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Do regulations work? A comprehensive analysis of price limits and trading restrictions in experimental asset markets with deterministic and stochastic fundamental values[☆]

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ABSTRACT

We examine how traders react to two prominent stock market regulations. Under a constant fundamental value (FV) process, price limits and trading restrictions significantly reduce the price level and mispricing size when traders are inexperienced. Under a Markov-process FV, there is no evidence for these regulations to reduce mispricing. The novel Markov process also serves as a testbed for several financial hypotheses related to the regulations. We find that price limits do not improve reactions to market news and the binding of price limits magnifies the momentum in the price movements. These findings suggest that the scope of these regulations is limited and that they can backfire in some market environments.

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1. Introduction

Asset market crashes have devastating consequences for society. They not only damage economic welfare by decreasing productivity (Miao and Wang, 2012) and increasing unemployment (Miao et al., 2016), but also adversely affect health and psychological wellbeing (Chen et al., 2016; Engelberg and Parsons, 2016; Lin et al., 2014; McInerney et al., 2013). Governments struggle with whether and to what extent they should intervene and experts are skeptical about asset market regulations (Gorton and Metrick, 2013; Hanson et al., 2011; Masciandaro and Passarelli, 2013). While there is little disagreement

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about the high cost of asset market failures, market authorities are uncertain about regulations to prevent the formation of bubbles¹ and reduce market volatility.²

In Chinese asset markets, price limits and same-day trading restrictions (the $t + 1$ rule) remain the two key regulations. The former rule, which is also common in western asset markets such as Belgium, France, the U.S., determines a price ceiling and floor for a share on a particular trading day.³ The price limits for Chinese domestic shares listed in the Shanghai and Shenzhen Stock Exchange are $\pm 10\%$ of the share's closing price on the previous trading day. The $t + 1$ rule prevents traders from selling shares purchased on the same trading day. The implementation of both regulations is controversial.⁴ Market regulators claim that price limits cool markets down when volatility is high and that the $t + 1$ rule deters speculation. However, others argue that price limits delay price discovery, lead to spillovers (see, e.g., Fama, 1988; Kim and Rhee, 1997), and have magnet effects (Ackert et al., 2001; Cho et al., 2003; Wang et al., 2015). Likewise, there are arguments against the $t + 1$ rule (Guo et al., 2012; Wu and Qin, 2015; Chen et al., 2017) and concerns that these two regulations cause market bubbles and anomalies.⁵

In this study, we examine how price limits and same-day trading restrictions function in a set of asset market experiments. Building upon Smith et al. (1988) (hereafter SSW) seminal study, we compare trader behavior in asset markets with and without these restrictions using two different fundamental value (FV) processes. More precisely, we randomly assign traders into trading groups facing either no regulation, one regulation (price limits or same-day trading restrictions), or both regulations. Departing from SSW who use decreasing FVs, we study these different trading groups in both a simplified environment with constant FVs and in another environment in which the FV varies by a Markov process. Using these two FV processes renders it possible to comprehensively test regulations in environments that capture key elements of naturally occurring markets.⁶

This paper provides several new insights. First, we find that the scope of these regulations to encourage value investing is limited. Regulations successfully reduce mispricing⁷ only when traders are inexperienced and the assets have constant FVs. Once traders gain experience in this simplified environment, these regulations do not make a discernable difference. Importantly, in the perhaps more realistic environment under FVs determined through a stochastic value process, these regulations fail to mitigate mispricing.

Beyond comparing price patterns across treatments, we provide novel evidence on how regulations affect trader reactions to market information. We find that traders underreact to news and that regulations other than the $t + 1$ rule, are of little help in this regard. In addition, we study how the price limits changes traders' behavior in other dimensions.⁸ Chen (1993), Fama (1988), and Kim and Rhee (1997) suggested that price limits make traders herd; that is, future stock prices increase (decrease) after an upper (lower) price limit comes into effect. We confirm this pattern with our experimental data.

Our study addresses different strands of the literature on finance and economics. It is closely linked to the literature varying experimental asset market FV (Ball and Holt, 1998; Bao and Leibbrandt, 2020; Bostian et al., 2005; Noussair and Powell, 2010; Smith et al., 1988; Kirchner, 2009), the literature studying the cause of asset market bubbles (Dufwenberg et al., 2005; Eckel and Füllbrunn, 2015; Haruvy et al., 2007; Hussam et al., 2008; Lei et al., 2001; Cason and Samek, 2015; Cheung et al., 2014; Breaban and Noussair, 2015; Baghestanian et al., 2015; Bao et al., 2017), and the experimental literature testing market regulations. There are several articles find that regulations may or may not work as expected. For example, Cipriani et al. (2018) find that the ability to serve as a collateral makes an asset to be traded at a higher price. Fischbacher et al. (2013), Haruvy and Noussair (2006), King et al. (1993) and Lugovskyy et al. (2014) suggest that short-selling, margin-buying, and monetary policy do not eliminate/abate bubbles in experimental asset markets. Our study contributes to this strand of research in several important ways. Besides studying the mispricing patterns in a new FV process, we provide novel evidence on the sensitivity to market news and excess price movements caused by the binding of the regulations. Additionally, we contribute methodologically in testing the stock market regulations using asset market experiments with different FV processes. Testing regulations with only one type of FV may be inadequate because regulations may work only in some market environments but backfire in others.

¹ We define a bubble as the price being above the FV.

² The Chinese Securities Regulatory Commission, for example, introduced a circuit breaker rule on Jan 7, 2016, but then quickly suspended this rule less than one week after it came to effect. The rule was triggered 4 times between Jan 4 and Jan 7, and the Shanghai Composite Index dropped by more than 10% in just 3 days. Further, regulators introduced price limits in the Shanghai Stock Exchange in 1990, abandoned them in 1992, but then reactivated them in 1996.

³ Price limits are also implemented in many stock markets in other non-western countries such as Japan, Korea, Malaysia, and Thailand.

⁴ See some Chinese blogs and newspapers arguing for and against regulations: <https://zhuanlan.zhihu.com/p/31961856>; http://bbs.tiexue.net/post_9335378_1.html; <http://www.bbtnews.com.cn/2017/0103/176380.shtml>.

⁵ Despite ranking among the top ten most capitalized stock markets globally, the Shanghai Stock Exchange experienced two major bubbles within the last decade. Moreover, the price of any newly listed IPO of Chinese domestic share always hits the upper price limit in the first few trading days, and then shows a bubbly pattern afterwards.

⁶ The flat FV represents a simplified scenario where shares' FV is stable over time instead of artificially decreasing. The Markov FV captures the idea that there are market business cycles and trends. News about firms' performance affect traders' evaluation of shares very frequently. To study how regulations interact with these realistic features, we consider a Markov FV process that mirrors typical financial market data, which is characterized by serial correlations and long-run growth (Lo and MacKinlay 1988; Jegadeesh, 1990; Mehra and Prescott, 1985; Moskowitz and Grinblatt, 1999). This process also allows us to study how regulations affect traders' reactions to new market information (Braun et al., 1995; Epstein and Schneider, 2008; Veronesi, 1999).

⁷ We define mispricing as the relative distance between the price and the FV.

⁸ To the best of our knowledge, there is no behavioral hypothesis on the $t + 1$ rule that we may test using our experiment.

Our study also adds on financial research on evaluating market regulations. Employing an experimental methodology complements the results based on market data because it allows us to bypass problems caused by self-selection, measurement of market information, sentiments change, and other limitations. Our work is connected to the literature studying the effectiveness of price limits, which reports positive impacts such as decreasing volatility (Brennan, 1986; Chowdhry and Nanda, 1998; Deb et al., 2010; Kim and Park, 2010, etc.) and negative impacts such as delaying price discovery and inflating bubbles (Chen, 1993; Fama, 1988; Kim and Rhee, 1997; King et al., 1993).⁹ Further, our exploration of traders' reactions to market information is related to a number of empirical studies analyzing existing market data (Hameed and Kusunadi, 2002; Hong and Stein, 1999; Wu, 2011). We provide new experimental evidence, supplementing market data, to consolidate the understanding of these financial hypotheses.

2. Experimental design

Before starting the experiment, we asked traders to read an information sheet and sign a consent form. Thereafter, we read the instructions out loud. After reading the instructions, traders were given sufficient time to read the instructions on their own and ask questions. We then implemented a five-minute practice round and asked traders to answer a set of quiz questions. After everyone answered these questions correctly, the asset market experiment started.¹⁰ When all traders completed the asset market experiment, we administered a short demographic questionnaire.

2.1. Baseline market environment

The asset market experiment is based on the seminal study by SSW. Each trading group has eight traders,¹¹ who stay in the same group throughout the experiment. Following other studies (Hussam et al., 2008; King et al., 1993; Van Boening et al., 1993), in our experiment traders took part in *three trading blocks* of the asset market experiment and each block consisted of *ten trading periods*.¹² At the end, we chose one trading block at random for payment.

At the start of each trading block, all traders have an initial endowment of tokens and shares to trade, with differing token-to-share ratios, but the same expected endowment values.¹³ In each of the ten trading periods in a given trading block, traders have 100 s trading time during which they can buy and sell shares. At the end of each trading period, each share pays a risky dividend (the dividend structure depends on the FV process) and tokens receive risk-free interest at the rate of 10%. Individual inventories of shares and tokens owned by a trader carry over from one period to the next (but not across trading blocks).

The double-auction mechanism functions as in SSW, where each trader can buy and sell as many times as they wish in each trading period, as long as they have enough money/shares. Shares are traded only in whole numbers, while the prices are quoted with two decimal places. To buy a share in the experiment, a trader has to accept the ask offer at the minimum ask price. Alternatively, the trader can make a bid offer; if this bid is accepted, then the trader buys the corresponding shares or receives nothing otherwise. Analogously, to sell a share in the experiment, a trader has to accept the bid offer with the highest bid price. Alternatively, the trader can make an ask offer and sells the corresponding shares if this bid is accepted or sell nothing otherwise. The program matches the minimum ask and the maximum bid such that purchases occur at the minimum ask price and sales at the maximum bid price. Outstanding offers are cleared and the corresponding frozen assets are released at the end of each period. There is only one type of share and there is no tax, brokerage, short-selling, or margin buying. We provide the experimental instructions and quiz questions in the Appendix.

2.2. Treatments

We implement a 4×2 experimental design. The first dimension varies the type of market regulation, the second the FV processes. We collected information from six independent groups (each with eight members) in each of the eight treatments. We thus test each regulation using two different FV processes. An overview table of all the treatments can be found in the Appendix.

⁹ King et al. (1993) study price limits using a monotonically decreasing FV and find that price limits may increase the bubble size. Our work provides an improvement to their design and findings in several important ways. First, because they use a decreasing FV, in their experiments, price limits always lead to an upward deviation with respect to the FV; in contrast, in our design, price limits may lead to deviations in both directions. Second, they study thin markets (their market has fewer than 20 shares available), which, according to the literature, leads to a much more pronounced volatility (see, e.g., Gandhi et al., 1980). In our design, there are 1600 shares in the market. Finally, they conduct only two independent sessions to examine the effects of price limits and do not report statistical tests of their findings. We analyse data from several independent sessions across a number of different treatments.

¹⁰ In general, most participants report to find the experiment clear. For instance, only 1 out of 48 participants in the baseline Markov FV treatment reported difficulties with understanding.

¹¹ A trading group of eight is common, and many recent studies use trading groups with seven to ten individuals (e.g., Haruvy et al., 2007; Haruvy and Noussair 2006; Kirchner et al., 2012; Lei et al., 2001; Stöckl et al., 2015). The detailed endowments can be found in the Appendix.

¹² Kirchner et al. (2012) also have 10 trading periods within each round.

¹³ Giving participants heterogeneous endowments and different cash/asset ratios is common and encourages trading (Palan, 2013).

2.2.1. Market regulations

We compare three market regulation regimes (price limits, $t + 1$, and BOTH¹⁴) to our baseline market environment with no regulation.

Price limit regulation: The price limit regulation imposes a price ceiling and a price floor for share prices throughout the different trading periods. In the experiment, the price ceiling in the current period is the closing price in the previous trading period multiplied by 1.2, while the price floor in the current period is the closing price in the previous trading period multiplied by 0.8. Prices outside this range are not allowed. If the price limits have more than two decimal places, they are rounded to two decimal places so they remain in line with the price system. The price limits are displayed on the computer screen. If a trader attempts to make a bid/ask outside the price limits, the software does not allow it and displays the message “Please submit a price within price limits!”

$t + 1$ regulation: The $t + 1$ regulation implies that traders cannot sell the shares that they purchased in the same trading period. The rule only applies to the shares bought in the “current” trading period and traders can sell shares bought in any previous trading period. In the experiment, the traders are informed of the number of shares they can sell. When the $t + 1$ rule is binding, the software forbids the trader’s attempt to sell these shares by showing the message “You cannot sell due to $t + 1$ rule!”

BOTH (price limits and $t + 1$ regulation): In this treatment, both the price limits and $t + 1$ regulations apply.

2.2.2. FV processes

Our experiment considers both deterministic (flat)¹⁵ and stochastic (Markov) FV processes.

Flat value process: Our flat process is implemented similar to Ball and Holt (1998). Dividends per share are 0, 0.4, 1.05, or 4.27 tokens, each with 25% probability. The expected value of the distribution is 1.43 tokens. This four-point distribution mimics the dividend structure in SSW: the dividend in the worst-case scenario is normalized to 0 and the distribution is positively skewed. At the end of period ten of each trading block, each share pays a redemption value of 14.33 tokens, which renders the FV equal to 14.33 tokens in all trading periods. We calculate the FV as $FV_t = \sum_{i=t}^{10} \frac{1.43}{(1+10\%)^{i-t+1}} + \frac{14.33}{(1+10\%)^{11-t}}$, where FV_t is the FV in period t .

If the price tracks the FV, then the expected return on the shares is 10% per period, and the variance of the rate of return is 0.0138.¹⁶ This parametric setting makes the FV close to the arithmetic average price in the A-share markets at the time of writing.¹⁷ Further, it allows us to generate a comparable Markov process (i.e., the same expected rate of return and variance) with a relatively simple parametric setting. The dividend series are drawn from a set of four cards representing four possible states of word, and are fixed in all markets; that is, all traders under the same FV process regime see the exact dividend sequence, so there is no difference in learning about the dividend across groups. We provide the realization of the dividend series in the Appendix.

Markov process: The flat process provides a simple environment to test the effects of market regulations, but it does not account for market news that may change the stock’s FV, nor does it include the cycles and trends that we typically observe in naturally occurring data (Lo and MacKinlay, 1988). A dividend process following a Markov rate of growth allows for such features. To compare the Flat and Markov processes, we use the same values for the expectation and variance (quadratic risk) of the rate of return in both processes. This implies that the wealth effect or differences in quadratic risk preferences at the beginning of each trading block would not explain the pricing differences between these two processes.

In the first period of each trading block, we normalized the dividend per share to one token for simplicity. The dividend per share then evolves according to a Markov process with two states – high or low. We adopted this two-state design to ensure that the rate of return for each share will have the same four-point distribution as in the flat process. When the state is high, the dividend increases by 10% compared to previous period; when the state is low, the dividend decreases by 5% compared to the previous period. The positively skewed growth rate causes a long-run growth trend in the FV, which approximates a growing industry/market. We set the transition probabilities for the Markov process at 70% and 30%; after each trading period, the dividend state remains unchanged with a 70% chance and switches with a 30% chance. The traders do not know the state of the dividend in the first period, but when calculating the market fundamentals of the shares, we use the unconditional probabilities, 50%, for each state.

At the end of each trading block, each share is redeemed at its FV. The risk-neutral FV in period t is

$$FV_t = d_t w_t,$$

where d_t is the dividend payment at the end of period t and w_t is the price-dividend ratio at time t ; $w_t=15$ if the dividend state is high at time t and $w_t=13.67$ if the dividend state is low at time t . We provide the derivation of this expression in

¹⁴ We capitalize the treatment with both of the two regulations to distinguish from the word “both” thereafter.

¹⁵ We use the flat FV process (Bostian et al., 2005; Holt et al., 2017; Razen et al., 2017; Weitzel et al., 2018; Huber et al., 2019) instead of the traditional SSW’s monotonic decreasing FV process for at least two reasons: a decreasing FV process may confuse participants (Kirchler et al., 2012) and a decreasing FV process makes prices mechanically more likely to hit the lower price limit if the price tracks the FV.

¹⁶ Calculated as $var(\text{rate of return}) = \frac{1}{4} \left(\left(\frac{0}{14.33} - 0.1 \right)^2 + \left(\frac{0.4}{14.33} - 0.1 \right)^2 + \left(\frac{1.05}{14.33} - 0.1 \right)^2 + \left(\frac{4.27}{14.33} - 0.1 \right)^2 \right) = 0.0138$. (./END) On Jan-5-2015, the first trading day of 2015, the arithmetic average price on the Shenzhen Stock Exchange was CNY 13.45, and on Jan-4-2016, the first trading day of 2016, it was CNY 16.96.

¹⁷ If the state is high in period t and $t + 1$, and the dividend is d_t in period t , then $FV_t = d_t w_t = d_t \times 15$ and $FV_{t+1} = d_{t+1} w_{t+1} = (1.1 \times d_t) \times 15 = (1 + 10\%) \times FV_t$. Thus, the FV increases by 10% in this case. The calculations are analogous in other cases.

the Appendix. Intuitively, the price-dividend ratio is higher under a high dividend state than under a low dividend state because the positive auto-correlation of the dividend state process yields a higher expected value for a continued dividend flow in the former case. The precise value of the price-dividend ratios above are determined by the transition probabilities, the discount rate, and the rate of growth of the dividend in the high and low states. When the dividend state goes from high to high, the fundamental increases by 10%;¹⁸ when it goes from high to low, the fundamental drops by 13.4%; when it goes from low to low, the fundamental drops by 5%, and when it goes from low to high, the fundamental increases by 20.7%.

The correlation between dividend states in different periods induces business cycles and market news. With such a dividend process, the fundamental price of shares is expected to increase by 2.85% per period in the long run. The three dividend series we used in the experiment are predetermined with a fair coin (to determine the initial state) and a set of cards with 7 red and 3 black cards (to determine the state transitions). The dividend sequences paid after every trading period is the same across all treatments and sessions and the actual value of the realized FV together with the corresponding cash-asset ratio is provided in the Appendix.

3. Hypotheses

*Hypothesis 1 (regulations & bubbles): Price limits and the $t + 1$ regulation decrease the bubble size, separately or jointly.*¹⁹

Our first hypothesis is motivated by the recent debate on whether the Chinese authority should remove these two regulations. China Securities Regulatory Commission claims that “the two regulations individually improve price discovery and they work together with synergy” but some experts argue otherwise. We take the reasoning for the status quo regulation regime as our null hypothesis.

There are several potential mechanisms. Price limits mechanically restrict the scope of speculation. They also deter speculative bubbles (Santos and Woodford, 1997) and momentum trading behavior, improving market efficiency (see the theoretical predictions in Westerhoff (2003)). The $t + 1$ rule forces traders to pay attention to the price at least one period ahead, which may help them to do backward induction to find the corresponding FV.²⁰

Hypothesis 2 (price limits & extra price momentum): Binding of price limits magnifies the momentum in the price.

The second hypothesis is based on theoretical and non-experimental evidence for price limits (Fama, 1988). The binding of price limits serves as a signal to traders and prices tend to over-react after the price reaches either price limit (i.e., prices tend to go up after reaching the upper price limit and tend to go down further after reaching the lower price limit).

Hypothesis 3 (regulations & reaction to market information): Traders respond partially to market information in the baseline, and regulations help traders to pay more attention to it.

Market information (high or low dividend state) is very salient in the Markov treatments, so we expect traders to use market information to evaluate shares. However, computing the changes in the FV (due to new market information) is hard, so it is likely that traders will have imperfect responses to new market information in the baseline. Price limits offer a cooling-off time when the volatility is high –and thus, they allow traders to think about the FV (Wan et al., 2018). The $t + 1$ rule mechanically deters within period speculation, and therefore nudges traders to pay attention to the profitability of holding shares across periods. This profitability is the sum of the dividend plus potential capital gain/loss, and both are related to market information.

4. Experimental findings

We recruited 384 subjects and the experiment was programmed in z-Tree (Fischbacher, 2007). The participants were university students with no experience with asset market experiments. Traders earned on average \$39 AUD in cash and in private at the end of the two-hour experiment; the minimum and maximum earnings were \$0.80 and \$105 AUD, respectively.

4.1. Regulations and the price level

4.1.1. Regulations and mispricing under fixed FVs

We study the individual impact of each of the regulatory settings using two bubble measures, Relative Deviation (RD) and Relative Absolute Deviation (RAD)²¹, proposed by Stockl et al. (2010), to form our policy recommendation. RD and RAD

¹⁸ There are many definitions of bubble in the literature (e.g., SSW; Lei et al., 2001; Razen et al., 2017). Regarding to this hypothesis, we define the bubble as mispricing in general (i.e., deviations from the FV).

¹⁹ Predictions regarding differences in bubble sizes and differential effects of the regulations in flat vs. Markov FV treatments are less clear. One could expect larger bubbles in Markov markets since there is more complexity in the FV process and complexity increases bubbles (Huber and Kirchler 2012; Kirchler et al., 2012). Regarding the regulations, price limits may be relatively less effective in Markov markets if the fluctuations of the FV cause the regulation to bind more often. The $t + 1$ rule may be relatively less successful in reducing mispricing in Markov FV treatments if participants cannot correctly calculate the expected terminal value, making the nudge to perform backward induction ineffective

²⁰ Powell (2016) provides a comprehensive survey on bubble measures. Among these bubble measures, RD and RAD allow us to directly compare the flat and Markov treatments because they take the FV process into account. They are easy to compute and widely used in the literature. Other analogous measures like GD and GAD lead to similar results.

²¹ The statistic being permuted is the bubble measures and we draw 100 simulations for each test.

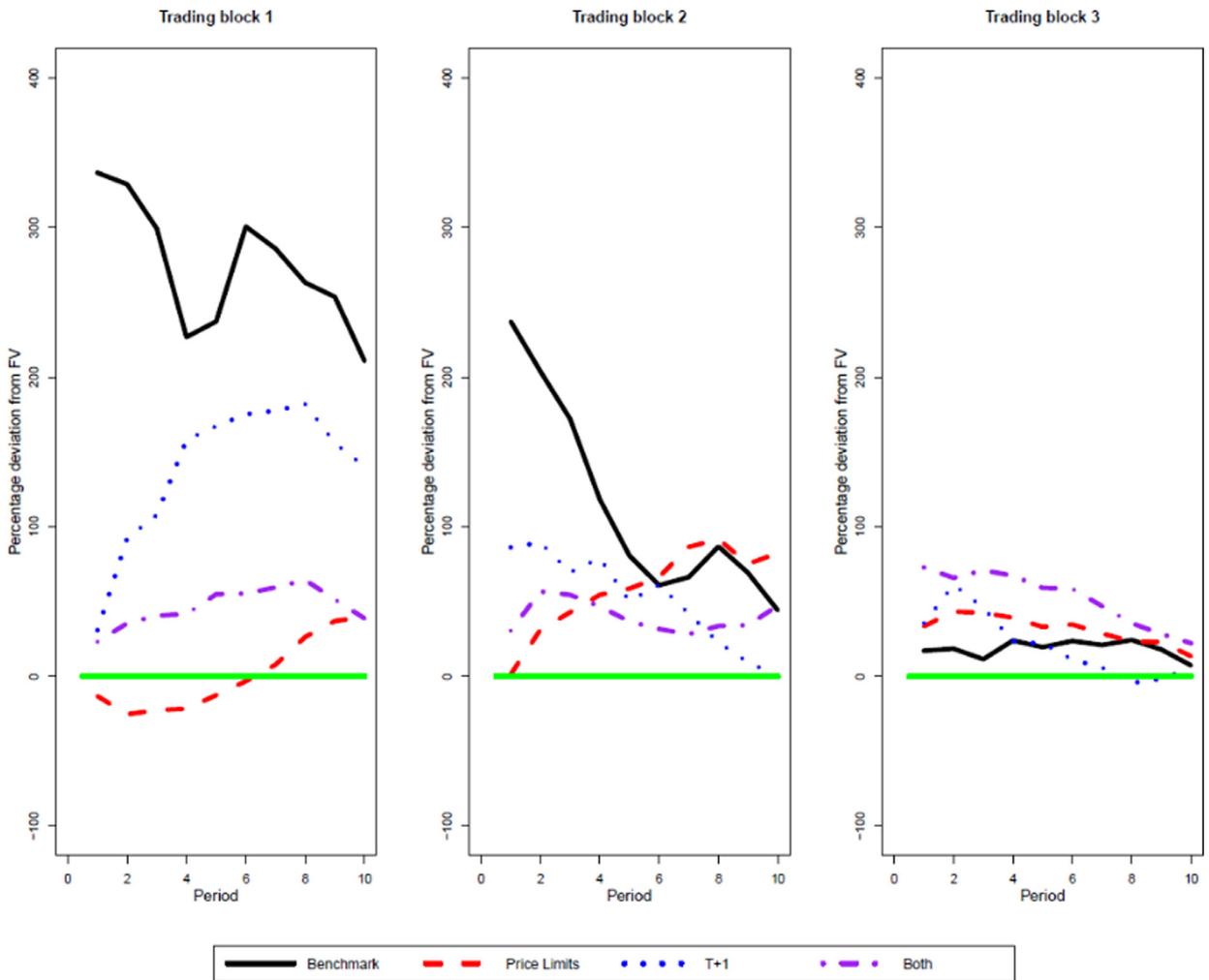


Fig. 1. Price deviation comparison between the benchmark and 3 regulation treatments (flat FVs)
 Notes: This graph shows the median mispricing of 6 markets under the benchmark and 6 markets under each regulation regime with flat FVs.

capture the overall price level and relative mispricing size, respectively. For both of these measures, a higher value indicates a higher price level or mispricing. Here, RD is $RD_{g,r} := \frac{\sum_{t=1}^{10} (q_{g,r,t} - FV_{g,r,t})}{\sum_{t=1}^{10} FV_{g,r,t}}$, where $t \in \{1, 2, 3, \dots, 10\}$, and $q_{g,r,t}$ is the volume-weighted average price of shares in period t in repetition r of Group g , and $FV_{g,r,t}$ is the FV of the share in period t in repetition r of Group g . RAD is $RAD_{g,r} := \frac{\sum_{t=1}^{10} |q_{g,r,t} - FV_{g,r,t}|}{\sum_{t=1}^{10} FV_{g,r,t}}$.

Fig. 1 shows the aggregated price patterns for each market regulation throughout the course of the experiment (the prices for individual markets are reported in the Appendix). The price of the baseline is similar to the result found in the literature: there is a bubble with inexperienced participants and the bubble size reduces when participants gain experience.

With respect to the regulations, we observe that when traders are inexperienced, all three regulation treatments have lower price levels than does the no regulation treatment. Further, we observe that when traders are twice experienced (right panel), price limits and BOTH regulations have higher price levels than does the no regulation treatment (the $t + 1$ treatment crosses the no regulation treatment). In Table 1, the Fisher permutation tests²² show that the bubble size in the price limits treatment is significantly lower than in the no regulation treatment in trading block 1 ($p = 0.02$ for RD and RAD in trading block 1).²³ The tests also show that the bubble is significantly smaller in BOTH treatments compared to the no

²² One potential reason for the regulations to not to significantly reduce the bubble measures with twice experienced participants is that the prices are already close to the FV in the baseline.

²³ To mitigate the loss of statistical power from multiple hypothesis testing (List et al., 2016), we pool all three trading blocks and report the p -value in the right column.

Table 1
Comparing bubble measures between the benchmark and 3 regulation treatments (Flat FV).

	Relative deviation				Relative absolute deviation			
	Trading block 1	Trading block 2	Trading block 3	Trading blocks average	Trading block 1	Trading block 2	Trading block 3	Trading blocks average
Benchmark	3.820 (3.883)	1.746 (1.688)	0.573 (0.788)	2.046 (1.963)	3.824 (3.879)	1.749 (1.686)	0.611 (0.756)	2.061 (1.953)
Price limits	0.251 (0.934)	0.774 (0.813)	0.691 (0.947)	0.572 (0.805)	0.612 (0.752)	0.826 (0.760)	0.794 (0.856)	0.744 (0.734)
<i>T</i> + 1 rule	-0.02** 1.628 (1.711)	-0.10* 0.555 (0.726)	0.84 0.282 (0.532)	-0.06* 0.822 (0.964)	-0.02** 1.779 (1.529)	-0.12 0.756 (0.483)	0.74 0.474 (0.360)	-0.10* 1.003 (0.761)
BOTH	-0.18 1.326 (2.325)	-0.14 0.570 (1.077)	-0.50 0.741 (0.961)	-0.16 0.879 (1.319)	-0.18 1.612 (2.098)	-0.16 0.845 (0.841)	-0.68 0.962 (0.687)	-0.16 1.140 (1.082)
	-0.10*	-0.06**	0.78	-0.12	-0.18	-0.14	0.42	-0.24

Notes: This table compares the size of bubbles between the benchmark and each regulation treatment using two bubble measures under flat FVs. We report the value of the measures in the first row and then its standard deviation in the bracket below and then the *p*-values of the Fisher permutation tests of H_0 : The comparative treatment has the same bubble measure as the benchmark does. Due to dependence between trading blocks in the same market, we take the average of the bubble measures of the three trading blocks in each treatment. Each test compares the 6 averaged observations across treatments. A negative sign on the *p*-value means that the benchmark has a higher bubble measure. * and ** indicate significance at the 10% and 5% levels, respectively.

Table 2
Comparison of bubble measures between benchmark and regulation treatments (Markov FV).

	Relative deviation				Relative absolute deviation			
	Trading block 1	Trading block 2	Trading block 3	Trading blocks average	Trading block 1	Trading block 2	Trading block 3	Trading blocks average
Benchmark	-0.092 (0.669)	0.217 (0.664)	-0.176 (0.366)	-0.017 (0.543)	0.597 (0.236)	0.629 (0.218)	0.301 (0.266)	0.509 (0.129)
Price limits	0.904 (1.836)	1.313 (1.422)	-0.001 (0.317)	0.739 (1.070)	1.291 (1.535)	1.431 (1.279)	0.344 (0.213)	1.022 (0.939)
<i>T</i> + 1 rule	0.24 0.653 (1.688)	0.04** 1.024 (1.305)	-0.26 0.346 (0.615)	0.02** 0.675 (1.193)	0.34 1.054 (1.430)	0.12 1.050 (1.287)	0.66 0.418 (0.571)	0.01** 0.841 (1.088)
BOTH	0.32 0.661 (1.294)	0.08* 1.081 (1.434)	0.96 1.744 (2.781)	0.04** 1.162 (1.138)	0.66 0.995 (1.011)	0.52 1.267 (1.269)	0.70 1.814 (2.785)	0.04** 1.359 (1.042)
	0.24	0.18	0.30	0.01**	0.34	0.30	0.02**	0.02**

Notes: This table compares the size of bubbles between the benchmark and each regulation treatment using two bubble measures under Markov FVs. We report the value of the measures in the first row and then its standard deviation in the bracket below and then the *p*-values of the Fisher permutation tests of H_0 : The comparative treatment has the same bubble measure as the benchmark does. Due to dependence between trading blocks in the same market, we take the average of the bubble measures of the three trading blocks in each treatment. Each test compares the 6 averaged observations across treatments. A negative sign on the *p*-value means that the benchmark has a higher bubble measure. * and ** indicate significance at the 10% and 5% levels, respectively.

regulation treatment in block 1 and 2 ($p = 0.100$ in trading block 1 and $p = 0.06$ in trading block 2 for RD). The *t* + 1 rule always tends to lower RD and RAD, but the effect is statistically insignificant.²⁴

Result 1a: Price limits and BOTH treatments reduce bubbles for inexperienced and once-experienced participants. The *t* + 1 rule qualitatively reduces price level and the size of mispricing, but is statistically insignificant.

4.1.2. Regulations and mispricing under varying FVs (Markov)

We replicate the same analysis for the Markov treatments. Fig. 2 shows the patterns for each regulation throughout the course of the experiment. We observe that when traders are inexperienced, all three regulatory treatments have higher price levels than the control treatment.²⁵ Further, we observe that when traders are twice experienced (right panel), the *t* + 1 and BOTH treatments have higher price levels than the no regulation treatment does (the price limits treatment crosses the no regulation treatment). In Table 2, the Fisher permutation tests show that the bubble size in the regulations treatments is always higher than in the no regulation treatment (i.e., $p > 0$), except for price limits in trading block 3 for RD. Price limits

²⁴ One potential reason for the regulations to not to reduce the bubble measures is that the prices are already close to the FV in the baseline.
²⁵ We lose the first observation in each time series because we use the previous period price to calculate the percentage change in the price. To control for past price movements in the time series, we include two lags in the price change. The errors behave like white noise after adding the lags. As a result of this, we lose two extra periods in our observations. The main results are robust to the choice of lags and estimation methods.

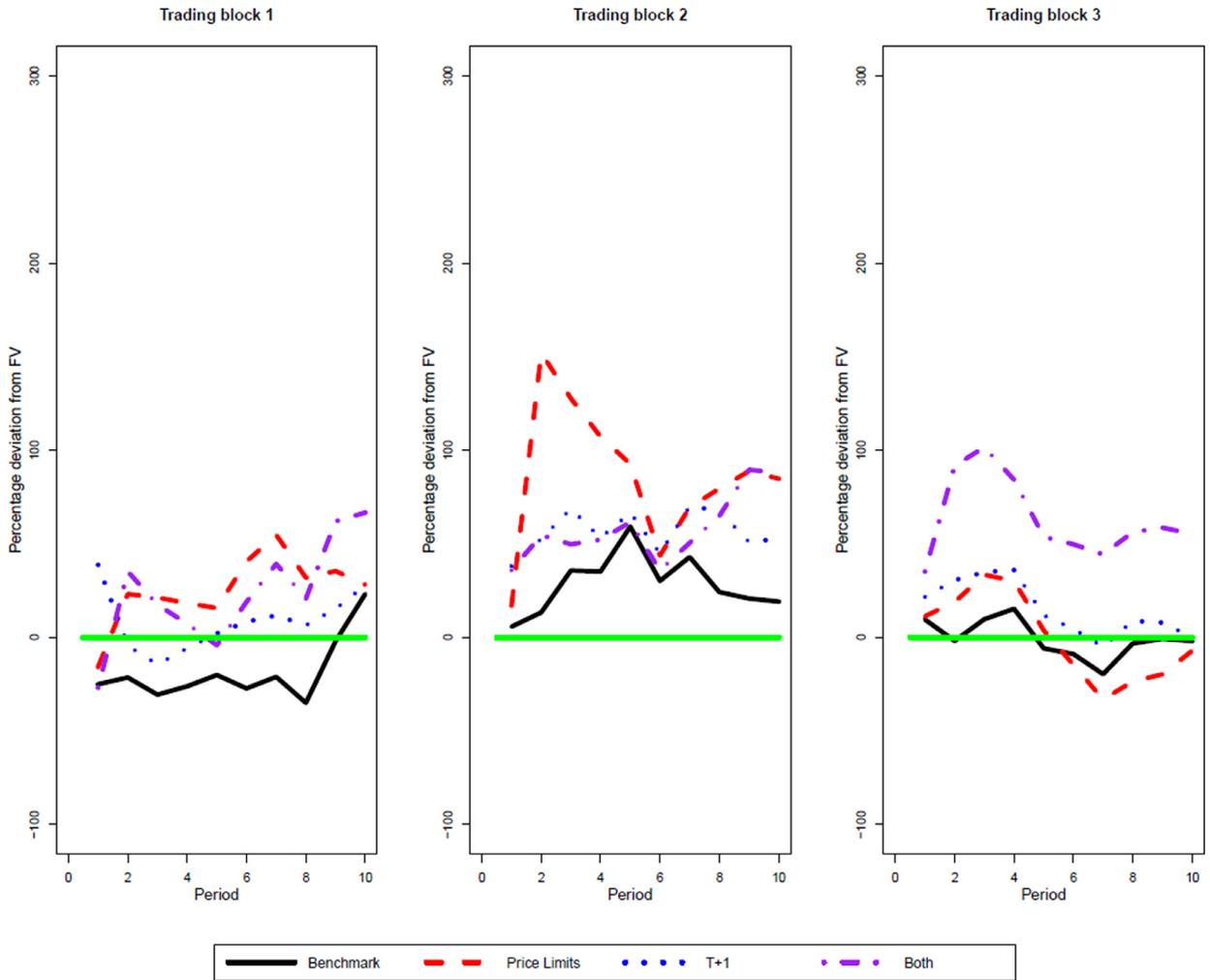


Fig. 2. Price deviation comparison between the benchmark and 3 regulation treatments (Markov FVs)
 Notes: This graph shows the median mispricing of 6 benchmark markets and 6 markets under each regulation regime with Markov FVs.

and the $t + 1$ treatments tend to inflate RD in trading block 2 ($p = 0.04$ for price limits and $p = 0.08$ for $t + 1$). It is worth noting that the two regulations jointly raise RAD significantly in both the economic and statistical sense, even when traders have played the game twice ($p = 0.02$).

Result 1b: We fail to find evidence that any of the three regulatory regimes reduces the two bubble measures (RD and RAD) when a Markov process determines the FV. On the contrary, we find that all of them can significantly inflate the bubble measures.

4.2. Extra price momentum caused by price limit hits

4.2.1. Extra price momentum under fixed FV

We perform regression analysis to test the extra price momentum hypothesis. In particular, we study whether price upper/lower limit hits can affect the price in the coming trading period. We control for price–FV gaps and price movements in the preceding period. The model we estimate is:

$$pc_{g,r,t} = \alpha + \delta_1 upper_{g,r,t-1} + \delta_2 lower_{g,r,t-1} + \beta_1 \cdot deviation_{g,r,t} + \beta_2 \cdot deviation_{g,r,t}^2 + \sum_{t'=1}^2 \gamma_{t'} \cdot pc_{g,r,(t-t')} + \epsilon_{g,r,t} ,$$

where the variables $upper_{g,r,t}$ ($lower_{g,r,t}$), which take the value of 1 when the price hits the price ceiling (floor), and 0 otherwise, capture delayed price discovery. To control for price–FV gaps, our regressions include the variable $deviation_{g,r,t} := \frac{p_{g,r,t-1}^{closing} - FV_{g,r,t}}{FV_{g,r,t}}$, where $p_{g,r,t-1}^{closing}$ is the closing price in the previous trading period and $FV_{g,r,t}$ is the FV in the corresponding period. The dependent variable $pc_{g,r,t}$ is the price percentage change of the average price of the shares in period t of the

Table 3

Extra price momentum caused by binding of price limits.

	Flat		Markov 1		Markov 2	
Price upper limits (δ_1)	0.144*** 0.000	0.117** 0.029	0.140*** 0.008	0.086** 0.036	0.140*** 0.004	0.081* 0.065
Price lower limits (δ_2)	-0.118*** 0.002	-0.120 0.108	-0.100** 0.027	-0.113*** 0.001	-0.084** 0.049	-0.116*** 0.001
Constant	-0.002 0.801	-0.007 0.725	-0.002 0.756	0.038 0.191	-0.010 0.251	0.034 0.472
Controls for deviations from FV	Yes	Yes	Yes	Yes	Yes	Yes
Controls on past price moves	Yes	Yes	Yes	Yes	Yes	Yes
Controls on FV change	N.A.	N.A.	No	No	Yes	Yes
Estimation method	QR	OLS	QR	OLS	QR	OLS

Notes: This table shows whether the price limits reached in the previous period have any impact on the price in the current period (delayed price discovery of price limits). There are 504 observations for each regression and all standard errors are clustered at the group level. Quantile regressions are estimated for the median response (quantile=0.5). We report the p -value under each point estimate. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

repetition r , with the group of subjects g , and $t \geq 4$.²⁶ The terms $pc_{g,r,(t-t')}$ are the lagged percentage changes of the average price, which captures the impact of price changes in the past on the current price change.

We estimate the model with both Quantile Regression (QR) and Ordinary Least Square (OLS) methods²⁷ and find support of the extra price momentum hypothesis. From the left column of Table 3, reaching the upper price limit in the previous period tends to push the price up by 11%–15% and reaching the lower price limit in the previous period leads to a price drop of about 12%.

Result 2a: The behavioral patterns confirm the hypothesis that the binding of price limits magnifies the momentum in the price when the FV is a constant.

4.2.2. Extra price momentum under variable FV

We replicate the analysis for the Markov treatments. We find evidence supporting the extra price momentum hypotheses in the Markov treatments as well. From the middle and right columns of Table 3, we find that reaching the upper price limit in the previous period tends to push the price up by 8%–14% and reaching the lower price limit in the previous period leads to a price drop of 8%–12%. The results are robust after controlling for the price movements in the past and variations in the FV.

Result 2b: The behavioral patterns confirm the extra momentum hypothesis of price limits when the FV is driven by a Markov process.

4.3. Regulations and market information

In our Markov FV treatments, traders receive news about the FV of the shares in every period. The FV of the shares decreases (bad news) or increases (good news) when the dividend decreases or increases, respectively. Thus, our design enables us to answer the question: do regulations help traders react to market news?

To test treatment differences in response to information, we estimate the model

$$pc_{g,r,t} = \alpha_0 + \sum \alpha_i FV_{g,r,t} \cdot 1_{\{\tau_g = i\}} + \epsilon_{g,r,t},$$

where $FV_{g,r,t}$ is the percentage rate of increase in the FV in period t of the repetition r , with the group g , for $t \in \{2, 3, 4, \dots, 10\}$. $1_{\{\tau_g = i\}}$ is a dummy variable indicating the treatment of group g (τ_g) is i for $i \in [\text{benchmark}, \text{price limits}, t + 1, \text{Bot}]$. If all markets trade at the FV, then the percentage change in the price should be the same as the percentage change in the FV; that is α_i would be equal to 1 for $i \in [\text{benchmark}, \text{price limits}, t + 1, \text{Bot}]$ and $\alpha_0 = \epsilon_{g,r,t} = 0$. The two regression models in Table 4 show that traders underreact to news when the regulations are absent, and that neither price limits nor both regulations together significantly improve traders' ability to respond to market news. In the benchmark, price limits and BOTH treatments, the elasticity of the price of shares with respect to the FV is not significantly different from 0. In contrast, for the $t + 1$ rule treatment, the estimate of the elasticity is 0.24–0.32, and is statistically different from zero and from the elasticity in the benchmark treatment in both models estimated by either OLS or QR.

²⁶ Since QR is robust to outliers (see, e.g., Koenker and Hallock, 2001), it is often preferred to deal with the high volatility in experimental asset market data. OLS estimations provide qualitatively similar results, which are reported as well.

²⁷ The role of limited attention and its impact on financial markets has been considered in previous work (see, e.g., Corwin and Coughenour, 2008; Peng and Xiong, 2006).

Table 4
Regulations and response to market news.

	Model 1		Model 2	
Benchmark × news ($\alpha_{benchmark}$)	0.079	0.437	0.097	0.378
	0.235	0.130	0.131	0.166
Price limits × news ($\alpha_{price\ limits}$)	0.071	0.115	0.025	0.056
	0.121	0.333	0.631	0.643
$T + 1 \times$ news (α_{t+1})	0.236***	0.315***	0.246***	0.256***
	0.000	0.000	0.000	0.000
BOTH × news (α_{both})	0.118	0.882	0.028	0.823
	0.186	0.127	0.757	0.152
Constant (α_0)	0.000	0.042	0.023*	0.092**
	0.972	0.134	0.091	0.036
Options	None		Fixed effects on trading blocks	
Method	QR	OLS	QR	OLS

Notes: This table shows the estimation results for whether regulations affect traders' ability to respond to news. There are 648 observations for each regression and all standard errors are clustered at the group level. The fixed effects include dummy variables for trading blocks (2 variables). Quantile regressions are estimated for the median response (quantile=0.5). We report the p -value under each point estimate. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5
Response to market news and binding of price limits.

	Model 1		Model 2	
Price upper limits	-0.506	-1.320***		
	0.340	0.005		
Price lower limits	0.775**	0.871		
	0.041	0.106		
Price upper limits × good news (δ_1)			0.532*	0.401**
Price upper limits × bad news (δ_2)			0.080	0.015
Price lower limits × good news (δ_3)			-2.018***	-2.400***
Price lower limits × bad news (δ_4)			0.000	0.001
Constant			-1.038***	-1.081***
			0.009	0.003
			2.239	0.356
			0.117	0.170
Constant	0.151***	0.402**	0.151***	0.401**
	0.005	0.014	0.005	0.015
Method	QR	OLS	QR	OLS

Notes: This table shows the estimation results for whether the binding of price limits affect traders' ability to respond to news. There are 648 observations for each regression and all standard errors are clustered at the group level. Quantile regressions are estimated for the median response (quantile=0.5). We report the p -value under each point estimate. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The above analysis shows that price limits do not have a significant overall impact on the responsiveness to market news. However, it is possible that, in the event that prices hit upper and lower price limits, traders respond to good and bad news differently. We estimate the following regression model to study this:

$$response_{g,r,t} = \alpha_0 + \delta_1 gupper_{g,r,t} + \delta_2 glower_{g,r,t} + \delta_3 bupper_{g,r,t} + \delta_4 blower_{g,r,t} + \epsilon_{g,r,t},$$

where the dependent variable $response_{g,r,t}$ is defined as (change in price)/(change in FV) in period t of the repetition r , with the group g , for $t \in \{2, 3, 4, \dots, 10\}$. All the explanatory variables are dummy variables. The variable $gupper_{g,r,t}$ takes value 1 if and only if in period t of the repetition r , with the group g the FV increases and the price hits the upper limit in the previous period; the variable $glower_{g,r,t}$ takes value 1 if and only if in period t of the repetition r , with the group g , the FV decreases and the price hits the lower limit in the previous period. The variables $bupper_{g,r,t}$ and $glower_{g,r,t}$ are defined analogously.

Table 5 shows the estimation results. In Model 1, we regress $response$ only on two dummy variables indicating whether the price reached the upper or lower limit in the previous period. In Model 2, we use the interaction of price limit hits with market news as independent variables. From Model 1, we find that when the price hits the upper limit in $t-1$, the reaction of the market price in t is in the opposite direction to the change in the fundamental value. In contrast, when the price hits the lower limit in $t-1$, the reaction of the market price to news is in the same direction as the change in the fundamental value and much stronger than when no limit is hit. In Model 2, we find that when the price hits the upper (lower) limit in $t-1$, the price momentum overrides the impact caused by bad (good) market news and magnifies the reaction to good (bad) market news.

Table 6
Comparison of Gini coefficient between benchmark and regulation treatments (Flat FV).

	Trading block 1	Trading block 2	Trading block 3	Trading blocks average
Baseline	0.327 (0.098)	0.265 (0.107)	0.087 (0.042)	0.226 (0.061)
	–	–	–	–
Price limits	0.139 (0.111) –0.02**	0.161 (0.111) –0.10*	0.115 (0.063) –0.38	0.138 (0.068) –0.04**
T + 1 rule	0.209 (0.159) –0.22	0.205 (0.129) –0.42	0.108 (0.056) 0.38	0.174 (0.101) –0.36
BOTH	0.129 (0.096) –0.02**	0.152 (0.097) –0.04**	0.116 (0.060) 0.42	0.132 (0.070) –0.04**

Notes: This table compares Gini coefficient between the benchmark and each regulation treatment. The numbers in the table are the p -values of the Fisher permutation tests of H_0 : The comparative treatment has the same Gini coefficient as the benchmark does. Each test compares the 6 averaged observations across treatments. A negative sign on the p -value means that the benchmark has a higher Gini coefficient. * and ** indicate significance at the 10% and 5% levels, respectively.

Table 7
Comparison of Gini coefficient between benchmark and regulation treatments (Markov FV).

	Trading block 1	Trading block 2	Trading block 3	Trading blocks average
Baseline	0.183 (0.073)	0.127 (0.082)	0.099 (0.084)	0.136 (0.064)
	–	–	–	–
Price limits	0.171 (0.112) –0.74	0.109 (0.047) –0.64	0.195 (0.119) 0.08*	0.158 (0.064) –0.40
T + 1 rule	0.245 (0.076) 0.14	0.158 (0.072) –0.46	0.135 (0.102) 0.40	0.179 (0.076) 0.24
BOTH	0.181 (0.077) –0.96	0.221 (0.106) 0.06*	0.089 (0.044) –0.86	0.164 (0.047) 0.38

Notes: This table compares Gini coefficient between the benchmark and each regulation treatment. The numbers in the table are the p -values of the Fisher permutation tests of H_0 : The comparative treatment has the same Gini coefficient as the benchmark does. Each test compares the 6 averaged observations across treatments. A negative sign on the p -value means that the benchmark has a higher Gini coefficient. * and ** indicate significance at the 10% and 5% levels, respectively.

Result 3: Traders underreact to market news in the baseline. The $t + 1$ regulation improves reactions to market news. The extra price momentum caused by upper (lower) price limit hits overturns the impact of next period bad (good) market news.

4.4. Wealth distribution and trading volume

In this section we analyze how wealth distribution and trading volume are affected by the regulations we study.

4.4.1. Wealth distribution

Another important aspect of financial market regulation is to prevent severe wealth redistribution. We study how the regulations affect wealth distribution in this section. We consider the Gini coefficient as the measure of inequality, which is defined as

$$Gini_{g,r} = \frac{\sum_{i=1}^n \sum_{j=1}^n |x_{g,r}^i - x_{g,r}^j|}{2n \sum_{i=1}^n x_{g,r}^i},$$

where $x_{g,r}^i$ is the wealth of individual i in group g and trading block r . A higher Gini index indicates greater inequality.

Table 6 provides the average Gini coefficient in each regulation regime and the comparison against the benchmark, when the FV is driven by a flat process. In the benchmark treatment, the Gini coefficient decreases with market experience. We also find that price limits and both regulations together reduce the Gini coefficient, with inexperienced and once-experienced participants. On the other hand, the $t + 1$ regulation's effect on distribution is not statistically significant.

Table 7 reports the Gini coefficient when the FV is driven by a Markov process. As with the flat process, the Gini coefficient decreases when participants gain experience. In the presence of the regulations, we find that price limits tend to

Table 8

Comparison of trading volume between benchmark and regulation treatments (Flat FV).

	Trading block 1	Trading block 2	Trading block 3	Trading blocks average
Baseline	184.940 (137.285)	193.240 (133.935)	229.500 (161.248)	202.560 (142.440)
	–	–	–	–
Price limits	361.650 (150.374) 0.08	388.350 (160.155) 0.15	402.000 (199.531) 0.75	384.000 (156.131) 0.20
$T + 1$ rule	211.400 (110.238) 1.00	166.167 (59.917) 0.75	173.383 (46.788) 0.75	183.650 (60.569) 0.34
BOTH	286.833 (236.082) 0.63	287.750 (192.260) 0.87	261.117 (168.086) 0.63	278.567 (196.297) 0.60

Notes: This table compares trading volumes between the benchmark and each regulation treatment. The numbers in the table are the p -values of the Fisher permutation tests of H_0 : The comparative treatment has the same trading volume as the benchmark does. Each test compares the 6 averaged observations across treatments. A negative sign on the p -value means that the benchmark has a higher volume. * and ** indicate significance at the 10% and 5% levels, respectively.

Table 9

Comparison of trading volumes between benchmark and regulation treatments (Markov FV).

	Trading block 1	Trading block 2	Trading block 3	Trading blocks average
Baseline	240.567 (84.294)	253.617 (96.350)	202.250 (111.683)	232.144 (82.161)
	–	–	–	–
Price limits	270.700 (242.868) 0.42	255.500 (121.937) 0.87	286.267 (137.420) 0.26	270.822 (158.264) 0.87
$T + 1$ rule	288.183 (122.358) 0.42	326.017 (163.393) 0.34	345.633 (196.155) 0.20	319.944 (154.688) 0.20
BOTH	190.633 (145.101) 0.20	186.817 (120.149) 0.15	152.867 (30.391) 0.75	176.772 (94.762) 0.26

Notes: This table compares trading volumes between the benchmark and each regulation treatment. The numbers in the table are the p -values of the Fisher permutation tests of H_0 : The comparative treatment has the same trading value as the benchmark does. Each test compares the 6 averaged observations across treatments. A negative sign on the p -value means that the benchmark has a higher volume. * and ** indicate significance at the 10% and 5% levels, respectively.

increase inequality with twice experienced participants. In the BOTH treatment, the Gini coefficient increases with once experienced participants, while in the $t + 1$ treatment, we do not find evidence of a significant experience effect on inequality for any level of experience.

4.4.2. Trading volume

Another interesting question is whether different regulations have an impact on the volume of trade. For instance, a natural conjecture is that the $t + 1$ rule leads to less trading. Our data, however, does not show that this is the case. We report the trading volume for the markets with flat FV in Table 8. In the baseline, the average trading volume in each period is around 200 shares (12.5% of all available shares). In general, the regulations do not cause significant changes in the volume of trade. As in the markets with flat FV, the trading volumes of the regulation treatments with Markov FV process are similar to the corresponding baseline and are reported in Table 9.

5. Conclusion

In this study, we examine the impact of regulations on multiple dimensions in a novel asset market experiment. We find that regulations abate mispricing, but only if traders are inexperienced and the FV of shares is constant. However, in environments that more closely resemble naturally occurring asset markets, in which FVs vary, these two regulations jointly can significantly increase mispricing even with twice experienced traders.

Besides providing insights on the price levels, our experiments with varying FVs capture cycles and trends that are typically outside of laboratory settings. Thus, they make it possible to rigorously test how regulations affect the price reaction to market news. We provide new evidence showing that traders respond partially to market information and price limits and BOTH regulations are of little help. Finally, our experimental data confirms the extra momentum hypothesis for price limits.

Our findings suggest that the scope to regulate asset markets is limited. Regulations appear only to successfully abate bubbles in an environment when traders are still inexperienced and the FV does not vary. Thus, we may speculate that regulations are a useful temporary tool to avoid mispricing for newly offered shares (IPOs). On the other hand, the regulations in markets with Markov FV appear to be counterproductive.

Our data also suggest that the experimental methodology is an important complement to empirical financial research based on data from real markets. We confirm several behavioral hypotheses in the literature without real-world complications like the evaluation of shares' FV, calibration of market information, and data non-availability.

Our study is just a first attempt to study regulations in complex asset markets with experiments. Caution should be exercised when applying our findings to form the policy recommendations on regulating Chinese stock markets. The lab environment does not capture communication and manipulation in real markets and our dividend structure may also be too abstract. More research is encouraged to test the robustness of our results.

Apart from further studying these two regulations, we envision several avenues for future research. First, it would be interesting to examine regulations in a population of traders with different levels of experience. Second, future research could explore why the Markov FV makes the price pattern different from the flat FV. Third, we believe there is merit in further studying price dynamics and financial hypotheses and go beyond the study of the bubble formation. Fourth, it seems interesting to study why these regulations perform differently under different FV regimes and how they interact. In particular, our results suggest that the $t + 1$ rule may be effective on driving market prices to be more responsive to changes in FV, but this effect seems to be diluted when also price limits are also imposed. A plausible explanation is that traders' attention is captured by price limits; however, future research is needed to properly address this issue.²⁸

Declarations of Competing Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.jebo.2020.07.012](https://doi.org/10.1016/j.jebo.2020.07.012).

Appendix

A.1. More details of the experiment

Here, we provide more details about the implementation and the realization of the dividend series. [Table A1](#) provides

Table A1
Endowments at the beginning of each trading block.

Endowment groups	Shares	Tokens	Number of traders
1	50	5016.67	2
2	150	3583.34	2
3	250	2150	2
4	350	716.67	2

Notes: This table lists the exact endowment of all 8 participants at the beginning of each trading block.

the endowments at the beginning of each trading block; [Table A2](#) report the sample size in each treatment; [Tables A3](#) and [A4](#) summarize the dividend series for flat and Markov treatments. [Fig. A3](#) visualizes the evolution of the FV in Markov treatments. [Figure A4–A11](#) plot the evolution of the prices in each market.

A.2. Experimental instructions (BOTH regulations with Markov FV)

Here, we provide the instructions for the treatments with a Markov dividend process. The instructions for the other treatments are analogous and available upon request.

(1) General instructions

²⁸ The role of limited attention and its impact on financial markets has been considered in previous work (see, e.g., [Corwin and Coughenour, 2008](#); [Peng and Xiong, 2006](#)).

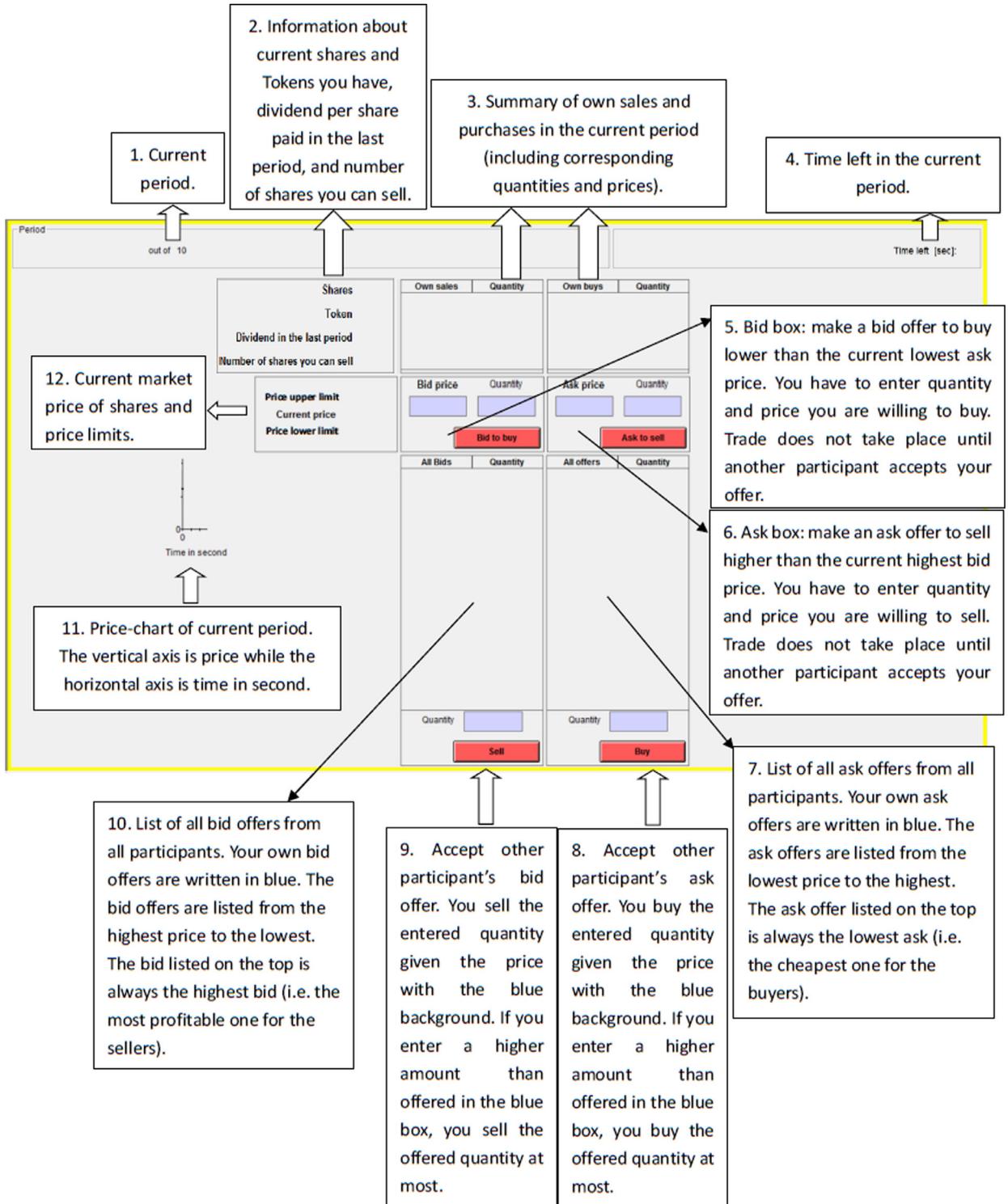


Fig. A1. Instructions for traders: using the experiment software.

Table A2
Treatments and sample size.

	Benchmark	Price limits	T + 1	BOTH
Flat	n = 6	n = 6	n = 6	n = 6
Markov	n = 6	n = 6	n = 6	n = 6

Notes: This table lists our 4×2 experimental design. The first treatment dimension varies the regulations and the second dimension varies the FV processes. Each number of observations represents a group of eight individuals.

Table A3
Realized dividend series for flat treatments.

Trading block	Period									
	1	2	3	4	5	6	7	8	9	10
1	4.27	0	4.27	0.4	4.27	0.4	1.05	0	0.4	1.05
Cash-asset ratio	1.00	1.40	1.54	1.99	2.22	2.74	3.04	3.42	3.76	4.16
2	0	0.4	1.05	0.4	0.4	0	0	4.27	1.05	1.05
Cash-asset ratio	1.00	1.10	1.24	1.44	1.61	1.80	1.97	2.17	2.69	3.03
3	4.27	0.4	0	0.4	1.05	0	4.27	4.27	0	1.05
Cash-asset ratio	1.00	1.40	1.57	1.72	1.92	2.19	2.41	2.95	3.54	3.89

Notes: This table lists our dividend series under flat FVs. All traders in markets with flat FVs observe the same dividend realization. The cash-asset ratio is the ratio of all subjects' cash holdings and the total asset value, i.e., number of shares outstanding multiplied by FV.

Table A4
Realized dividend states for Markov treatments.

Trading block	Period									
	1	2	3	4	5	6	7	8	9	10
1	H	H	H	H	L	L	H	L	L	H
Cash-asset ratio	1.00	1.02	1.09	1.16	1.22	1.63	1.96	1.85	2.42	2.88
2	L	L	L	L	H	L	L	L	L	H
Cash-asset ratio	1.00	1.29	1.56	1.88	2.25	2.12	2.77	3.28	3.87	4.55
3	H	L	L	H	H	H	L	L	L	L
Cash-asset ratio	1.00	1.02	1.37	1.66	1.58	1.65	1.71	2.25	2.68	3.18

Notes: This table lists our dividend states under Markov FVs. All traders in markets with Markov FVs observe the same dividend realization. H and L indicate high and low dividend states, respectively. The cash-asset ratio is the ratio of all subjects' cash holdings and the total asset value, i.e., number of shares outstanding multiplied by FV.

Thanks for participating in this experiment. Please read the instructions carefully. A clear understanding of the instructions will help you make better decisions and thus increase your earnings. After reading the instructions, there will be a five-minute practice round to help you become familiar with the experiment software. The earnings in the practice round do not affect your final payment. After the practice round, there will be some questions to guarantee that everyone understands the experiment. You cannot move on unless you enter the correct answer. The main experiment consists of three sessions, which follow the same instructions. You will be paid for only one randomly chosen session from all three sessions.

The game money in this experiment is expressed in tokens. The exchange rate is 400 tokens = 1 Australian Dollar. Your earnings will be paid to you in private and in cash at the end of the experiment. If you decide to leave early, you will forgo all of your earnings. Prices quoted in the experiment have two decimal places, and range from 0.01 to a maximum of 999.00 tokens.

If you have any questions during the experiment, please raise your hand and one of us will come to you. Please do not ask your questions out loud, attempt to communicate with other participants, or look at other participants' computer screens at any time during the experiment. Please turn your mobile phone to silent mode and place it on the floor.

(2) Asset market environment

In this experiment, each participant can be a buyer and a seller at the same time. The goods participants can buy and sell in the market are called shares. Shares must be traded in whole numbers. The market consists of eight participants including you, who are endowed with tokens and shares. This market will be open for exactly 10 trading periods for each session. In each trading period, the market will be open for 100 s, during which time you may buy and sell shares.

Dividend

After each trading period, each share pays a dividend. The dividend can either increase by 10% or decrease by 5% compared to the dividend in the previous period. We refer to these two dividend states as high or low, respectively, hereafter. For example, if the dividend for each share in the previous period was 1 token, then the dividend paid for each share in this period is either

After each trading period, you will see a summary table like this to summarize essential trading history for you.

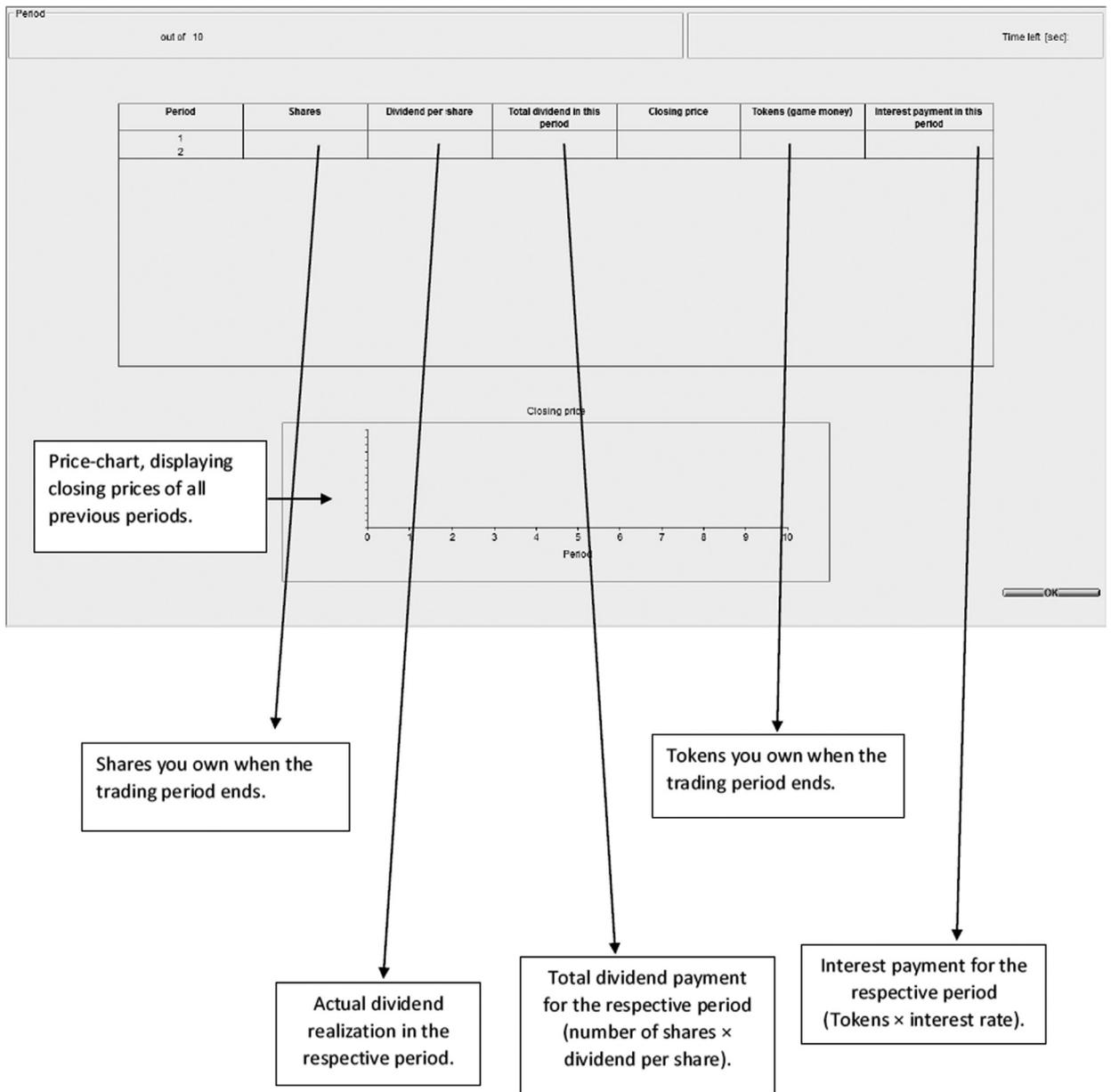


Fig. A2. Instructions for traders: How to read trading history.

$1 \times (1 + 10\%) = 1.1$ token per share, if the dividend state is high in this period, or $1 \times (1 - 5\%) = 0.95$ token per share, if the dividend state is low in this period.

Whether the dividend state is high or low in the current period is related to its state in the previous period. The dividend state in the current period remains in the same state as in the previous period with a 70% chance, and will change from its previous state with a 30% chance. Please see the summary table below.

	High dividend in the current period	Low dividend in the current period
High dividend in the previous period	70%	30%
Low dividend in the previous period	30%	70%

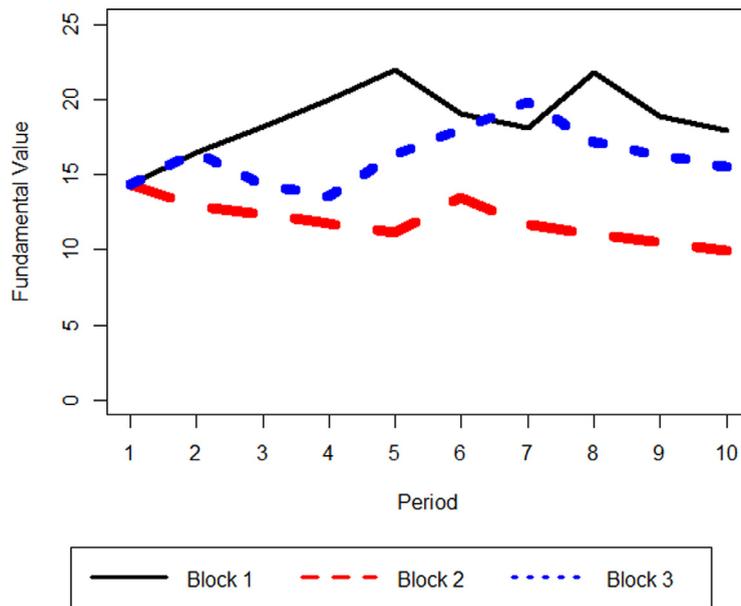


Fig. A3. Realization of Markov FV
Notes: this graph shows the realization of FV of each trading block.

You are informed of the dividend per share in the current period after the current trading period ends. You do not know the dividend in the current period before the current trading period ends.

Redemption (final buy out) value

At the end of period 10, each share pays a dividend for that period (as in previous periods) plus a redemption value. The redemption value is

- $15 \times$ the dividend at period 10, if the dividend state is high in period 10
- $13.67 \times$ the dividend at period 10, if the dividend state is low in period 10.

For example, if the dividend in period 10 is 1 token per share, the redemption value is

- $15 \times 1 = 15$ tokens per share, if the dividend state is high in period 10
- $13.67 \times 1 = 13.67$ tokens per share, if the dividend state is low in period 10.

Interest rate

Tokens that have not been used to purchase shares earn interest at the rate of 10% per period after each trading period ends.

Price limits

Except for trading period 1, price limits apply to all offers. Price limits are the price ceiling and price floor of the share price in a particular trading period. In this experiment, the price ceiling in the current period is the closing price in the previous trading period $\times 1.2$, while the price floor in the current period is the closing price in the previous trading period $\times 0.8$. Prices outside this range are not allowed.

For example, if the price at the end of period 5 is 10 tokens per share, the price ceiling in period 6 is $10 \times 1.2 = 12$ tokens per share, while the price floor in period 6 is $10 \times 0.8 = 8$ tokens per share.

You are informed of the price ceiling and floor in each period.

T + 1 rule

The “ $t + 1$ ” scheme means that you cannot sell the shares purchased in the same trading period – you have to wait until the next trading period or later to do so. For example, if a person has 10 shares at the end of the previous period, then the maximum number of shares he/she can sell in the current period is 10 shares, regardless the number of shares he/she buys in the current period.

You are informed of the number of shares you can sell in each period.

To sum up the market features:

Shares earn dividends after each trading period ends. The dividend in each period can either increase by 10% or decrease by 5% compared to the dividend in the previous period.

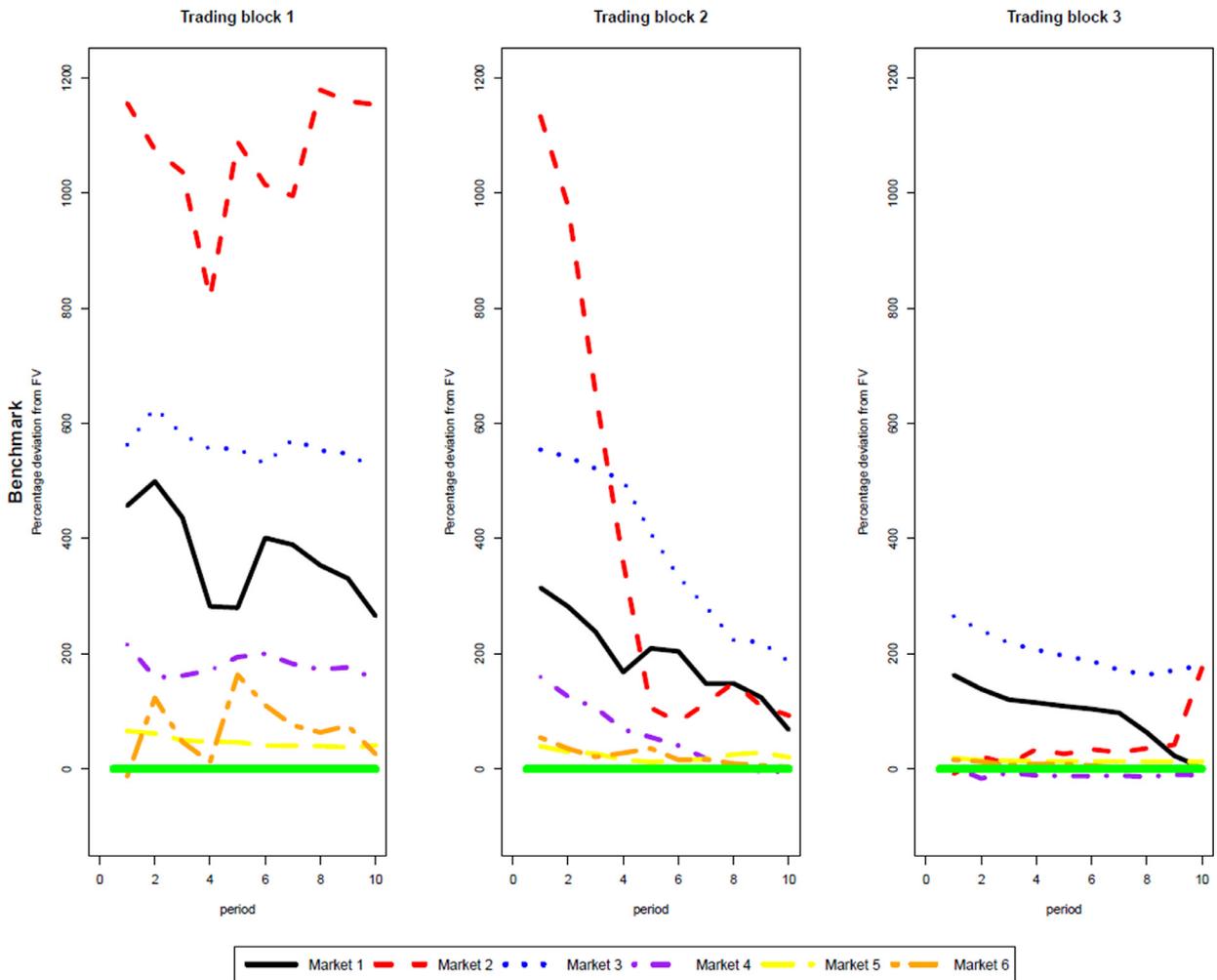


Fig. A4. Mispricing of 6 individual markets without regulations (Flat FVs)

Notes: this graph shows the mispricing of 6 individual markets without regulations under flat FVs.

The dividend state in the current period depends on its state in the previous period. The dividend state in the current period remains the same as in the previous period with a 70% chance, while the dividend state in the current period differs from the previous period with a 30% chance.

At the end of period 10, each share pays a dividend (as in previous periods) plus a redemption value. The redemption value is $15 \times$ the dividend at period 10 if the dividend state is high in period 10; or is $13.67 \times$ the dividend at period 10 if the dividend state is low in period 10.

Tokens that have not been used to purchase shares earn interest at the rate of 10% per period after each trading period ends.

Due to price limits, the price ceiling is the closing price in the previous trading period $\times 1.2$; the price floor is the closing price in the previous trading period $\times 0.8$.

Due to the “ $t + 1$ ” scheme, you cannot sell the shares purchased in the same trading period – you have to wait until the next trading period or later to do so.

(3) Earnings

The amount of tokens you will earn at the end of the experiment is equal to:

- Tokens you receive at the beginning of the experiment
- + Dividends you receive throughout the experiment
- + Interest you receive throughout the experiment

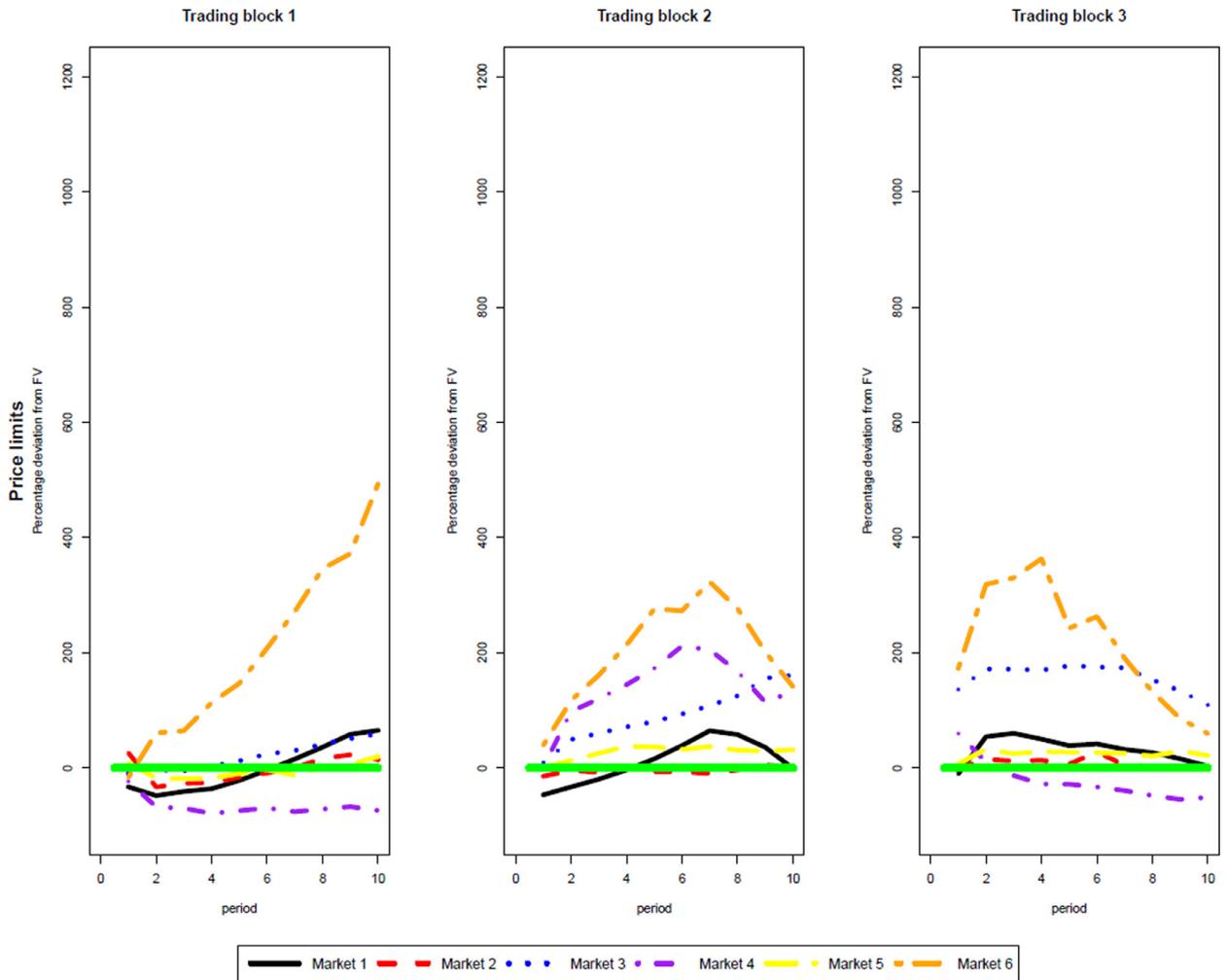


Fig. A5. Mispricing of 6 individual markets with price limits (Flat FVs)

Notes: this graph shows the mispricing of 6 individual markets with price limits under flat FVs.

- + Redemption value of your shares
- + Money received from the sales of shares
- Money spent on purchases of shares

(4) How to use the software

There are two buttons to buy shares: “Buy” and “Bid to buy.” By clicking the “Buy” button, you buy at the current lowest ask price with the quantity equal to the minimum quantity offered and the quantity you entered. By clicking the “Bid to buy” button, you make a bid offer with the price (below the current lowest ask price) and the quantity you entered in the Bid box. By making a bid offer, you indicate that you are only willing to buy at a price less than the current lowest ask price (otherwise, you have to use the “Buy” button), but your bid offer may not be accepted. You do not buy anything if no one accepts your bid offer.

Similarly, there are two buttons to sell shares: “Sell” and “Ask to sell.” By clicking the “Sell” button, you sell at the current highest bid price with the quantity equal to the minimum quantity offered and the quantity you entered. By clicking the “Ask to sell” button, you make an ask offer with the price (above the current highest bid price) and the quantity you entered in the Ask box. By making an ask offer, you indicate that you are only willing to sell at a price higher than the current highest bid (otherwise, you have to use the “Sell” button), but your ask offer may not be accepted. You do not sell anything if no one accepts your ask offer. The entire bid and ask offer cannot be revoked. This means that if you have non-transacted ask/bid offers outstanding, the amount of shares/money you may further use to sell/buy is less than the balance that appears on your screen. Non-transacted offers will be cleared at the end of each trading period. You cannot buy from or sell to yourself. Please turn to page four of the instructions to see the window you will see during trading time.

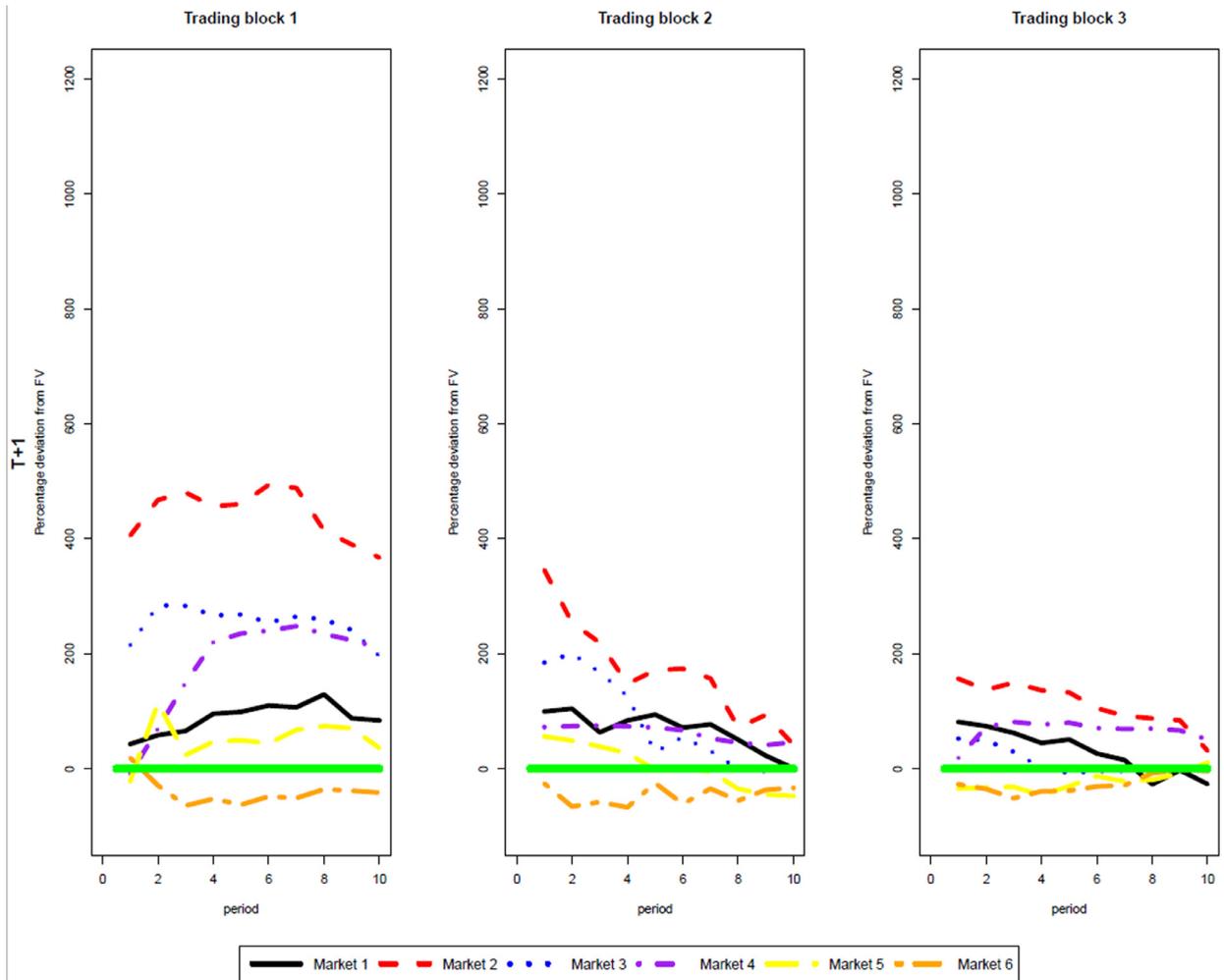


Fig. A6. Mispricing of 6 individual markets with the $t + 1$ rule (Flat FVs)

Notes: This graph shows the mispricing of 6 individual markets with the $t + 1$ rule under flat FVs.

A.3. Quiz questions (BOTH regulations with Markov FV)

Here, we provide the quiz questions for the treatments with a Markov dividend process. The questions for the other treatments are analogous and available upon request. All participants need to answer all questions correctly before the start of each session.

Q1 (multiple choice): If the dividend state was high in the previous period, what is the probability that the dividend is low in the current period?

1="30%"; 2="10%"; 3="70%"; 4="20%"

If the participant provides a wrong answer, then a message "Your answer is incorrect! Please refer to "Dividend" section in the instruction to find the right answer" pops up.

If the participant enters a correct answer, then the software displays "Your answer is correct! As mentioned in the "Dividend" section of the instructions, dividend state in the current period differs from the state in the previous period with 30% chance."

Q2: If the dividend payment for one share was 10 tokens in the previous period, and its state is low in the current period, what is the dividend payment for one share in the current period?

If the participant provides a wrong answer, then a message "Your answer is incorrect! Please refer to "Dividend" section in the instruction to find the right answer" pops up.

If the participant enters a correct answer, then the software displays "Your answer is correct! As mentioned in the "Dividend" section of the instruction, the dividend is $10 \times (1-5\%)=9.5$ if the dividend is low in the current period."

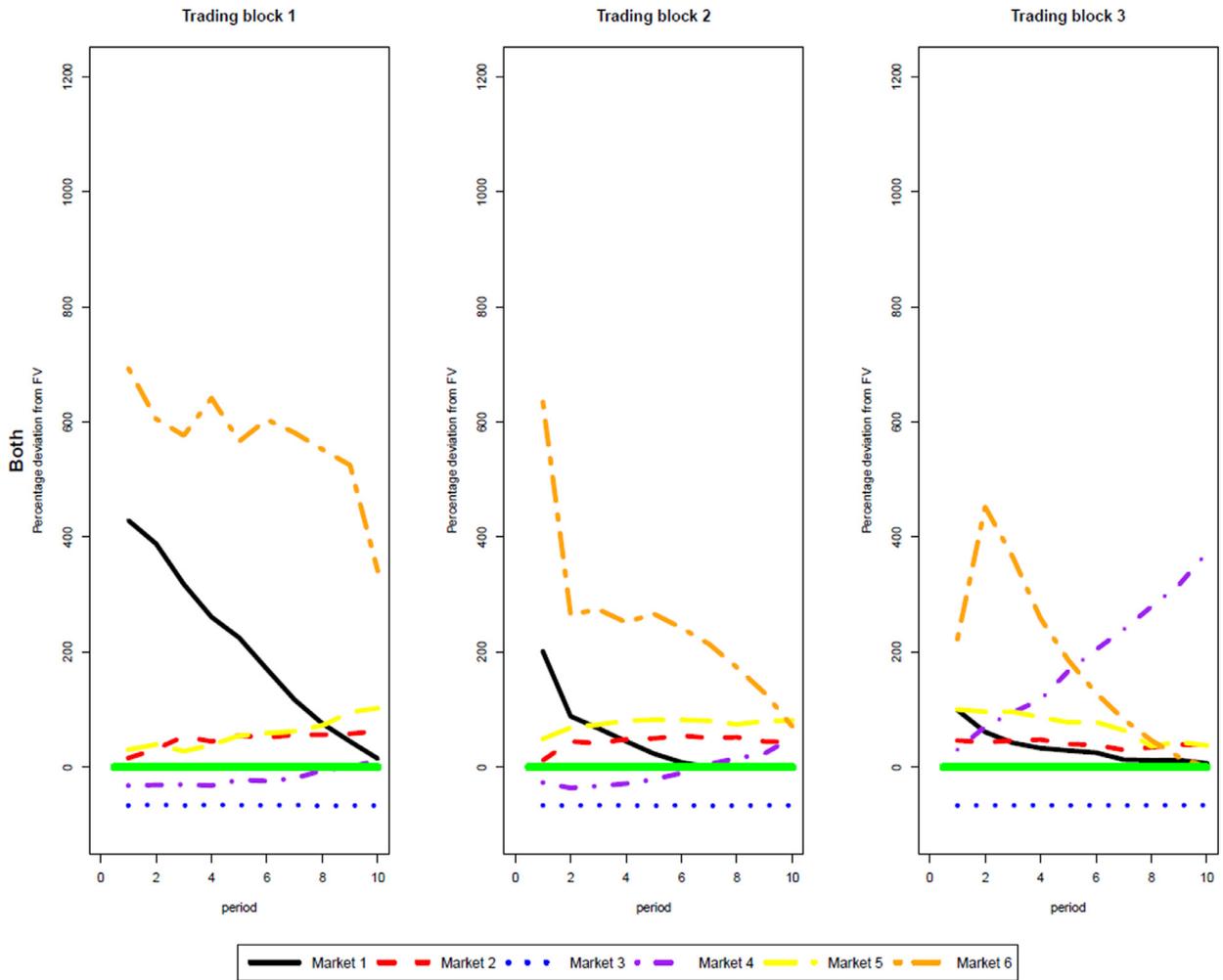


Fig. A7. Mispricing of 6 individual markets with both price limits and the $t + 1$ rule (Flat FVs)
 Notes: This graph shows the mispricing of 6 individual markets with both price limits and the $t + 1$ rule under flat FVs.

Q3: If the dividend state in period 10 is low and the dividend is 1 token per share, what is the redemption value for a share after period 10?

If the participant provides a wrong answer, then a message “Your answer is incorrect! Please refer to “Redemption value” section in the instruction to find the right answer” pops up.

If the participant enters a correct answer, then the software displays “Your answer is correct! As mentioned in “Redemption value” part of the instruction, one share will have a redemption value equals $13.67 \times$ dividend in the period if the dividend is low.”

Q4: If you entered 3 units and click “Buy” to buy from an ask offer with price 10 Tokens per share and quantity 1 unit, how much money will you pay for this action?

If the participant provides a wrong answer, then a message “Your answer is incorrect! Please refer to “Redemption value” section in the instruction to find the right answer” pops up.

If the participant enters a correct answer, then the software displays “Your answer is correct! As mentioned in box 8 on page 4 of the instructions, if you enter a higher amount than offered, you buy the offered quantity at most. So you only buy 1 unit at price 10 Tokens per share.”

Q5 (multiple choice): Can you make a bid offer with a price higher than the current lowest ask offer?
 1=“Yes”; 2=“No”

If the participant provides a wrong answer, then a message “Your answer is incorrect! Please refer to box 5 on page four of the instruction to find the right answer” pops up.

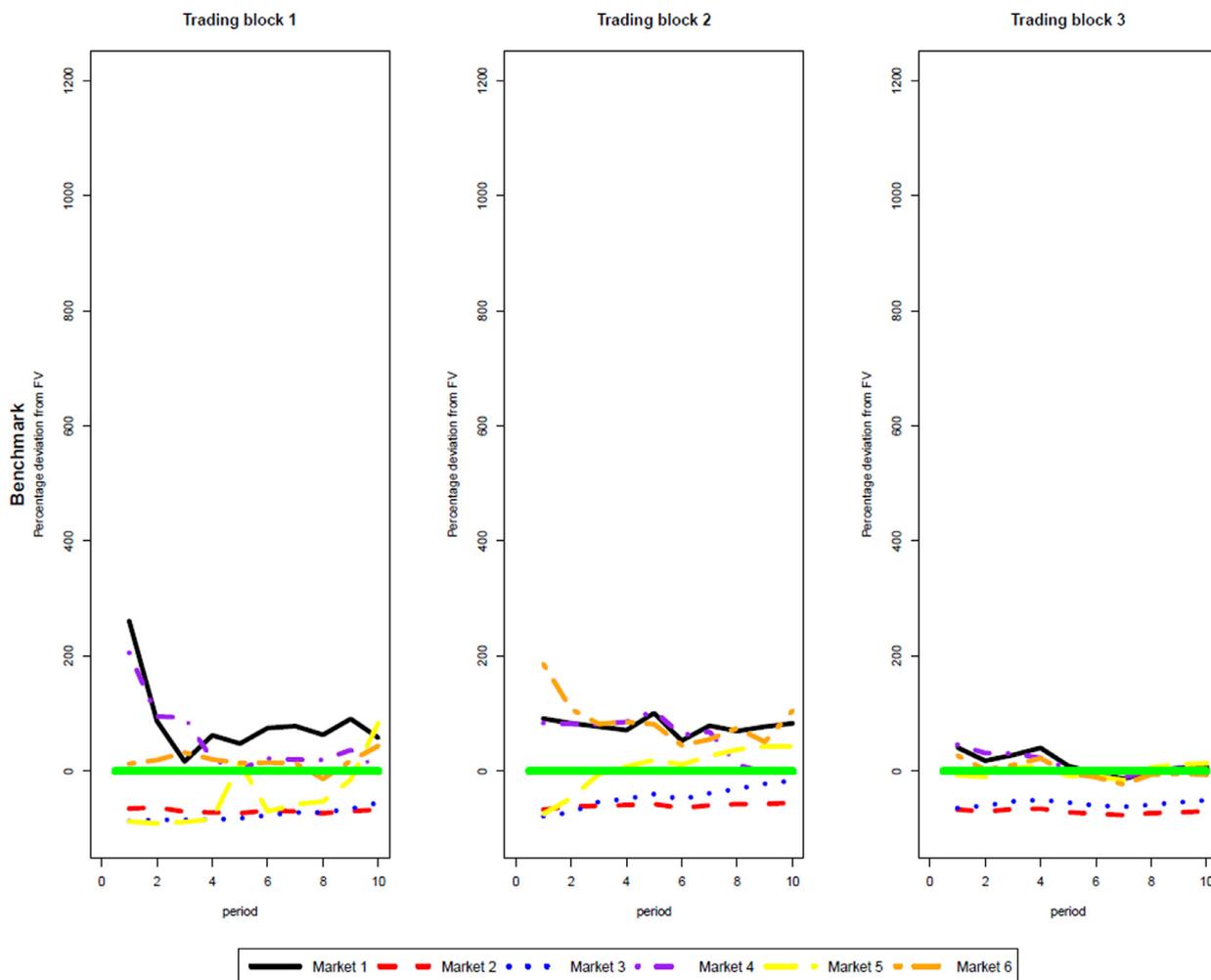


Fig. A8. Mispricing of 6 individual markets without regulations (Markov FVs)

Notes: This graph shows the mispricing of 6 individual markets with no regulations under Markov FVs.

If the participant enters a correct answer, then the software displays “Your answer is correct! You can simply accept the lowest ask offer!”

Q6: If the closing price in the previous period was 10 tokens per share, what is the highest price a share can be sold/bought in the current period?

If the participant provides a wrong answer, then a message “Your answer is incorrect! Please refer to “Price Limits” part of the instruction to find the right answer” pops up.

If the participant enters a correct answer, then the software displays “Your answer is correct! As per “price limits” trading rule, the price range in the current period is the closing price in the previous period $\times (1 \pm 20\%)$, so the highest price is 12 tokens per share.”

Q7: If you have 5 shares at the end of the previous period and you have bought 5 shares during the current period (i.e., now you have 10 shares), how many shares can you sell in the current period?

If the participant provides a wrong answer, then a message “Your answer is incorrect! Please refer to “T + 1” to find the right answer” pops up.

If the participant enters a correct answer, then the software displays “Your answer is correct! As per “T + 1” trading rule, you cannot sell the shares purchased in the same trading period.”

A.4. Fundamental value for Markov process

We follow [Mehra and Prescott \(1985\)](#) to calculate the fundamental value for the Markov process. Let $\lambda_t \in \{\lambda_1, \lambda_2\}$ be 1 plus the dividend growth rate in period t , where λ_1 is 1 plus the dividend growth rate when the state is high ($1 + 10\% = 1.1$

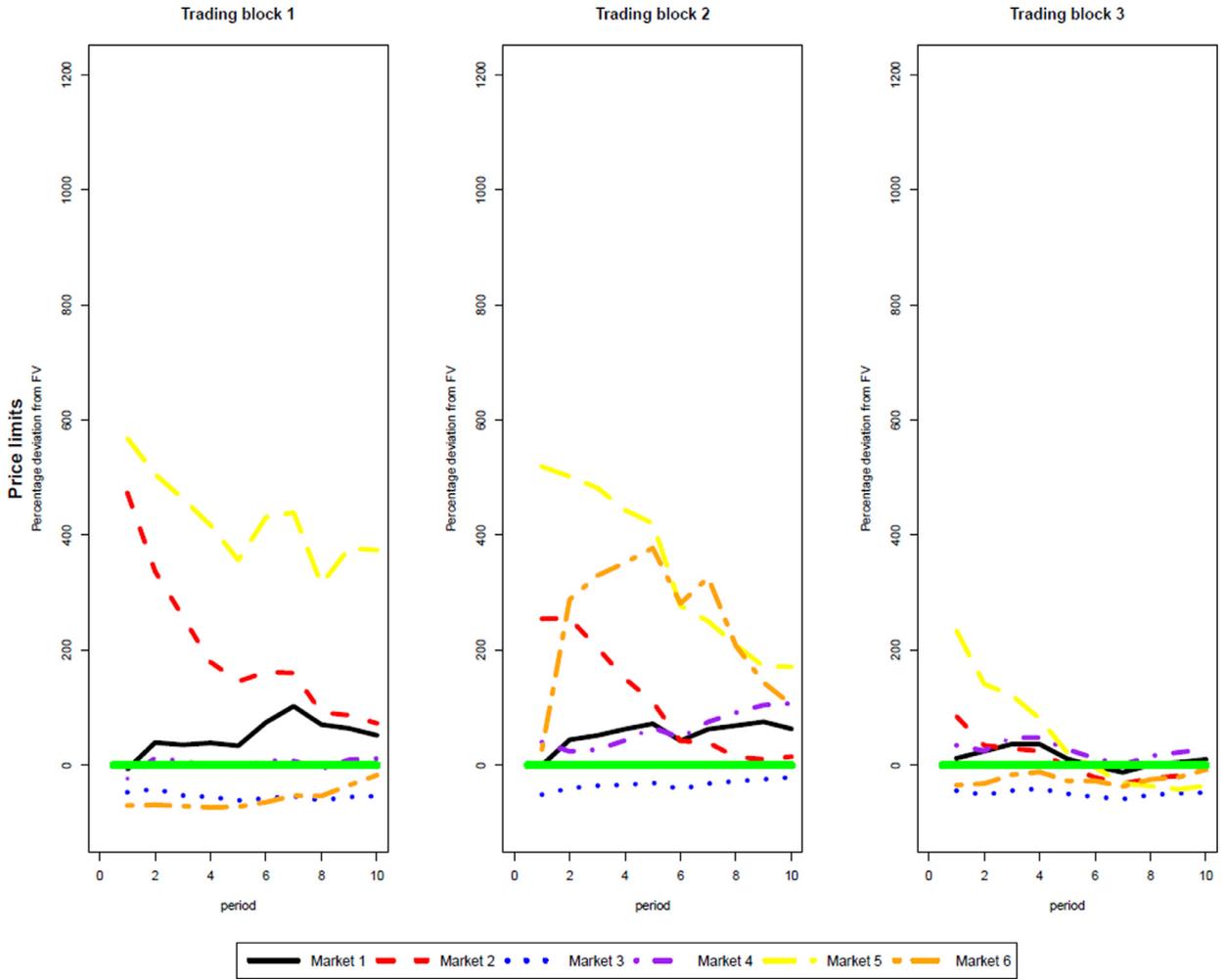


Fig. A9. Mispricing of 6 individual markets with price limits (Markov FVs)
 Notes: This graph shows the mispricing of 6 individual markets with price limits under Markov FVs.

in our case), and λ_2 is 1 plus the dividend growth rate when the state is low ($1-5\%=0.95$ in our case). Let d_t be the dividend per share in period t . Under the assumption that the growth rate of the dividend series follows a Markov chain, we can write

$$d_s = d_t \cdot \prod_{i=t+1}^{t+s} \lambda_i, \text{ so the fundamental value in period } t \text{ is homogeneous of degree one in } d_t. \text{ Thus, we can write:}$$

Eq. (1)

$$FV_t(d_t, i) = w_i d_t,$$

where $FV_t(d_t, i)$ is the fundamental value in period t , given the dividend payment and dividend state in that period. w_i is the price-dividend ratio associated with the dividend state i , where $i = 1$ means the dividend state is high and $i = 2$ means the dividend is low.

From the risk neutral and no arbitrage assumptions, we can also write the fundamental price of shares in period t by discounting the expected dividend payment and the fundamental price in period $t + 1$:

Eq. (2)

$$FV_t(d_t, i) = \beta \sum_{j=1}^2 \phi_{ij} [FV_{t+1}(\lambda_j d_t, j) + \lambda_j d_t],$$

where ϕ_{ij} is the probability that the dividend state goes from i to j , β is the discount factor $\beta = \frac{1}{1+r}$, and r is the interest rate. Since the fundamental value only depends on the dividend payment d and the dividend state i , we can ignore the time subscripts in Eqs. (1) and (2). Thus, we have

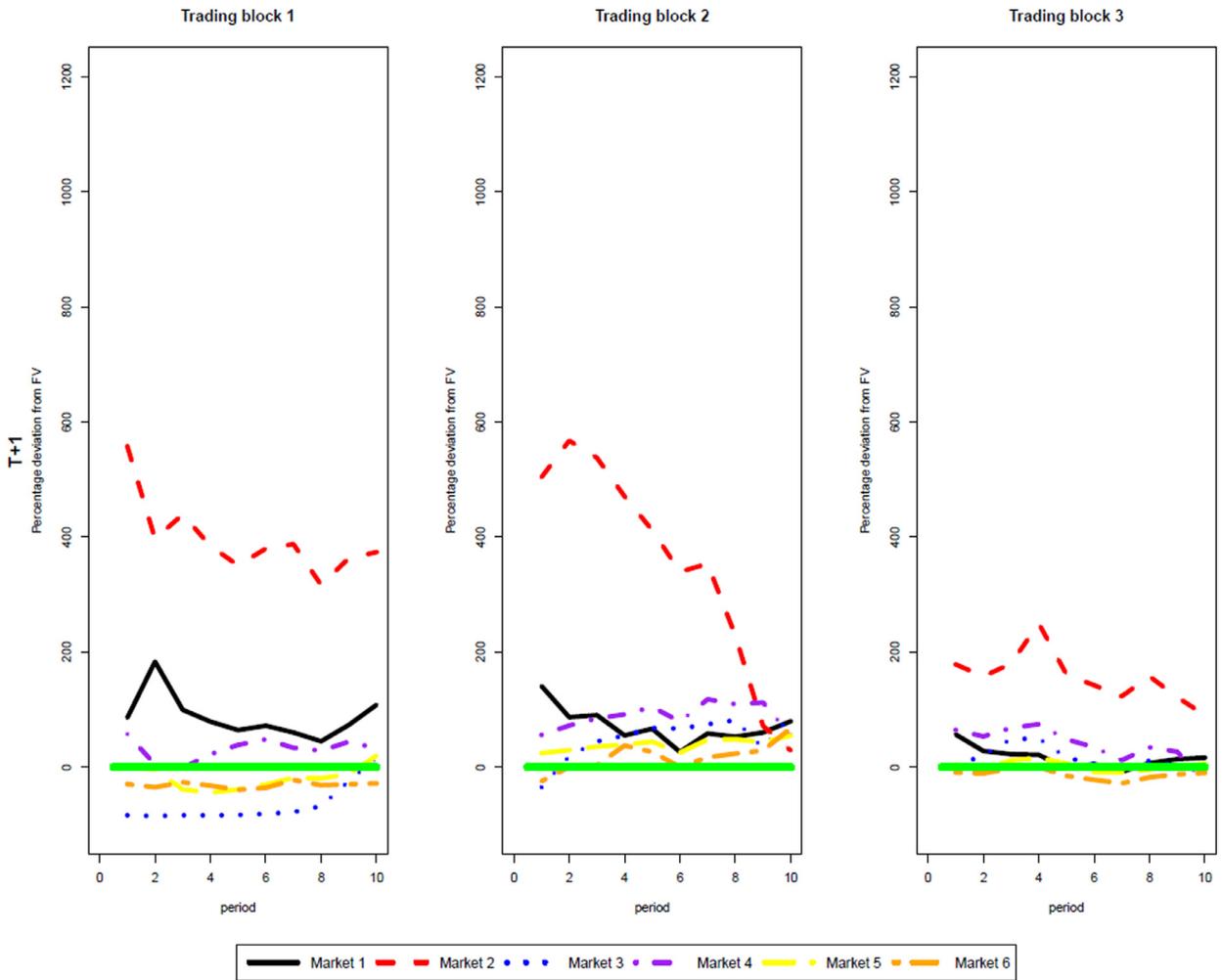


Fig. A10. Mispricing of 6 individual markets with the $t + 1$ rule (Markov FVs)
 Notes: This graph shows the mispricing of 6 individual markets with the $t + 1$ rule under Markov FVs.

Eq. (3)

$$FV(d, i) = w_t d,$$

Eq. (4)

$$FV(d, i) = \beta \sum_{j=1}^2 \phi_{ij} [FV(\lambda_j d, j) + \lambda_j d].$$

We then substitute $FV(\cdot)$ from Eq. (4) in Eq. (3) and get
 Eq. (5)

$$w_t d = \beta \sum_{j=1}^2 \phi_{ij} \lambda_j d [w_j + 1].$$

In our experiment, the discount factor is $\beta = \frac{10}{11}$ and the transition probability of the Markov chain is $\phi_{11} = \phi_{22} = 0.7$ and $\phi_{12} = \phi_{21} = 0.3$. We substitute these numbers into Eq. (5) and solve for w_1 and w_2 :

$$\begin{cases} w_1 = 15 \\ w_2 = \frac{41}{3} \end{cases}.$$

Thus,

$$FV_t(d_t, i) = \begin{cases} 15 \times d_t, & \text{if } i = 1 \\ \frac{41}{3} \times d_t, & \text{if } i = 2 \end{cases}.$$

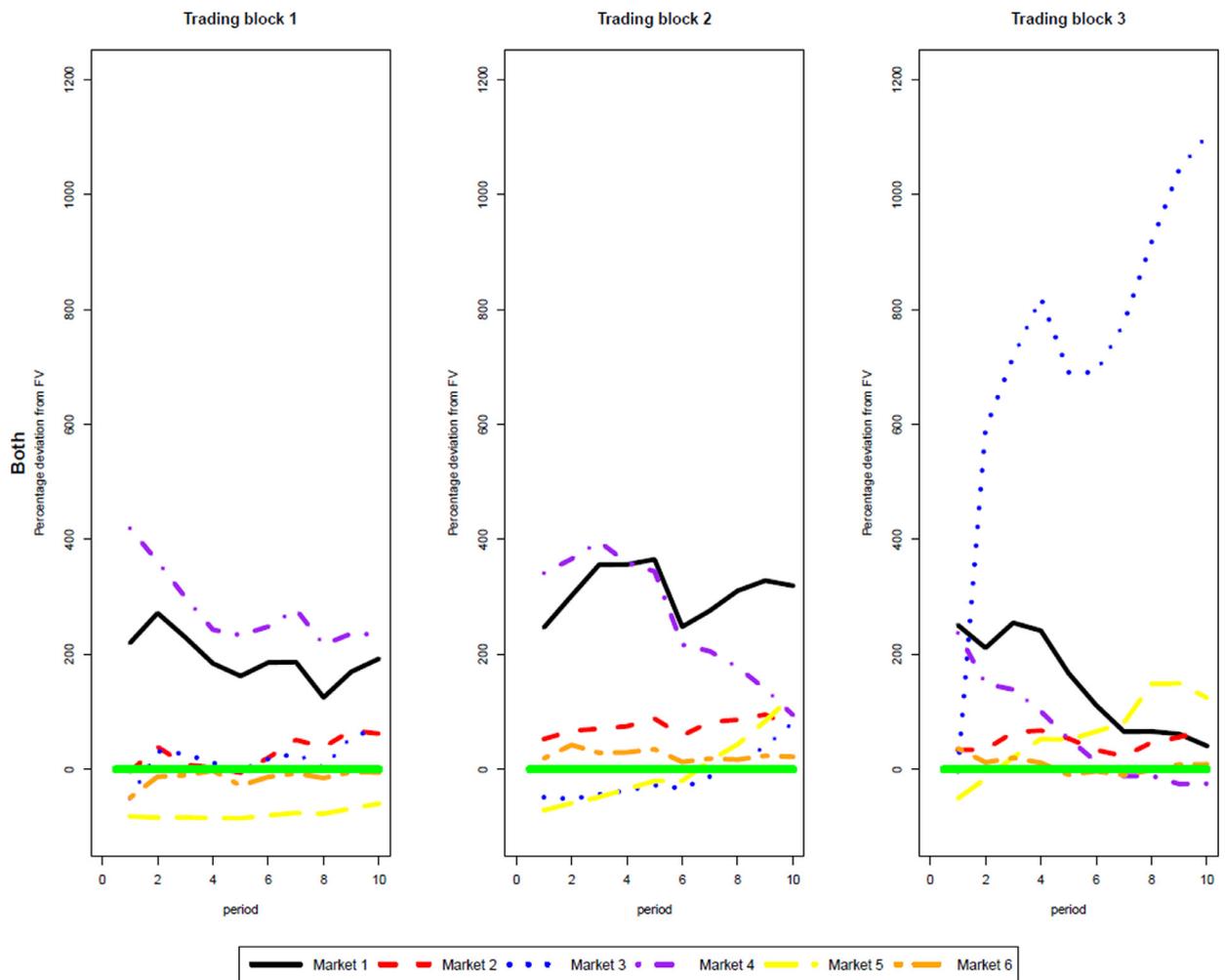


Fig. A11. Mispricing of 6 individual markets with both price limits and the $t + 1$ rule (Markov FVs)

Notes: This graph shows the mispricing of 6 individual markets with both price limits and the $t + 1$ rule under Markov FVs.

A.5. Price patterns in individual markets

Here, we provide more information regarding to the mispricing in each individual market.

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