Regulating Bubbles Away?
Experiment-Based Evidence of Price Limits and Trading Restrictions in 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 abate bubbles when traders are inexperienced, but inhibit price adjustments when traders gain experience. Under a Markov-process FV, these regulations always increase mispricing. Traders underreact to market news when the FV increases and do not react when the FV decreases. We find evidence of momentum trading and the delayed price discovery hypothesis of price limits. These findings emphasize stress-testing asset market interventions and suggest that price limits and trading restrictions do more harm than good.

Keywords: Asset market experiment, price limits, the t+1 rule, fundamental values

JEL Codes: C92, D14, D81, D84, G01, G11, J16

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1. Introduction

Asset market crashes have devastating consequences for society. They not only damage economic welfare by decreasing productivity (Miao & Wang 2012) and increasing unemployment (Miao, Wang & Xu 2016), but also adversely affect health and psychological wellbeing (Chen et al. 2016; Engelberg & Parsons 2016; Lin, Chen & Liu 2014; McInerney, Mellor & Nicholas 2013). Governments struggle with whether and to what extent they should intervene and experts are skeptical about asset market regulations (Gorton & Metrick 2013; Hanson, Kashyap & Stein 2011; Masciandaro & Passarelli 2013). While there is little disagreement about the high cost of asset market crashes, market authorities are indecisive about regulations to prevent the formation of bubbles and reduce market volatility.¹

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 common in other asset markets in the U.S. and elsewhere, determines a price ceiling and floor for a share on a particular trading day. The price limits for A-shares on the Shanghai and Shenzhen Stock Exchange are ±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.² 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 & Rhee 1997), and have magnet effects (Cho et al. 2003; Wang, Wu & Wang 2015). Likewise, there are arguments

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¹ 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.

against the t+1 rule (Gneezy, Kapteyn & Potters 2003; Thaler et al. 1997) and concerns that these two regulations cause A-share market bubbles and anomalies. 

In this study, we examine how price limits and same-day trading restrictions function in a set of asset market experiments. Building upon Smith, Suchanek, and Williams’ (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. We stress test the behavior in the different trading groups by having them go through three trading blocks to collect experience. Importantly, we study these different trading groups in both a simplified environment with constant FVs and another environment in which the FV varies by a Markov process.

Studying a stochastic Markov value process has several advantages. First, it mirrors typical financial market data, which is characterized by serial correlations and long-run growth (Lo & MacKinlay 1988; Jegadeesh 1990; Mehra & Prescott 1985; Moskowitz & Grinblatt 1999). Second, it enables us to study reactions to new market information that affects an asset’s FV (Braun, Nelson & Sunier 1995; Epstein & Schneider 2008; Veronesi 1999). Lastly, the Markov process makes it harder to calculate the market FV, which mimics the fact that market fundamentals in real asset markets are difficult to estimate.

This paper provides several new insights. First, we find that the scope of regulations to reduce bubbles is quite limited. Regulations successfully prevent bubbles only when traders are inexperienced and the assets have constant FVs. Once traders gain experience in this simplified environment, there is no discernable difference in mispricing. Importantly, in

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3 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 on A-share markets always hits the upper price limit in the first a few trading days, and then shows a bubbly pattern afterwards. Additionally, there is a huge price gap for firms cross-listed in both Shanghai and Hong Kong the share price for the same firm is much higher in Shanghai (Fernald & Rogers 2002), but Hong Kong does not have these two regulations.
the perhaps more realistic environment under FVs determined through a stochastic value process, regulations cause more mispricing than when there are no regulations.

Beyond evaluating two popular market regulations, we provide novel evidence of how traders respond to market information. We find that traders underreact to news and do not account for bad news. Regulations are of little help in this regard. Only the t+1 rule leads traders to consider more market news. Finally, this study provides new evidence corroborating the momentum trading hypothesis (Caginalp, Porter & Smith 2000; Hong & Stein 1999; Jegadeesh & Titman 1993) and the delayed price discovery hypothesis (Chen 1993; Fama 1988; Kim & Rhee 1997). In particular, we observe that traders overreact when stocks hit price limits; that is, future stock prices strongly increase (decrease) after an upper (lower) price limit comes into effect.

Our study addresses different strands of the literature on finance and economics. It is closely linked to the experimental literature on asset market bubbles (Ball & Holt 1998; Bostian, Goeree & Holt 2005; Dufwenberg, Lindqvist & Moore 2005; Eckel & Füllbrunn 2015; Haruvy, Lahav & Noussair 2007; Hussam, Porter & Smith 2008; Lei, Noussair & Plott 2001; Noussair & Powell 2010; Smith, Suchanek & Williams 1988) and experiments testing market regulations. For example, Cipriani, Fostel, and Houser (2018) find that the ability to serve as a collateral makes an asset trade at a higher price. Fischbacher, Hens & Zeisberger 2013; Haruvy & Noussair 2006; King et al. 1993 suggest that short-selling, margin-buying, and monetary policy do not eliminate bubbles in experimental asset markets. Our study departs from this existing experimental research in several important ways. In particular, besides pioneering the experimental investigation of two important Chinese market regulations, we are also the first to study pricing and bubbles under a stochastic FV process.

Our study is also related to non-experimental research on the effectiveness of price limits, which reports positive impacts such as decreasing volatility (Brennan 1986; Chowdhry & Nanda 1998; Deb, Kalev & Marisetty 2010; Kim & Park 2010, etc.) and negative impacts such as delaying price discovery (Chen 1993; Fama 1988; Kim & Rhee 1997; King et al. 1993).4 Further, our exploration of the momentum trading hypothesis and traders’ reactions to

4 King et al. (1993) also study price limits in experimental asset markets. However, their design and findings are limited in several important ways. First, because they use a decreasing FV, their design always leads to an
market information is related to a number of empirical studies analyzing existing market data (Hameed & Kusnadi 2002; Hong & Stein 1999; Wu 2011) that also show that prices exhibit momentum (Bondt & Thaler 1985; Braun, Nelson & Sunier 1995; Engle & Ng 1993).

2. Experiment Design
Before beginning 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. 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,\(^5\) who stay in the same group throughout the experiment. To test the robustness of bubbles and following other studies (Hussam, Porter & Smith 2008; King et al. 1993; Van Boening, Williams & LaMaster 1993), our experiment contained repetitions. More precisely, traders took part in three trading blocks of the asset market experiment and each block consisted of ten trading periods.\(^6\) At the end, we chose one trading block at random for payment.

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\(^5\) A trading group of eight is common, and many recent studies use trading groups with seven to ten individuals (e.g., Haruvy, Lahav & Noussair 2007; Haruvy & Noussair 2006; Kirchler, Huber & Stöckl 2012; Lei, Noussair & Plott 2001; Stöckl, Huber & Kirchler 2015).

\(^6\) Kirchler, Huber, and Stöckl (2012) also have 10 trading periods within each round.
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 (Table 1). In each of the ten trading periods in a given trading block, traders have 100 seconds 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. Outstanding offers are cleared and the corresponding frozen assets are released at the end of each period. The program is set up such that purchases occur at the minimum ask price and sales at the maximum bid price. There is only one type of share and there is no tax, brokerage, short-selling, or margin buying. We provide the experiment instructions and describe the treatments in the Appendix.

2.2 Treatments
Table 2 illustrates our $4 \times 2$ experiment 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.

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7 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 regulations (price limits, t+1, and both) 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. 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 regulations (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)\(^8\) and stochastic (Markov) FV processes.

\(^8\) We use the flat FV process (Bostian, Goeree & Holt 2005) instead of the traditional SSW's monotonic decreasing FV process for at least two reasons: a decreasing FV process may confuse participants (Kirchler, Huber & Stöckl 2012) and a decreasing FV process makes prices mechanically more likely to hit the lower price limit if the price tracks the FV.
**Flat value process**

Table 3 provides an overview of the flat value process, which uses the following parameters. 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. This parametric setting makes the FV close to the arithmetic average price in the A-share markets at the time of writing. Further, it allows to us to generate a comparable Markov process (i.e., the same expected rate of return and variance) with a relatively simple parametric setting. As Table 3 also shows, the dividend series are drawn before the experiment by four cards, 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.

**Markov**

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 & MacKinlay

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9 Calculated as $\text{var}(\text{rate of return}) = \frac{1}{4} \left( \left( \frac{0}{14.33} - 0.1 \right)^2 + \left( \frac{0.4}{14.33} - 0.1 \right)^2 + \left( \frac{1.05}{14.33} - 0.1 \right)^2 + \left( \frac{4.27}{14.33} - 0.1 \right)^2 \right) = 0.0138$.

10 On Jan-5-2015, the first trading day of 2015, the arithmetic average price on the Shenzhen Stock Exchange was 13.45, and on Jan-4-2016, the first trading day of 2016, it was 16.96.
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 period, 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 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%;\textsuperscript{11} 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%.

\textbf{INSERT TABLE 4 ABOUT HERE}

The correlation between 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 order of the dividend sequences is the same across all treatments and sessions.

\textbf{3. Hypotheses}

Hypothesis 1 (\textit{regulations & bubbles}): \textit{Price limits and the \(t+1\) regulation decrease the bubble size, separately or jointly.}

Our first hypothesis is motivated by the China Securities Regulatory Commission's claim that the “two regulations individually improve price discovery and decrease the bubble size and they work together with synergy.”

Hypothesis 2 (\textit{momentum trading & price discovery}): \textit{There is momentum trading behavior and delayed price discovery.}

The second hypothesis is based on theoretical and non-experimental evidence (Kim, Yagüe & Yang 2008; Kim & Yang 2009) for momentum trading behavior (i.e., that price movements in the past affect price movements in the future, even if past price movements do not affect the market fundamentals) (see, e.g., Hong & Stein 1999; Jegadeesh & Titman 2001; Hameed & Kusnadi 2002; Wu 2011). The delayed price discovery hypothesis (Fama 1988) claims that 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 passing the lower price limit).

\textsuperscript{11}If the state is high in period \(t\) and \(t+1\), and the dividend is \(d_t\) in period \(t\), then \(FV_t = d_t \times w_t = d_t \times 15\) and \(FV_{t+1} = d_{t+1} \times w_{t+1} = (1.1 \times d_t) \times 15 = (1 + 10\%) \times FV_t\). Thus, the FV increases by 10% in this case. The calculations are analogous in other cases.
Hypothesis 3 (reaction to market information): Traders respond to market information – prices increase when the FV increases and decrease when the FV decreases in the Markov treatments.

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.

4. Experiment findings
Our experiment included 384 participants (traders) and was programmed using 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 bubbles

4.1.1 Regulations and bubbles under fixed FVs
Figure 1 and Table 5 present the first look at the price levels with (purple dashed-dotted line) or without (black straight line) regulations. We plot the median price percentage deviation\(^{12}\) for the 6 independent control groups (no regulation) and 18 treatment groups (we pool the three regulation treatments) for all periods in each trading block. At the start of the experiment, when traders still lack experience (first trading block, left panel), prices are at 274% of the FV in the absence of regulations – a finding consistent with previous evidence (see, e.g., Holt 2007). In contrast, in the presence of regulations, prices are much lower.

\(^{12}\) Price percentage deviation\(_{g,r,t} := \frac{\overline{p}_{g,r,t} - FV_{g,r,t}}{FV_{g,r,t}}\), where \(g, r,\) and \(t\) are indices for group, repetition, and period, respectively, and \(\overline{p}_{g,r,t}\) is the average price of the shares across transactions in period \(t\) in repetition \(r\) of group \(g\).
(62.1% above FV) and significantly different from the treatment without regulations (p=0.02, Fisher permutation tests). However, as traders gain experience, the differences in price levels in the treatments with and without regulations narrow and disappear. In the second trading block, when traders have some experience (middle panel of Figure 1), the average price levels significantly fall in the no regulation treatment, whereas they remain constant in the regulation treatments (113% vs. 50%, p=0.08). The difference in price levels completely disappears when traders have experience. In the third trading block, price levels are even lower on average in the no regulation treatments (18.4%) than in the regulation treatments (34.8%), although this difference is not significant (p=0.88).

Next, we test the treatment impacts with two common bubble measures and study the individual impact of each of the regulatory settings. We consider the two most relevant bubble measures to our policy recommendation: Relative Deviation (RD) and Relative Absolute Deviation (RAD), which capture the overall price level and total price deviation, respectively. For both of these measures, a higher value indicates a higher price level or price dispersion. 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 $$t \in \{1,2,3,\ldots,10\}$$, 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 $$RAD_{g,r} := \frac{\sum_{t=1}^{10}|q_{g,r,t} - FV_{g,r,t}|}{\sum_{t=1}^{10}FV_{g,r,t}}$$.

Both RD and RAD confirm the patterns of our previous findings. When traders are inexperienced, regulations not only reduce prices, but also reduce the size of the bubbles.
(p=0.02 in the first trading block for both RD and RAD). However, as traders obtain more experience, the differences in the bubble size vanishes (p<0.05 in the second trading block, but p>0.66 in the third trading block).

Figure 2 corresponds to Figure 1, but shows the patterns for each market regulation throughout the course of the experiment. 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 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). The Fisher permutation tests show that the bubble size in the price limit treatment is significantly lower than in the no regulation treatment (p=0.02 for RD and RAD in trading block 1, p<0.1 in trading block 2 for RD) and significantly lower in both treatments compared to the no regulation treatment (p<0.1 in trading block 1 and p<0.05 in trading block 2 for RD). The t+1 rule always tends to lower RD and RAD, but the effect is statistically insignificant.

RESULT 1a: Regulations reduce bubbles, but the impact is short-term. Over time, when traders are more experienced, regulations do not help prices adjust closer to a fixed FV.

4.1.2 Regulations and bubbles under varying FVs (Markov)

We replicate the same analysis for the Markov treatments. Figure 3 provides a first view of price levels with (purple dashed-dotted line) and without (black straight line) regulations. We plot the median price percentage deviation\(^{15}\) of the 6 independent control groups (no regulation) and 18 treatment groups (we pool the three regulation treatments) for all periods in each trading block. At the start of the experiment, when traders lack experience (first

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\[^{15}\text{Price percentage deviation}_{g,r,t} := \frac{\bar{p}_{g,r,t} - FV_{g,r,t}}{FV_{g,r,t}}, \text{where } g, r, \text{and } t \text{ are indices for group, repetition, and period, respectively, and } \bar{p}_{g,r,t} \text{ is the average price of the shares across transactions in period } t \text{ in repetition } r \text{ of group } g.\]
trading block, left panel), prices are 18.50% below the FV in the absence of regulations, and the traditional bubbly pattern is not present. In contrast, in the presence of regulations, prices are much higher (19.10% above the FV) and significantly different from the treatments with regulations (p=0.08).

Unlike in the sessions with a flat FV, the price level does not always decrease with traders’ experience. In the second trading block, when traders have some experience (middle panel of Figure 3), the average price levels increase in both the control and treatment groups, and the presence of regulations significantly inflate the price level (28.60% for the control groups vs. 67.00% for the treatment groups, p=0.04). The difference in price levels narrows when traders have double the experience. In the third trading block, price levels are closer to the FV on average in the no regulation treatments (-0.70%) than in the regulation treatments (26.00%), although this difference is not significant (p=0.60).

Next, we test the treatment impacts with two common bubble measures and examine the individual impact of each regulation treatment. We again consider RD and RAD as the most relevant measure of bubbles in our context.

Both RD and RAD confirm the patterns of our previous findings. When traders are inexperienced, regulations do not reduce the prices nor the size of bubbles (p>0.1 in the first trading block for both RD and RAD). As traders gain more experience, the regulations significantly increase the price level and mispricing size (p<0.05 in the second trading block for both RD and RAD), but the difference becomes insignificant again when traders have experience (p>0.68 in the third trading block).

Figure 4 corresponds to Figure 3, but shows the patterns for each regulation throughout the course of the experiment. We observe that when traders are inexperienced, all three regulation treatments have higher price levels than does the control treatment. Further, we observe that when traders have experience (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). 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, though the effect is small and insignificant. Price limits 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 twice the experience (p=0.02).

**Result 1b:** Regulations do not reduce bubbles at all experience levels when a Markov process determines the FV. Over time, when traders gain twice the experience, the two regulations together significantly push the price away from the FV.

### 4.2 Momentum trading and delayed price discovery

#### 4.2.1 Momentum trading and delayed price discovery under fixed FV

We use quantile regression analysis to test two financial hypotheses. In Table 9, we estimate the extent to which prices have momentum; that is, when upward (downward) price movements cause price increases (decreases) in subsequent periods and whether price limits delay price discovery. We control for price–FV gaps in the preceding period. The models in Table 9 are:

\[
p_{g,r,t} = \alpha + \sum_{t' = 1}^{2} p_{g,r,(t-t')} + \delta_1 \text{upper}_{g,r,t-1} + \delta_2 \text{lower}_{g,r,t-1} + \beta_1 \cdot \text{deviation}_{g,r,t} \\
+ \beta_2 \cdot \text{deviation}_{g,r,t}^2 + \epsilon_{g,r,t},
\]

where the dependent variable \(p_{g,r,t}\) is the price percentage change of the average price of the shares in period \(t\) of the repetition \(r\), with the group of subjects \(g\), and \(t \geq 4\).\(^{16}\) The terms \(p_{g,r,(t-t')}\) are the lagged percentage changes of the average price, which captures the impact of price changes in the past on the current price change (momentum trading). The

\(^{16}\) We find that the error behaves like white noise after adding two lags. The main results are robust to the choice of lags and estimation methods.
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 $deviation_{g,r,t} := \frac{p_{g,r,t}^{closing} - FV_{g,r,t}}{FV_{g,r,t}}$, where $p_{g,r,t}^{closing}$ is the closing price in the previous trading period and $FV_{g,r,t}$ is the FV in the corresponding period.

We find evidence of momentum trading. In particular, we observe that a 1% increase (decrease) in the price 2 periods prior leads to a significant increase (decrease) of the price in the current period of around 0.20% (p=0.015).

We also find evidence of delayed price discovery. Reaching the upper price limit in the previous period tends to push the price up by 14% (p<0.001), and reaching the lower price limit in the previous period leads to a price drop of 12% (p=0.002).

**Result 2a:** The behavioral patterns confirm the Momentum Trading Hypothesis and the Delayed Price Discovery Hypothesis of price limits.

### 4.2.2 Momentum trading and delayed price discovery under variable FV

We replicate the analysis for the Markov treatments. We find evidence of both the momentum trading and delayed price discovery hypotheses in the Markov treatments as well. From the right column of Table 9, we find that a 1% increase (decrease) in the price 2 periods prior leads to an increase (decrease) in the price in the current period of around 0.07% (p=0.036). We also find that reaching the upper price limit in the previous period tends to push the price up by 14% (p=0.008), and reaching the lower price limit in the previous period leads to a price drop of 10% (p=0.027).

**Result 2b:** The behavioral patterns confirm the Momentum Trading Hypothesis and the Delayed Price Discovery Hypothesis of price limits – even when the FV varies.

### 4.3 Market information: Reactions to changes in FV

In our Markov 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 provide the first answers to three important questions from an experiment: Do traders react to market news? Assuming that they do, does the response depend on the type of news (good or bad)? Finally, does the response depend on treatment and experience?

Table 10 reports the results of four quantile regression models to provide the first insights into whether traders react to market news. The regression models in this table are:

\[ p_{cg,rt} = \alpha_0 + \alpha_1 FV_{cg,rt} + \epsilon_{g,rt}, \]

where \( p_{cg,rt} \) and \( FV_{cg,rt} \) are the percentage rate of increase in the average share price and the FV, respectively, in period \( t \) of the repetition \( r \), with the group \( g \), for \( t \in \{2,3,4,...,10\} \).

We then look at whether the effect of the FVs of the share prices differ when the news is good (high dividend state) or bad (low dividend state). We introduce the variable Good news, denoted by \( G_{g,rt} \) and defined as

\[ G_{g,rt} := FV_{cg,rt} \cdot 1_{\{FV_{cg,rt}>FV_{cg,rt-1}\}}, \]

where \( 1_{\{FV_{cg,rt}>FV_{cg,rt-1}\}} \) is an indicator function that takes the value 1 if the news makes the FV increase in the current period and 0 otherwise; similarly, we define the variable Bad news, denoted by \( B_{g,rt} := FV_{cg,rt} \cdot 1_{\{FV_{cg,rt}<FV_{cg,rt-1}\}} \). We estimate the model

\[ p_{cg,rt} = \alpha_0 + \beta_1 G_{g,rt} + \beta_2 B_{g,rt} + \epsilon_{g,rt}. \]

We find that traders imperfectly react to market news. As Models 1 – 2 in Table 10 show, news is a significant predictor of the share price (\( p<0.02 \)). However, we can also see that the news coefficients are quite small (0.108 – 0.122), showing that traders clearly undervalue market news. Models 3 and 4 distinguish between good and bad news. We observe that traders do not consider bad news (\( p>0.369 \)), but do react to good news (Model 3, \( p<0.01 \)). Thus, we find the first evidence suggesting that market news has an asymmetric impact on how share prices track to their FVs.

Table 11 provides a more refined analysis by investigating the impact of news in each of the trading blocks. Interestingly, traders only significantly react to good market news at the beginning of the experiment in the first trading block. More precisely, with inexperienced subjects and good news, the elasticity of the price of shares with respect to the FV ranges
between 0.385 and 0.536 (p<0.01). However, with experience, the elasticity estimates decrease and become insignificant. For bad news, the elasticity is never significantly different from 0 for any level of experience.

INSERT TABLE 11 ABOUT HERE

To test treatment differences in response to information, we decompose the effect of the change in the FV by treatment, replacing $FV_{c,g,r,t}$ in Table 10 with the variables $FV_{c,g,r,t} \cdot 1_{[\tau_g=i]}$ for $i \in \{benchmark, price limits, t + 1, Both\}$, where $\tau_g$ is the treatment of group $g$:

$$pc_{g,r,t} = \alpha_0 + \Sigma_{i} \alpha_i FV_{c,g,r,t} \cdot 1_{[\tau_g=i]} + \epsilon_{g,r,t}.$$

The two models in Table 12 show that traders underreact to news when the regulations are absent, and that neither the price limits nor both treatments significantly improved a trader’s ability to respond to market news. In the benchmark, the elasticity of the price of shares with respect to the FV is only 0.08 (p<0.05 in Model 2). The elasticity estimates for price limits and both treatments are not significantly different from 0. The estimate for the t+1 rule is around 0.24 and is significant (p<0.01 in Model 1 and 2), as is that of the benchmark ($H_0: \alpha_{benchmark} = \alpha_{t+1}$ with p<0.05 in both Models).

RESULT 3: Traders respond to market news imperfectly by: (i) underreacting, (ii) responding only to good but not bad news, (iii) reacting only when they lack experience. Only the t+1 regulation improves reactions to market news.

5. Conclusion

In this study, we examine the impact of regulations on mispricing in a novel asset market experiment. We find that regulations abate bubbles, but only if traders are inexperienced and the FVs of shares is constant. However, in environments that more closely resemble naturally occurring asset markets, in which FVs vary, regulations inflate rather than deflate mispricing.

Besides providing insights on the formation and magnitude of bubbles, our experiments with varying FVs capture cycles and trends that are typical outside of laboratory settings, and thus render it possible to rigorously test how traders react to market news to evaluate shares. We provide new evidence that traders respond to market information, but
only partially and asymmetrically. Finally, our experiment data confirms the Momentum Trading Hypothesis and the Delayed Price Discovery 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. On the other hand, time-independent regulations appear to be counter-productive for established shares.

Our study is just a first attempt to study regulations in complex asset markets with experiments. 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 use other experiments to test different stochastic FV processes besides a Markov process. Third, we believe there is merit in further studying price dynamics and financial hypotheses and go beyond the study of the bubble formation.
6. Appendix

6.1 Experiment 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

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 seconds, 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

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

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.

<table>
<thead>
<tr>
<th></th>
<th>High dividend in the current period</th>
<th>Low dividend in the current period</th>
</tr>
</thead>
<tbody>
<tr>
<td>High dividend in the previous period</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Low dividend in the previous period</td>
<td>30%</td>
<td>70%</td>
</tr>
</tbody>
</table>

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 \text{the dividend at period 10, if the dividend state is high in period 10}
13.67 \times \text{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 \text{ tokens per share, if the dividend state is high in period 10}
13.67 \times 1 = 13.67 \text{ 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 \text{ tokens per share}, while the price floor in period 6 is 10 \times 0.8 = 8
\text{ tokens per share.}

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

T+1

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.

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 × the dividend at period 10 if the dividend state is high in period 10; or is 13.67 × 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 × 1.2; the price floor is the closing price in the previous trading period × 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
+ Redemption the 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.

INSERT FIGURES 5 & 6 ABOUT HERE

6.2 Fundamental value for Markov process

We follow Mehra & 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 $\lambda_1$ is 1 plus the dividend growth rate when the state is high (1+10%=1.1 in our case), and $\lambda_2$ 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 $d_\tau = d_t \cdot \prod_{i=t+1}^{t+s} \lambda_i$, so the fundamental value in period $t$ is homogeneous of degree one in $d_t$. Thus, we can write:
Equation 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 \( t + 1 \):

Equation 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 \( \phi_{ij} \) is the probability that the dividend state goes from \( i \) to \( j \), \( \beta \) 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 Equations 1 and 2.

Thus, we have

Equation 3

\[ FV(d, i) = w_i d, \]

Equation 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 Equation 4 in Equation 3 and get

Equation 5

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

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 Equation 5 and solve for \( w_1 \) and \( w_2 \):
\[
\begin{align*}
\begin{cases}
    w_1 = 15 \\
    w_2 = \frac{41}{3}.
\end{cases}
\end{align*}
\]

Thus,

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

6.3 Price patterns in individual markets

INSERT FIGURES 7-14 ABOUT HERE
References


Fama, EF 1988, *Perspectives on October 1987, Or what Did We Learn from the Crash?*, University of Chicago.


Holt, CA 2007, Markets, Games, & Strategic Behavior, Pearson Addison Wesley Boston, MA.


### Tables

**Table 1: Endowments at the beginning of each trading block**

<table>
<thead>
<tr>
<th>Endowment groups</th>
<th>Shares</th>
<th>Tokens</th>
<th>Number of traders</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>5016.67</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>3583.34</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
<td>2150</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>350</td>
<td>716.67</td>
<td>2</td>
</tr>
</tbody>
</table>

Notes: This table lists the exact endowment of all 8 participants at the beginning of each trading block.
### Table 2: Treatments and sample size

<table>
<thead>
<tr>
<th></th>
<th>Benchmark</th>
<th>Price limits</th>
<th>T+1</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
</tr>
<tr>
<td>Markov</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
<td>n=6</td>
</tr>
</tbody>
</table>

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 3: Realized dividend series for flat treatments

<table>
<thead>
<tr>
<th>Trading block</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.27</td>
<td>0</td>
<td>4.27</td>
<td>0.4</td>
<td>4.27</td>
<td>0.4</td>
<td>1.05</td>
<td>0</td>
<td>0.4</td>
<td>1.05</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0.4</td>
<td>1.05</td>
<td>0.4</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>4.27</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>3</td>
<td>4.27</td>
<td>0.4</td>
<td>0</td>
<td>0.4</td>
<td>1.05</td>
<td>0</td>
<td>4.27</td>
<td>4.27</td>
<td>0</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Notes: This table lists our dividend series under flat FVs. All traders in markets with flat FVs observe the same dividend realization.
Table 4: Realized dividend states for Markov treatments

<table>
<thead>
<tr>
<th>Trading block</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>H</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
</tr>
<tr>
<td>3</td>
<td>H</td>
</tr>
</tbody>
</table>

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.
Table 5: Mean mispricing of the benchmark and 3 regulation treatments (Flat FV)

<table>
<thead>
<tr>
<th></th>
<th>Trading block 1</th>
<th>Trading block 2</th>
<th>Trading block 3</th>
<th>3 Trading blocks averaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean mispricing—Benchmark</td>
<td>274%</td>
<td>113%</td>
<td>18.40%</td>
<td>135.13%</td>
</tr>
<tr>
<td>Mean mispricing—Regulations aggregated</td>
<td>62.10%</td>
<td>50.00%</td>
<td>34.80%</td>
<td>48.96%</td>
</tr>
<tr>
<td>Fisher permutation test p-value</td>
<td>-0.02**</td>
<td>-0.08*</td>
<td>0.88</td>
<td>-0.02**</td>
</tr>
</tbody>
</table>

Notes: This table compares the mean mispricing of the benchmark with 3 regulation treatments pooled together under flat FVs. We take the average of the 10 mispricing values from the 10 trading periods within each trading block to form a data point, so there are 6 observations for the benchmark and 18 observations for the regulations pooled. The first two rows report the value of mean mispricing. The third row reports the p-value of a Fisher permutation test examining the null hypothesis $H_0$: The benchmark has the same price level as the three regulation treatments aggregated. A negative sign on the p-value means that the benchmark has a lower price level. * and ** indicate significance at the 10% and 5% levels, respectively.
Table 6: Comparing bubble measures between the benchmark and 3 regulation treatments (Flat FV)

<table>
<thead>
<tr>
<th></th>
<th>Relative deviation</th>
<th>Relative absolute deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trading block 1</td>
<td>Trading block 2</td>
</tr>
<tr>
<td>Price limits</td>
<td>-0.02**</td>
<td>-0.10*</td>
</tr>
<tr>
<td>T+1 rule</td>
<td>-0.18</td>
<td>-0.14</td>
</tr>
<tr>
<td>Both</td>
<td>-0.10*</td>
<td>-0.06**</td>
</tr>
<tr>
<td>Regulations pooled</td>
<td>-0.02**</td>
<td>-0.02**</td>
</tr>
</tbody>
</table>

Notes: This table compares the size of bubbles between the benchmark and each regulation treatment using two bubble measures under flat FVs. The numbers in the table are 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 7: Comparing mean mispricing of benchmark and 3 regulation treatments (Markov FV)

<table>
<thead>
<tr>
<th></th>
<th>Trading block 1</th>
<th>Trading block 2</th>
<th>Trading block 3</th>
<th>3 trading blocks average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean mispricing–Benchmark</td>
<td>-18.50%</td>
<td>28.60%</td>
<td>-0.70%</td>
<td>3.13%</td>
</tr>
<tr>
<td>Mean mispricing–Regulations aggregated</td>
<td>19.10%</td>
<td>67.00%</td>
<td>26.00%</td>
<td>37.37%</td>
</tr>
<tr>
<td>Fisher permutation test p-value</td>
<td>0.08*</td>
<td>0.04**</td>
<td>0.60</td>
<td>0.04**</td>
</tr>
</tbody>
</table>

Notes: This table compares the mean mispricing of the benchmark with the 3 regulation treatments pooled together under Markov FVs. We take the average of the 10 mispricing values from the 10 trading periods within each trading block to form a data point, so there are 6 observations for the benchmark and 18 observations for the regulations pooled. The first two rows report the value of mean mispricing. The third row reports the p-value of a Fisher permutation test of the null hypothesis $H_0$: 'The benchmark has the same price level as three regulation treatments aggregated. A negative sign on the p-value means that the benchmark has a lower price level. * and ** indicate significance at the 10% and 5% levels, respectively.
Table 8: Compare bubble measures between benchmark and regulation treatments (Markov FV)

<table>
<thead>
<tr>
<th></th>
<th>Relative deviation</th>
<th>Relative absolute deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trading block 1</td>
<td>Trading block 2</td>
</tr>
<tr>
<td>Price limits</td>
<td>0.24</td>
<td>0.04**</td>
</tr>
<tr>
<td></td>
<td>0.02**</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>0.66</td>
<td>0.01**</td>
</tr>
<tr>
<td></td>
<td>0.32</td>
<td>0.08*</td>
</tr>
<tr>
<td></td>
<td>0.04**</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
<td>0.04**</td>
</tr>
<tr>
<td></td>
<td>0.24</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>0.01**</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>0.02**</td>
<td>0.02**</td>
</tr>
<tr>
<td>Regulations combined</td>
<td>0.20</td>
<td>0.04**</td>
</tr>
<tr>
<td></td>
<td>0.00**</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00**</td>
</tr>
</tbody>
</table>

Notes: This table compares the size of bubbles between the benchmark and each regulation treatment using two bubble measures under Markov FVs. The numbers in the table are 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 9: Momentum trading and delayed price discovery of price limits hypotheses

<table>
<thead>
<tr>
<th></th>
<th>Flat</th>
<th>Markov</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price change 1 period ago ($\gamma_1$)</td>
<td>-0.021</td>
<td>0.160</td>
</tr>
<tr>
<td></td>
<td>0.117</td>
<td>0.464</td>
</tr>
<tr>
<td>Price change 2 periods ago ($\gamma_2$)</td>
<td>0.198**</td>
<td>0.066**</td>
</tr>
<tr>
<td></td>
<td>0.015</td>
<td>0.036</td>
</tr>
<tr>
<td>Price upper limits ($\delta_1$)</td>
<td>0.144***</td>
<td>0.140***</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.008</td>
</tr>
<tr>
<td>Price lower limits ($\delta_2$)</td>
<td>-0.118***</td>
<td>-0.100**</td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td>0.027</td>
</tr>
<tr>
<td>Price – FV gap ($\beta_1$)</td>
<td>-0.014</td>
<td>-0.029***</td>
</tr>
<tr>
<td></td>
<td>0.207</td>
<td>0.003</td>
</tr>
<tr>
<td>Price – FV gap square ($\beta_2$)</td>
<td>0.002</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td>0.445</td>
<td>0.073</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.002</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>0.801</td>
<td>0.756</td>
</tr>
<tr>
<td>Estimation method</td>
<td>QR</td>
<td>QR</td>
</tr>
</tbody>
</table>

Notes: This table shows the estimation results for whether past price movements have any impact on the price in the current period (momentum trading) and 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.
Table 10: Response to market news

<table>
<thead>
<tr>
<th></th>
<th>News (not decomposed)</th>
<th>News decomposed into good news and bad news</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td><strong>News (α₁)</strong></td>
<td>0.122***</td>
<td>0.108**</td>
</tr>
<tr>
<td></td>
<td>0.004</td>
<td>0.014</td>
</tr>
<tr>
<td><strong>Good news (β₁)</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bad news (β₂)</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Constant (α₀)</strong></td>
<td>-0.023*</td>
<td>-0.023*</td>
</tr>
<tr>
<td></td>
<td>0.084</td>
<td>0.084</td>
</tr>
<tr>
<td>Options</td>
<td>None</td>
<td>Fixed effects on periods and trading blocks</td>
</tr>
<tr>
<td>Estimation method</td>
<td>QR</td>
<td>QR</td>
</tr>
</tbody>
</table>

Notes: This table shows the estimation results for whether and to what extent participants react to market 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 the period (9 variables) and 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 11: Market experience and response to market news

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodnews@block1</td>
<td>0.536***</td>
<td>0.385***</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.003</td>
</tr>
<tr>
<td>Goodnews@block2</td>
<td>0.135</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>0.250</td>
<td>0.542</td>
</tr>
<tr>
<td>Goodnews@block3</td>
<td>0.157</td>
<td>0.070</td>
</tr>
<tr>
<td></td>
<td>0.106</td>
<td>0.550</td>
</tr>
<tr>
<td>Badnews@block1</td>
<td>-0.109</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>0.340</td>
<td>0.773</td>
</tr>
<tr>
<td>Badnews@block2</td>
<td>-0.095</td>
<td>0.246</td>
</tr>
<tr>
<td></td>
<td>0.481</td>
<td>0.181</td>
</tr>
<tr>
<td>Badnews@block3</td>
<td>-0.084</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>0.502</td>
<td>0.736</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.018</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>0.124</td>
<td>0.114</td>
</tr>
</tbody>
</table>

Options: None, Fixed effects on periods and trading blocks
Method: QR, QR

Notes: This table shows the estimation results for whether experience affect participants’ 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 the period (9 variables) and 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 12: Regulations and response to market news

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark × news ((\alpha_{benchmark}))</td>
<td>0.079</td>
<td>0.080**</td>
</tr>
<tr>
<td></td>
<td>0.235</td>
<td>0.027</td>
</tr>
<tr>
<td>Price limits × news ((\alpha_{price\ limits}))</td>
<td>0.071</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>0.121</td>
<td>0.786</td>
</tr>
<tr>
<td>T+1 × news ((\alpha_{t+1}))</td>
<td>0.236***</td>
<td>0.245***</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Both × news ((\alpha_{both}))</td>
<td>0.118</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td>0.186</td>
<td>0.638</td>
</tr>
<tr>
<td>Constant ((\alpha_0))</td>
<td>0.000</td>
<td>0.054*</td>
</tr>
<tr>
<td></td>
<td>0.972</td>
<td>0.055</td>
</tr>
<tr>
<td>Options</td>
<td>None</td>
<td>Fixed effects on periods and trading blocks</td>
</tr>
<tr>
<td>Method</td>
<td>QR</td>
<td>QR</td>
</tr>
</tbody>
</table>

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 the period (9 variables) and 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.
Figures

Figure 1: Price deviations for the benchmark and 3 regulation treatments (combined, flat FVs)

Notes: This graph shows the median mispricing of 6 benchmark markets and 18 regulations markets with flat FV.
Figure 2: 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.
Figure 3: Price deviation comparison between the benchmark and 3 regulation treatments (combined, Markov FVs)

Notes: This graph shows the median mispricing of 6 benchmark markets and 18 regulated markets with Markov FVs.
Figure 4: 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.
Figure 5: Instructions for traders: Using the experiment software


2. Information about current shares and Tokens you have, dividend per share paid in the last period, and number of shares you can sell.

3. Summary of own sales and purchases in the current period (including corresponding quantities and prices).

4. Time left in the current period.

5. Bid box: make a bid offer to buy lower than the current lowest ask price. You have to enter quantity and price you are willing to buy. Trade does not take place until another participant accepts your offer.

6. Ask box: make an ask offer to sell higher than the current highest bid price. You have to enter quantity and price you are willing to sell. Trade does not take place until another participant accepts your offer.

7. List of all ask offers from all participants. Your own ask offers are written in blue. The ask offers are listed from the lowest price to the highest. The ask offers listed on the top is always the lowest ask (i.e. the cheapest one for the buyers).

8. Accept other participant’s ask offer. You buy the entered quantity given the price with the blue background. If you enter a higher amount than offered in the blue box, you buy the offered quantity at most.

9. Accept other participant’s bid offer. You sell the entered quantity given the price with the blue background. If you enter a higher amount than offered in the blue box, you sell the offered quantity at most.

10. List of all bid offers from all participants. Your own bid offers are written in blue. The bid offers are listed from the highest price to the lowest. The bid listed on the top is always the highest bid (i.e. the most profitable one for the sellers).

11. Price-chart of current period. The vertical axis is price while the horizontal axis is time in second.

Figure 6: Instructions for traders: How to read trading history

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

<table>
<thead>
<tr>
<th>Period</th>
<th>Shares</th>
<th>Dividend per share</th>
<th>Total dividend in this period</th>
<th>Closing price</th>
<th>Tokens (game money)</th>
<th>Interest payment in this period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Price-chart, displaying closing prices of all previous periods.**

- Shares you own when the trading period ends.
- Tokens you own when the trading period ends.
- Actual dividend realization in the respective period.
- Total dividend payment for the respective period (number of shares × dividend per share).
- Interest payment for the respective period (Tokens × interest rate).
Figure 7: Mispricing of 6 individual markets without regulations (Flat FVs)

Notes: This graph shows the mispricing of 6 individual markets without regulations under flat FVs.
Figure 8: 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.
Notes: This graph shows the mispricing of 6 individual markets with the t+1 rule under flat FVs.
Figure 10: 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.
Figure 11: 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.
Figure 12: 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.
Figure 13: 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.
Figure 14: 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.