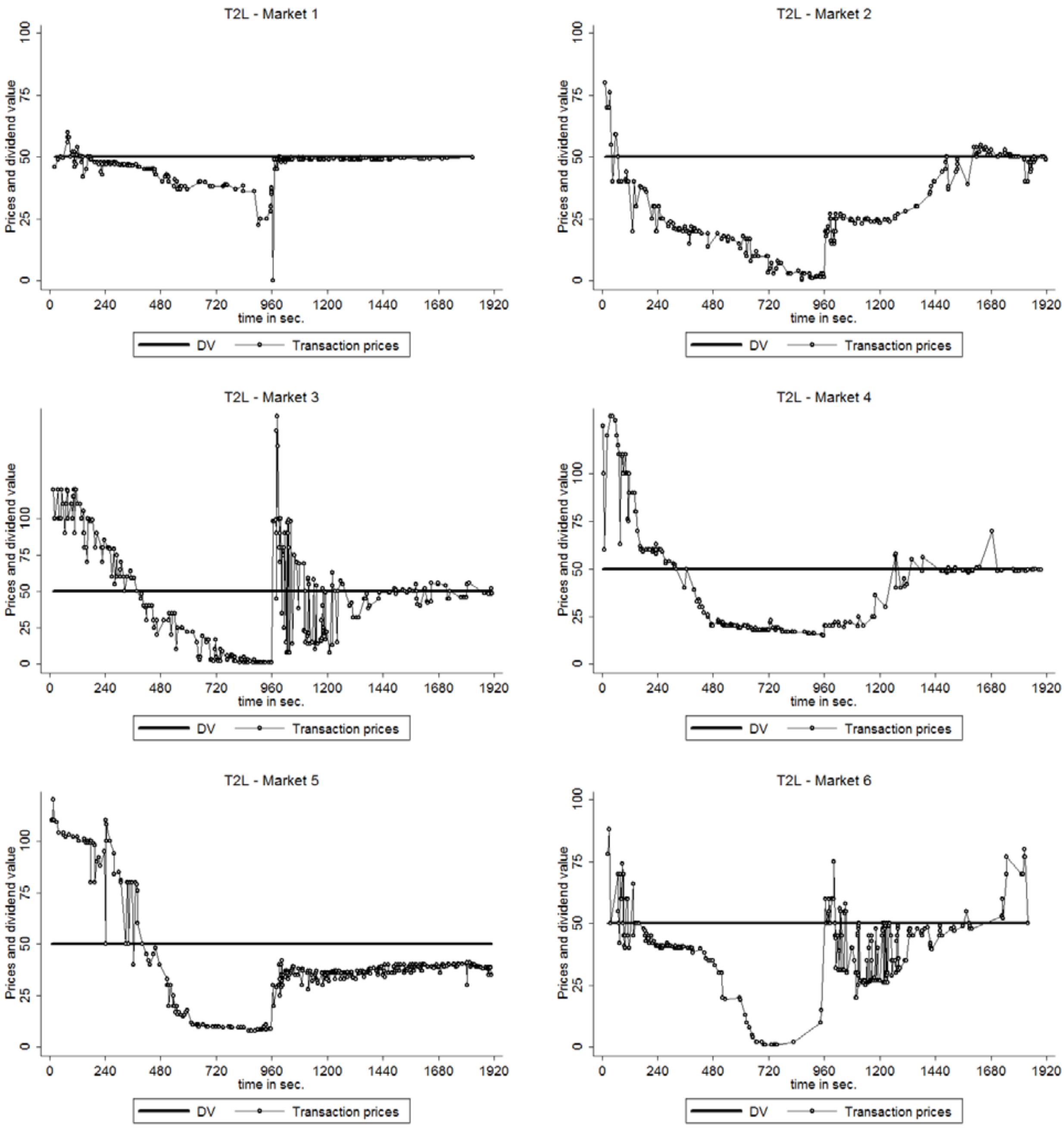
Notes: xx

Figure A4: Individual market results for T1H.



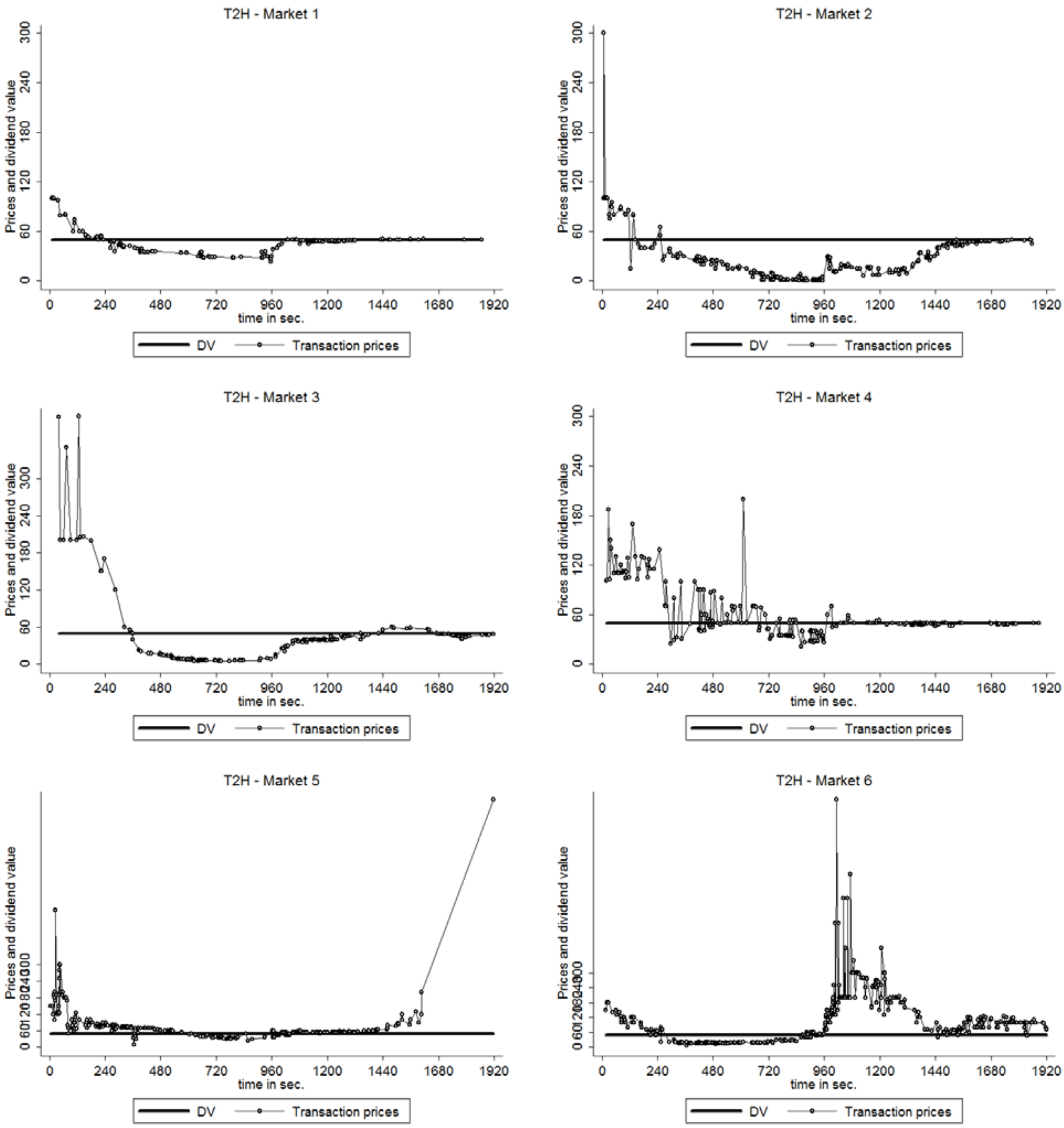
Notes: xx

Figure A5: Individual market results for T2L.



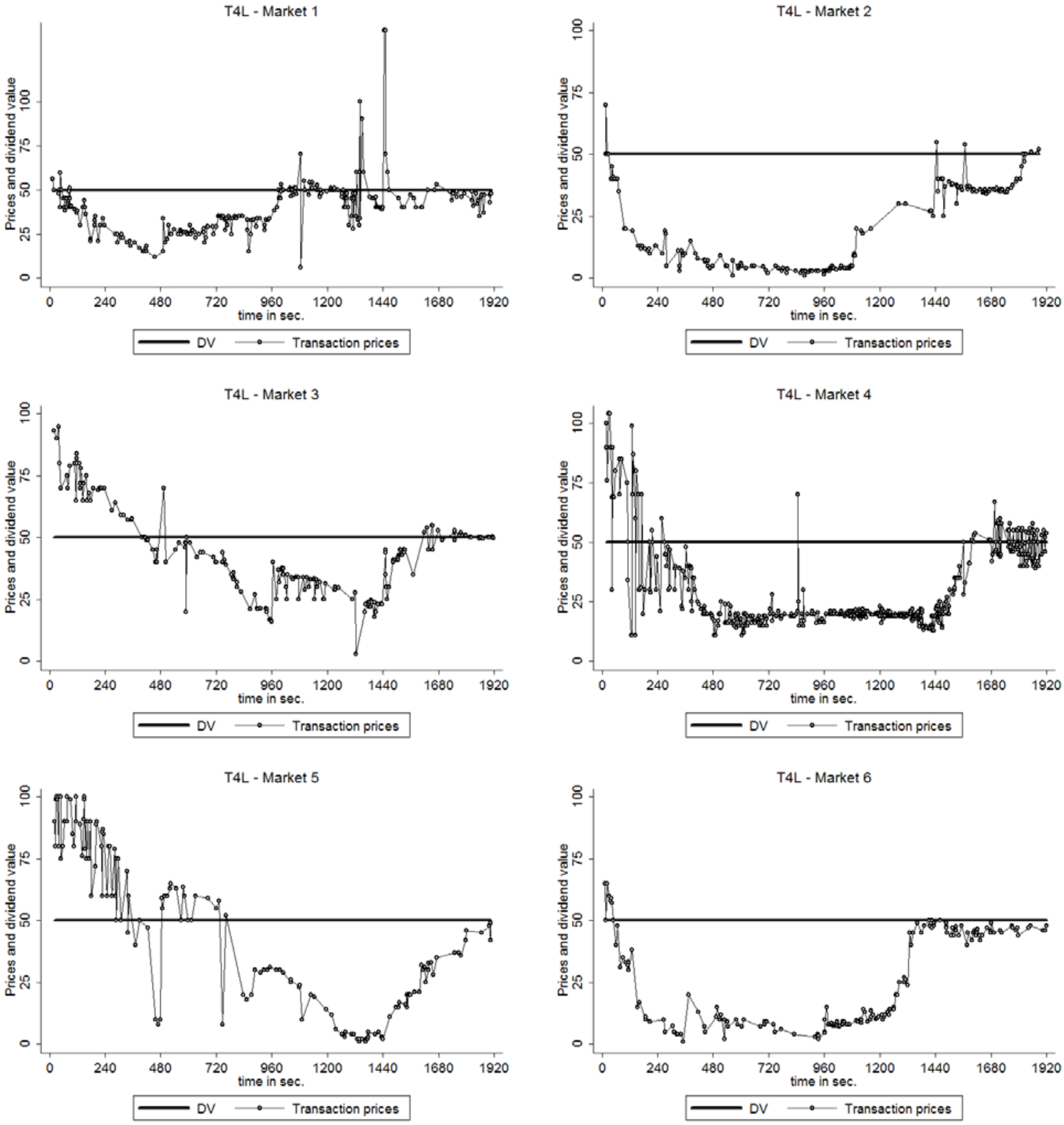
Notes: xx

Figure A6: Individual market results for T2H.



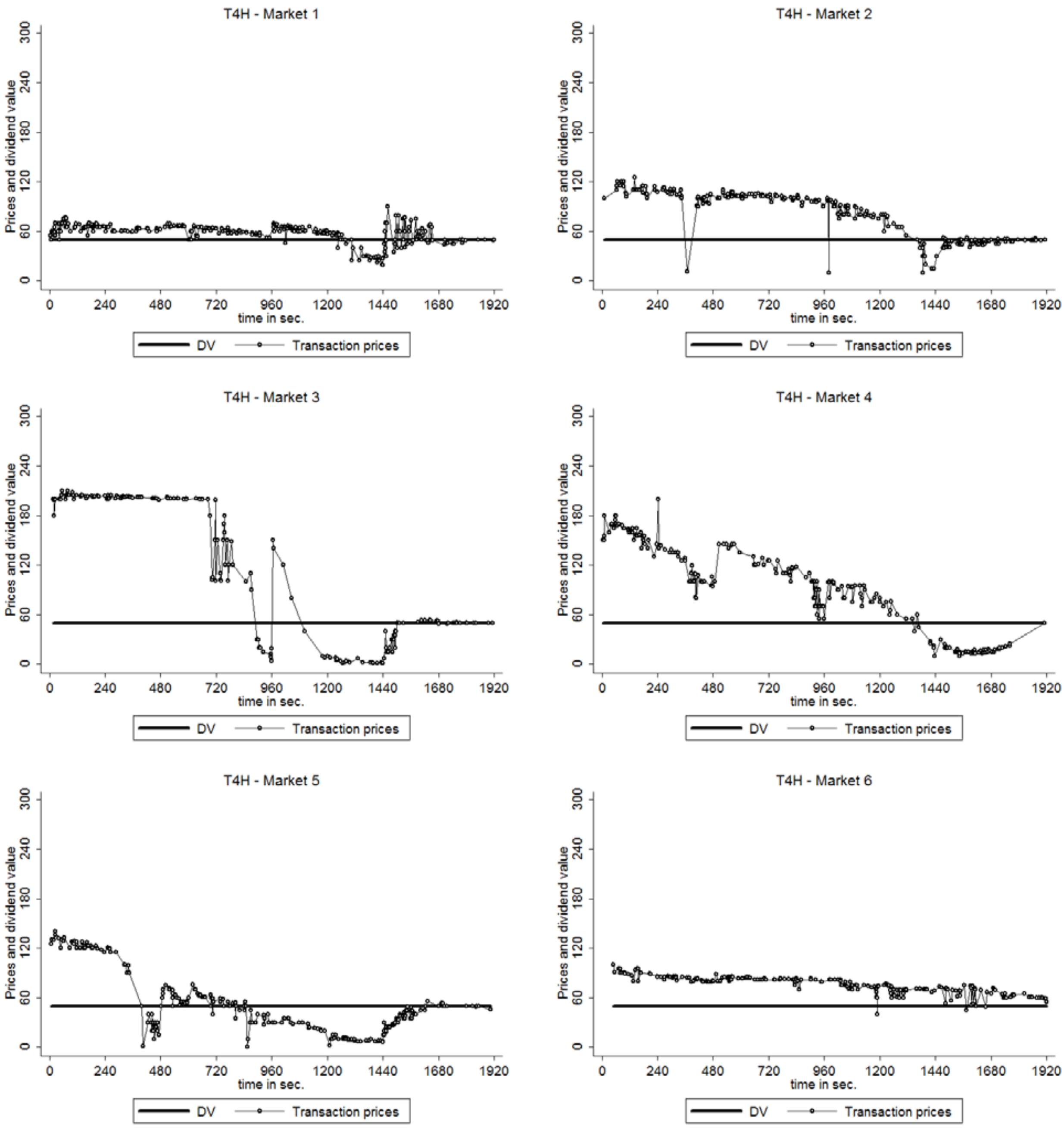
Notes: xx

Figure A7: Individual market results for T4L.



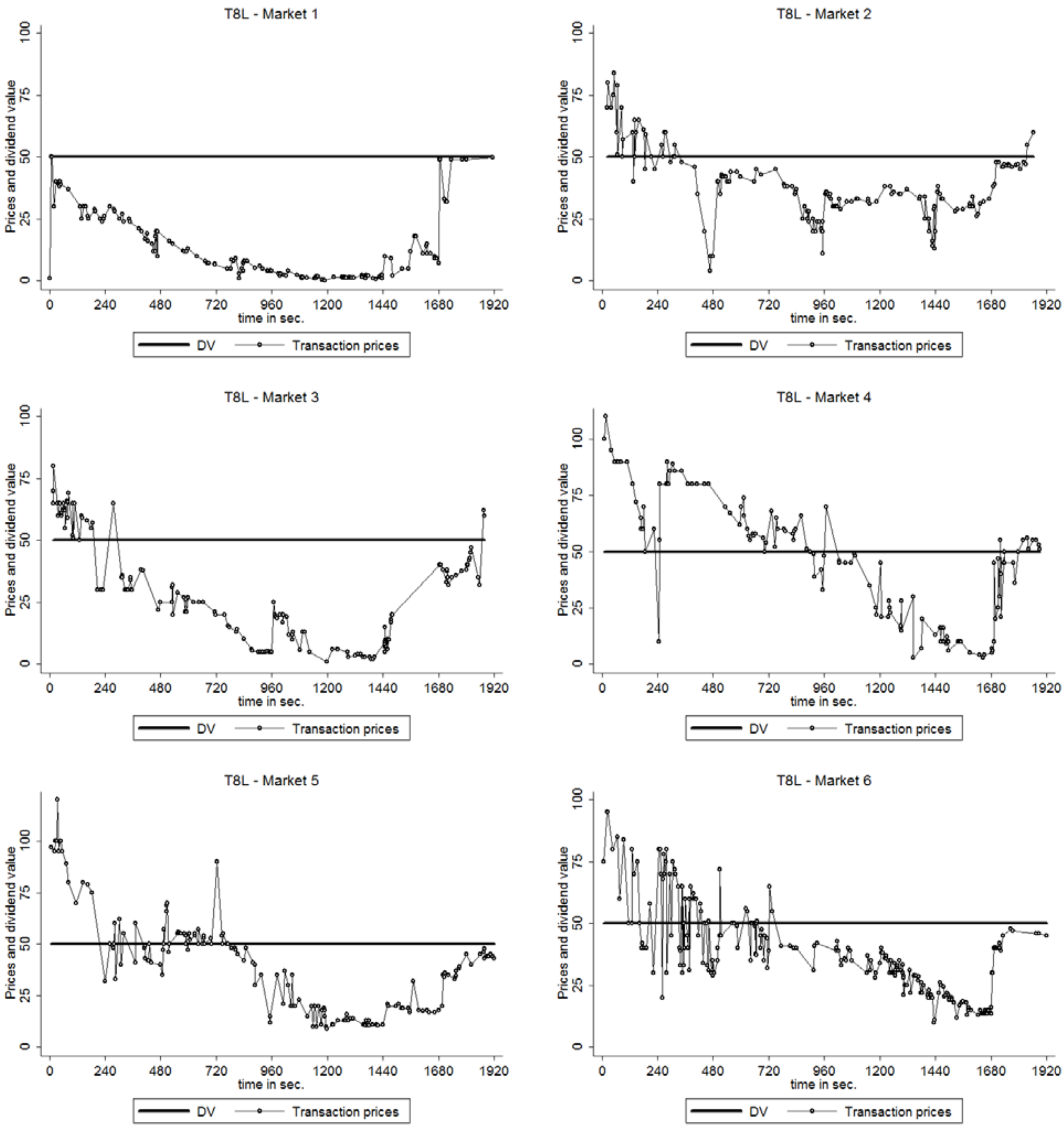
Notes: xx

Figure A8: Individual market results for T4H.



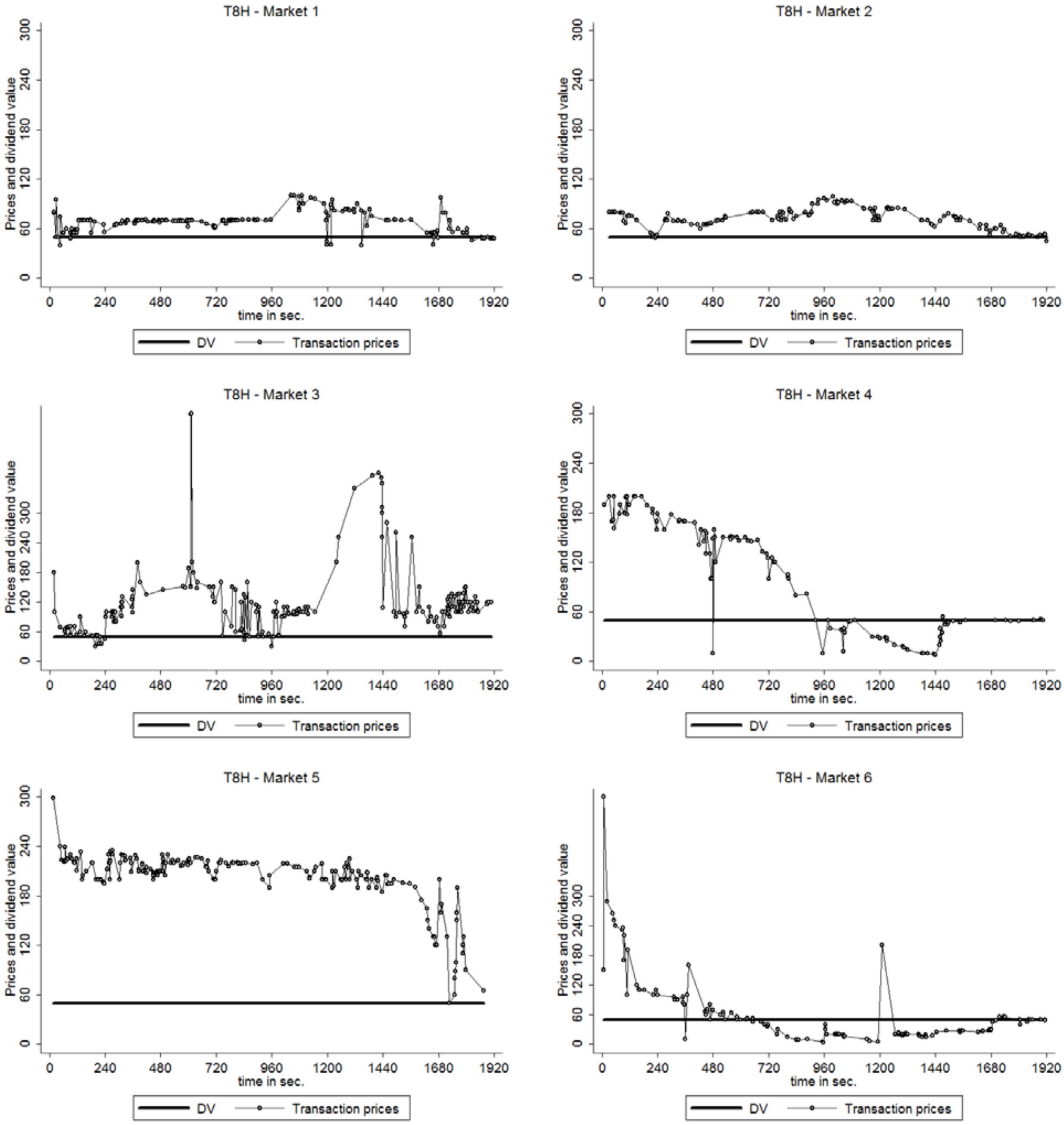
Notes: xx

Figure A9: Individual market results for T8L.



Notes: xx

Figure A10: Individual market results for T8H.



Notes: xx

Appendix E: Instructions of the experiment[9]

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

General Instructions

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

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

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

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

Course of the experimental session

Market experiment

Instructions to the experiment and explanation of the trading mechanism

2 trial periods (not relevant for payment) and questionnaire

Market experiment

Private payment

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

Active market participants

Assignment process

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

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

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

Figure 1

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

Share value

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

Endowments and payment

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

Cohort 2 will enter the market at the beginning of period 1 with an endowment of 1.600 Taler each and no shares. They may use these Talers to buy any number of shares they wish to. Again, when they exit the market at the end of Period 16, any remaining shares in their hands are worthless.

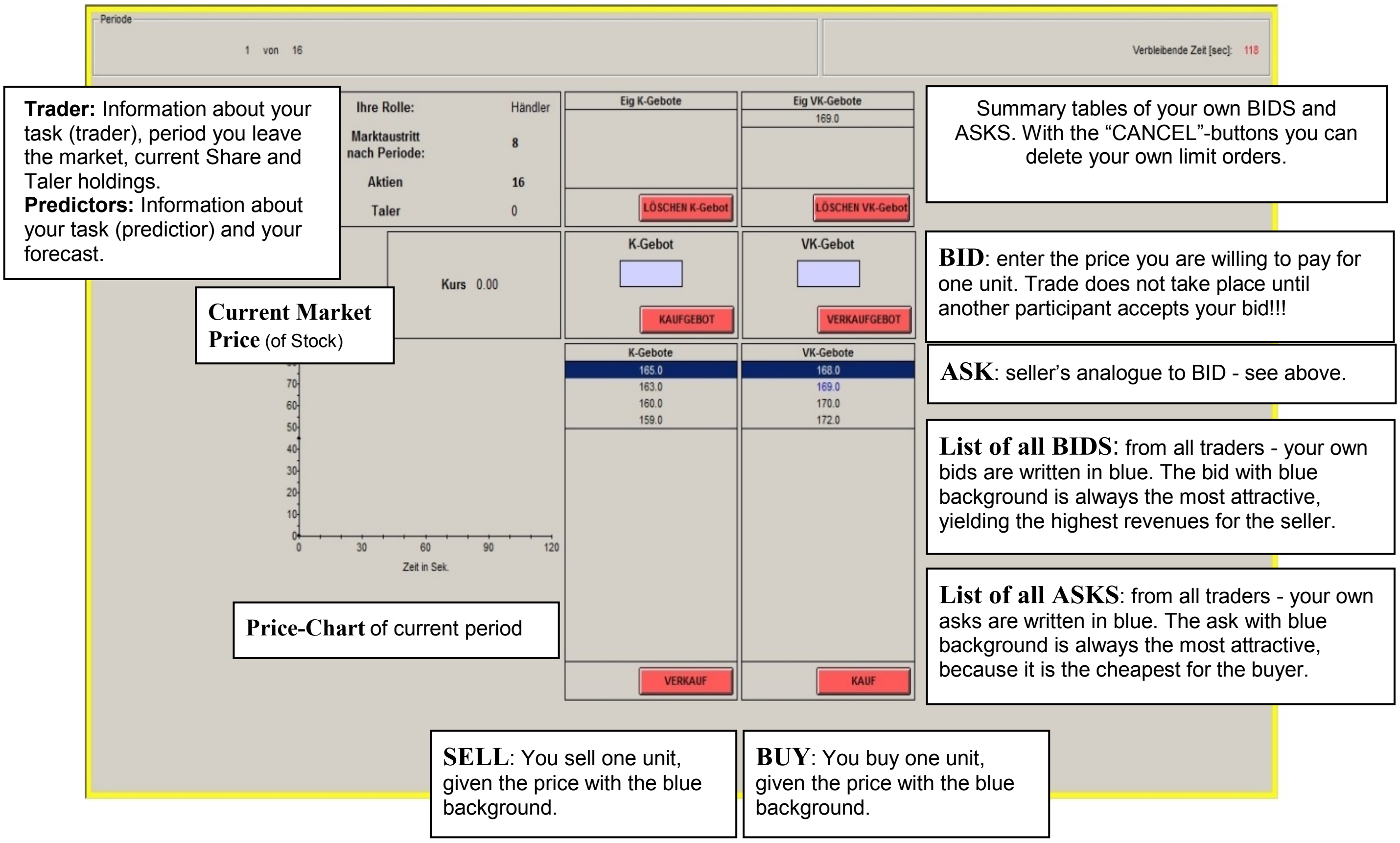
Cohort 3 also enters the market with 1.600 Talers each and will be able to use these Talers to buy any shares they wish to during periods 9-16. At the end of Period 16, any shares remaining in their hands pay a dividend of 50 Taler each, which is added to their Taler holdings.

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

Trading

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

Figure 2:Trading screen



Market predictions

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

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

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

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

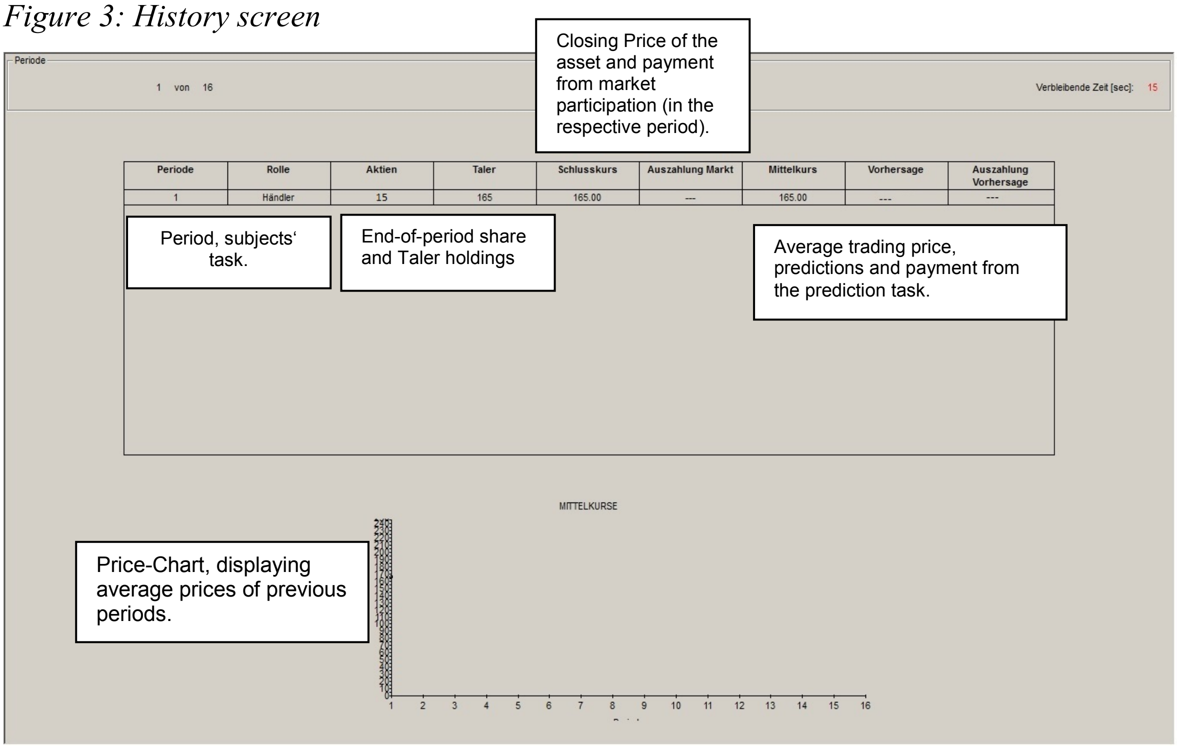
Important information

- No interest is paid for Taler holdings.
- Each trading period lasts for 120 seconds.
- You have 30 sec. to enter your prediction.
- The session ends after 16 periods.
- Offers to buy/sell shares can be placed in the range from 0 to 999 Taler (with at most one decimal places).
- Members of Cohort 3 (and only this cohort) receive a dividend of 50 Talers per share for their holdings at the end of Period 16. Shares are worthless thereafter.
- Use the full stop (.) for decimal.

Trial periods

Before the actual session starts, there will be two trial periods to familiarize you with the trading mechanism. Each participant will be an active trader split into two cohorts. Members of Cohort 1 receive 4 shares and no Taler, while members of Cohort 2 receive 400 Taler and no shares. The asset pays a dividend of 50 to members of Cohort 2. In contrast to the main experiment, you will also make predictions about the average trading price. Trial periods have no influence on your Euro earnings!

Figure 3: History screen



Your payment from the experiment

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

Your payment = Sum of earnings from market experiment +
Sum of earnings prediction tasks

Appendix F: Questionnaire for understanding (correct answers in italic font).

1. How many trading periods are there during the session? *16*
2. For how many seconds does one trading period last? *120 sec*
3. If you buy a share for 350 Taler, what happens to your cash balance? (i) *My cash balance decreases by 350*. (ii) My cash balance increases by 350. (iii) Nothing happens to my cash balance.
4. If you sell a share for 350, what happens on your cash balance? (i) My cash balance decreases by 350. (ii) *My cash balance increases by 350*. (iii) Nothing happens to my cash balance.
5. Can you buy a share when you do not have enough cash to pay for the purchase? Yes/*No*.
6. Can you sell a share when you do not have a share? Yes/*No*.
7. What are the two ways of buying a share? (i) *Submit a bid or accept an open offer to sell (ask)*. (ii) Submit an offer (ask) or accept an open offer to buy (bid). (iii) Submit a bid or accept an open offer to buy (bid). (iv) Submit an offer (ask) or accept an open offer to sell (ask).
8. What are the two ways of selling a share? (i) Submit a bid or accept an open offer to sell (ask). (ii) *Submit an offer (ask) or accept an open offer to buy (bid)*. (iii) Submit a bid or accept an open offer to buy (bid). (iv) Submit an offer (ask) or accept an open offer to sell (ask).
9. You are a member of cohort 2. How are your Taler converted into real euros? (i) Exchange rate of 50 (100) Taler to 1 Euro. (ii) Exchange rate of 100 (500) Taler to 1 Euro. (iii) Exchange rate of 200 (1000) Taler to 1 Euro. *Values in parenthesis for high cash treatments. Correct answers vary by treatment.*
10. Are you allowed to talk, use email, or surf the web during the session? *No*.
11. Your role is "predictor": You predict a price which is 8 Taler less than the actual average price of the period. What is your profit (in Taler)? *140-8=132*
12. You are a member of cohort 1 and you will leave the market at the end of that period. What is the value of the shares you are holding at the end of the period? (i) Shares have a value 50. (ii) *Shares have a value of 0*. (iii) Shares have a value of 200.