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Market Reactions to Stock Splits: Experimental Evidence

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Abstract

Stock splits and reverse splits often result in short-term abnormal returns even though such split events do not change any fundamental factors affecting the valuation of a firm's stock. In this paper we report an experiment designed to better understand market reactions to stock splits and reverse splits. In one treatment, two assets have increasing fundamental values, and one asset is subject to a 2-for-1 share split while the other asset is not. In a second treatment, the fundamental values of both assets are decreasing, and one asset is subject to a 1-for-2 reverse split while the other asset is not. We find that in both cases, share prices do not fully adjust to changes in fundamental values per share following a split announcement. We provide evidence that the incomplete adjustment of share prices to splits or reverse splits can be attributed to heterogeneity in traders' cognitive abilities.

Keywords: Stock splits, asset pricing, behavioral finance, cognitive reflection, experimental finance.

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JEL codes: C92, G10, G40, G41

1 Introduction

Recent stock splits of leading companies, e.g., Amazon, Apple and Tesla, have renewed debate about the impact of such splits on the prices of the split stock. A stock split, unlike the issuance of new shares or a buyback of existing shares, does not dilute existing ownership claims. Therefore, absent any changes to a firm's profit-making potential stock splits should *not* affect the firm's fundamental value. Since there are costs to implementing a stock split and no change in the firm's fundamental value, stock splits should not be observed. Nevertheless, stock splits occur rather frequently and produce at least a temporary effect on a firm's market capitalization by driving the post-split share price of the company's stock higher or lower, depending on the nature of the split. Fama et al. (1969) were the first to report evidence of abnormal returns one to three years following the announced split of a company's stock, with subsequent studies confirming positive abnormal returns for stock splits and the opposite, negative abnormal returns for reverse splits. See, for example, Grinblatt et al. (1984), Lamoureux and Poon (1987), Ikenberry and Ramnath (2002), and Titman et al. (2022).

In this paper, we study market reactions to stock splits and reverse splits in a market experiment that makes use of the Smith et al. (1988) environment (hereafter SSW), which has been widely used in the experimental asset pricing literature. Our experiment aims to complement findings from the large empirical literature in finance on stock splits. In the laboratory, by contrast with the field, we know precisely the fundamental value (FV) of the asset over time, both pre- and post-split, and can therefore cleanly evaluate whether splits and reverse splits result in pricing anomalies. We also collect individual data, which provides us with new insights as to the cause of the market's asymmetric reactions to stock splits and reverse splits.

In the experiment, market participants can trade two types of assets with positively correlated dividends/holding costs. In the stock split treatment (SS), both assets' FVs follow a known upward trend. The rationale for this design is that stocks subject to splits are usually rising in value over time, and we wanted to capture this feature of split stocks. At some time t, that is unknown to market participants, one of the two assets —the one with a higher FV— is subject to a 2 for 1 stock split, while the other asset continues to follow its original fundamental upward trend to provide a counterfactual scenario. A two asset market experiment allows us to understand the effect of a stock split by comparing the deviation of asset prices relative to their FVs.[1] We also consider

[1]Relative prices have been shown to converge to FVs in prior experiments; see the survey of

a reverse split treatment (RS) where two assets follow a known, downward fundamental trend, and where the asset with the lower FV is subject, at some unknown date t, to a 1 for 2 reverse split. We use a downward trend for the FV of the two assets in the RS treatment because a reverse stock split generally occurs only when a stock price is falling. In fact, some exchanges have a minimum list price requirement which has triggered reverse splits in an effort to raise the price of a stock above the minimum requirement.

One possible explanation for why stock splits occur concerns the optimal price range for a stock. This optimal range balances the competing needs of investors of different means (Copeland, 1979). If the stock price departs from the optimal price range, then a split (or a reverse split) can bring the stock price back within its optimal range.[2] A second, and related, explanation concerns liquidity: shares that trade at lower prices may be viewed as more liquid (Muscarella and Vetsuypens, 1996). A third and final explanation concerns signaling. For example, recent splits by Amazon, Apple, and Tesla may signal to investors that the firm expects profits to grow, leading to greater demand for the stock and triggering speculative, short-term oriented, trading behavior.[3]

In this paper, we set aside the question of *why* firms choose to split or reverse split their stock shares and we focus instead on the *market reaction* to such splits. Understanding *how* the market reacts to stock splits or reverse splits may be critically important for understanding why firms engage in splits or reverse splits in the first place: it may be that market reactions to stock splits are the reason that firms engage in stock splits. Indeed, Warren Buffet has stated that the reason he has never split class A shares of Berkshire Hathaway (currently trading in excess of USD $500,000 per share) is because, "I don't want anybody buying Berkshire thinking that they can make a lot of money fast." (*Wall St. Journal* Aug 14, 2014).

A possible mechanism that may contribute to short-term abnormal returns is that subjects respond differently to news. In the field, Brandt et al. (2010) associate split events to the idiosyncratic volatility phenomenon, and argue that the observed volatility in low-priced stocks is related to trading on the part of retail investors. In a recent

literature in Duffy et al. (2022).

[2]This argument is less relevant today than it once was as brokerages have become quite willing to sell *fractions* of shares to investors, so that no investor is priced out of acquiring equity in a company *why* its share price grows large.

[3]Cui et al. (2021) explore a signaling explanation in the Chinese stock market, and they find evidence of greater optimism following a stock split, and improved future performance.

study, Shue and Townsend (2021) find that low-priced shares have a higher volatility as compared with high-priced shares following stock split events, after controlling for firm size.[4] Previous experiments have shown that nominal shocks (Fehr and Tyran, 2001; Noussair et al., 2012), buy backs (Haruvy et al., 2014), and changes in the structure of the asset (Kirchler, 2009; Lin and Rassenti, 2012) are prone to mispricing, suggesting that some subjects have trouble computing the correct relative prices after an event. To proxy for subject's ability to properly assess changes in the FV per share, we consider their scores on cognitive reflection test (CRT) questions (see, e.g., Frederick, 2005). We hypothesize that subjects with higher CRT scores are better able to compute relative changes in share prices since the CRT questions measure the ability to think carefully instead of providing intuitively more immediate and wrong answers. Poor CRT scores by some subjects may translate into mispricing at the market level. Indeed, Bosch-Rosa et al. (2018) provide evidence that markets populated by traders with lower CRT scores result in higher mispricing.

In the *SS* treatment, we observe higher prices for the split asset in the short-run, where the short-run is defined as the 5 periods immediately following the split announcement at the end of period 5. This is an *under*-reaction by the market to the change in the FV per share. The measure of order imbalance, defined as the excess of bid orders relative to ask orders in the order book, is *negative*. This suggests that there should be downward pressure on prices, which is what we observe, but only in the long run. By contrast, the other asset in the market of the SS treatment, which is not subject to a split, remains fairly priced relative to its FV. We further find that the proxy we use for subjects' cognitive abilities (their CRT score) helps to explain the observed market behavior. Subjects with higher CRT scores submit orders that are closer to the FV for both assets.

In the *RS* treatment, we find weak evidence of underpricing in the short-term for the reverse split asset. In later periods, when the difference between the FV of the two assets shrinks, and the cash to asset ratio increases, both assets are found to be overpriced relative to the FV. However, the relative price is closer to the FV following the split announcement, which is consistent with previous multiple asset experiments (see the survey of literature in Duffy et al., 2022). The measure of order imbalance is positive for both assets after the announcement, and decreases in the long-run. A positive imbalance suggests that prices adjust upwards, which is common in SSW

[4] Higher volatility following a stock split is also found in options data (Gharghori et al., 2017).

environments. The individual adjustment of orders is less clear as compared with the *SS* treatment since market prices for both assets deviate from FVs. Further analysis of the absolute deviation of orders with respect to FVs shows that subjects with higher CRT scores submit orders that are closer to FV in this treatment as well.

Stock splits and reverse splits are a common occurrence in financial markets. A search of stock split events using the CRSP database (code 5523) for the NYSE over the period 2012-2021 reveals that there were 445 such events. Of these, 210 (47.2%) were regular, i.e., forward splits while 235 (52.8%) were reverse splits. The average (modal) forward split factor was 1.32 (1), which is approximated by a 2.33 for 1 (2 for 1) split, while the average (modal) reverse split factor was -0.76 (-0.90), approximated by a 1 for 4 (1 for 10) reverse split.

As noted earlier, Fama et al. (1969) were the first to find evidence of abnormal returns in the periods following a stock split. More recently, Desai and Jain (1997) report that for stock splits, the buy and hold average for 1 and 3 year abnormal returns are 7.05% and 11.87%, respectively. For reverse splits, the 1 and 3 year abnormal returns are -10.76% and -33.90%, respectively. For an overview of the empirical literature on stock splits, we refer the reader to Easley et al. (2001) and He and Wang (2012).

In an individual choice experiment, Svedsäter et al. (2007) asked subjects whether they would be more willing to buy/sell a stock following a stock split or a reverse split and report that individuals were more willing to buy/sell lower priced stocks following a split than they were to buy/sell higher priced stocks following a reverse split, but trading was preferred in both cases even though nothing fundamentally had changed about the stock value. The experimental market study that is perhaps most closely related to our paper is by Haruvy et al. (2014), who evaluate the effects of repurchase and share issues on asset prices in a market with a single asset that has a downward sloping FV. They find that prices deviate significantly from the FV when shares are repurchased. It should be noted that their implementation of a share issue or repurchase is different from a share split, as the latter changes the FV per share. In another study, Penalver et al. (2020) also provide experimental evidence on the impact of repurchase (via quantitative easing) on higher bond prices.

Noussair et al. (2012) study the effect of a nominal shock in cash holdings in a single asset environment with a constant FV. In their inflation (deflation) treatment, the cash and the asset are multiplied (divided) by a scalar, without altering the FV. They find that prices go up significantly in the deflation treatment in the aftermath of the shock, and decrease toward the FV in the later periods. A possible explanation for the divergence of prices from FV is difficulty in computing relative prices, which may be related to cognitive ability. The effect of cognitive skills on trading behavior is consistent with previous evidence that higher CRT scores are positively correlated with performance in laboratory (Corgnet et al., 2018) and individual portfolio choice experiments (Magnani et al., 2022).

2 The environment

We extend the original SSW design where market participants trade a single asset having an uncertain dividend process to a setting where agents can trade two assets. In the stock split treatment, SS, the assets are indexed by $j \in \{S, B\}$ where asset S (the *split* stock) undergoes a change to its liquidation value and its dividend process due to a stock split while the other asset B (the *benchmark* stock) does not. Both assets follow an upward trending FV process, where S, the asset with higher FV, splits at time $\tau = t^*$.[5]

In the RS treatment, the two assets $j = \{\tilde{S}, \tilde{B}\}$ follow a downward trending FV process, where the asset with the lower FV, $\tilde{S}$, undergoes a reverse split at $\tau = t^*$, while the other (baseline) asset, $\tilde{B}$, does not.[6] Note that both assets for all treatments have perfectly positively correlated holding costs (or dividends) when the FV is upward (downward) trending. As noted earlier, this design feature enables a comparison of trends in the prices of the two assets, both pre- and post-split.

In each period, the costs (or dividends) per share d_j are either low or high with equal probability, $d_j = \{d_L, d_H\}$. These costs/dividends accrue to a separate account for each subject that is *not* available for trading so as to not alter the liquidity of the market over time. At the end of the terminal period, each share of asset j yields a liquidation payoff of TV_j which is paid to the participant in addition to the accrued balance of costs/dividends in the separate account, which may be positive or negative.

[5]The second asset, which is used as a control, has a different FV to differentiate between the two assets. This can be interpreted as two firms with different capital structures, i.e., the firm with the lower equity value has a higher debt burden. Charness and Neugebauer (2019) find that both firms, under different capital structures, are priced fairly when (as assumed in our experiment) dividends are perfectly positive correlated.

[6]In an SSW environment, if subjects are risk neutral, then given the same endowment, there should be no trade at all or trade will occur only at FV. However, past studies have shown significant trading in SSW environments.

In the SS treatment assets are subject to per period *holding costs*, which, together with a large and positive termination value TV_j lead to an increasing FV for each asset. In the RS treatment (as in SSW) assets are subject to per period dividend payments, which together with small, but a positive termination value result in a decreasing FV as detailed below.

The number of shares, n, of each asset is such that $n_{(S,\tilde{S})} = n_{(B,\tilde{B})}$ *prior* to the split, and changes to $\phi \times n_{(S,\tilde{S})}$ after the split, where in a 2 for 1 split $\phi = 2$ and in a 1 for 2 reverse split $\phi = 1/2$. Prior to the start of period t^* (and not before) an announcement of the impending split (in SS) or of the reverse split (in RS) is sent to all market participants. Following the announcement, the adjusted liquidation value is TV_j/ϕ per share, and the dividend or holding cost per share is converted to d_j/ϕ. If a participant holds an odd number of shares and there is a reverse split, then the odd unit is paid out at the last available market price in cash which can be used to trade.[7] In the actual experiment, we work with the labels A and B for the 2 types of assets in a given market, where A is the split stock and B is the baseline (non-split stock). In the experimental instructions, we mention that a share conversion might occur and, if so, that it would be announced just prior to the period in which the conversion takes place.

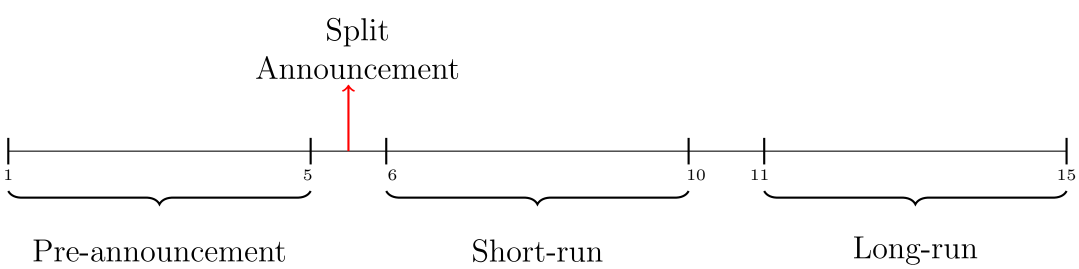


Figure 1: Market timeline in SS and RS environments

[7]Cash payment for fractional shares is commonly used, e.g. see https://www.investor.gov/introduction-investing/investing-basics/glossary/reverse-stock-splits.

2.1 Stock split

In our SS treatment, we set $T = 15$, $t^* = 6$, and $d_j = \{-12, 0\}$. Initially, $TV_S = 270$, and $TV_B = 210$. Note that the dividend realizations are the same for both assets ($d_S = d_B$). The main difference between the two assets lies in the termination values, TV_j, and in the fact that one asset, S, experiences a split. The FV of an asset, assuming no discounting, is equal to the expected holding cost over the remaining life of the asset in periods $T - \tau + 1$, plus the termination value, TV, such that

$$FV_{j,\tau} = \sum_{\tau=t}^{T} E[d_{j,\tau}] + TV_j. \tag{1}$$

Figure 1 shows the timing of the stock split or reverse split announcement following the end of period $t = 5$, and prior to the beginning of period $t = 6$. In our subsequent analysis, we concentrate on 3 trading intervals: (i) the pre-announcement period where $\tau \leq 5$, (ii) the short-run period immediately following the split where $6 \leq \tau \leq 10$, and (iii) long-run period where $\tau \geq 11$. The FV of each asset in the SS treatment can be written as

$$FV_{S,\tau} := \begin{cases} 270 - 6 \times (T - \tau + 1) & \text{for } \tau \leq 5 \\ 135 - 3 \times (T - \tau + 1) & \text{for } 5 < \tau \leq 15 \end{cases}$$
$$FV_{B,\tau} := 210 - 6 \times (T - \tau + 1). \tag{2}$$

We further assume that $n_S = n_B = 2$ at the start of the market for each trader. Participants can only sell assets that are currently in their portfolio —that is, short-selling is not allowed– and there is no borrowing. They can only utilize their cash holdings in order to trade. Table 1 summarizes the endowment per capita, and the parameters for both treatments.

2.2 Reverse split

For the RS environment, the parameters employed are: $T = 15$, $t^* = 6$, $d_j = \{0, 12\}$, $TV_{\tilde{S}} = 40$, and $TV_{\tilde{B}} = 80$. Therefore, the FV of each asset, assuming no discounting, is equal to the expected dividends over the remaining life of the asset in periods $T - \tau + 1$,

Table 1: Endowment bundles per capita and market parameters

	Split (SS)	Reverse split (RS)
Endowment per capita		
Cash	600	600
Number of converted shares	2	2
Number of baseline shares	2	2
Parameters		
Trading Periods	15	15
Dividends (holding cost) per share	{-12,0}	{0,12}
Liquidation value of converted share	135	80
Liquidation value of baseline share	210	80
Cash-Asset ratio (in terms of initial FV)	1	1

plus TV, as in equation (2). Specifically in RS the FV of each asset can be written as

$$FV_{\tilde{S},\tau} := \begin{cases} 40 + 6 \times (T - \tau + 1) & \text{for } \tau \leq 5 \\ 80 + 12 \times (T - \tau + 1) & \text{for } 5 < \tau \leq 15 \end{cases}$$
$$FV_{\tilde{B},\tau} := 80 + 6 \times (T - \tau + 1). \tag{3}$$

The FVs for both assets converge over time because the reverse split asset decreases in value faster relative to the non-split asset. As in the SS environment, we set $n_{\tilde{S}} = n_{\tilde{B}} = 2$. There is no short-selling, nor borrowing; participants can only utilize their current asset position and cash holdings to make trades.

2.3 Market format

The market functions in a call market institution. This institution reduces the complexity of the market setting, where agents can choose to trade in two asset markets operating at the same time. The call market has the further advantage of producing a single, uniform market price for each asset traded in period, τ, which provides greater clarity with respect to the differences in asset prices across markets and over time. In each period τ, market participants are allowed to submit one buy order and/or one sell order in each market. They can also choose not to participate in one or both markets. A complete buy order specifies a single bid price and the number of units desired at that price. Similarly, a complete sell order includes a single ask price and the number of units for sale at that price. Our computer program checks that each trader's posted bid and ask orders are feasible given that trader's current endowment of assets and cash; if not, then the trader must change to a feasible position. After all bids and asks are submitted, the computer program sorts the submitted bids in a descending order and the submitted asks in an ascending order, to derive the demand and supply schedules for each asset. The intersection of demand and supply (if it exists) results in a single, uniform market price for each asset market (and in the case of a price range, we use the midpoint price). All buyers whose bids are greater than or equal to the market price can buy the number of units of the asset they specified at the market price, while all sellers whose asks are less than or equal to the market price can sell the number of units they had specified at the market price. A rationing rule is applied when there are more bids or asks made at the market clearing price.[8]

2.4 Hypotheses

We structure our hypotheses first based on the assumption of perfect rationality, and then consider some possible deviations for the first three predictions.

Hypothesis 1: *The total market value of the split and the benchmark assets does not change after the split announcement.*

Under the assumption of perfect rationality, traders should react to the stock (reverse) split by adjusting their bids and asks so that they are proportional to the change in the FV per share. This implies that the total market capitalization for each asset should remain unchanged. To see this, note that the total market value (per capita) for the converted asset can be written as $(FV_j/\phi) \times n \times \phi$, where $\phi = 1$ before the split announcement, and, following that announcement $\phi = 2$ for the SS treatment ($\phi = 1/2$ for RS treatment).

In the RS treatment, it is possible that the number of shares in the market changes post conversion if participants hold an odd number of shares. In such cases, the odd share is destroyed, since it cannot be converted, and subjects are paid the most recent market value for that odd share which gets added to the income they have to trade in the market.

While the shareholder's wealth is not affected (in expectation) if prices follow FVs,

[8] Specifically, on the long side of the market, some traders are randomly chosen to have their bid/ask orders implemented while the rest are precluded from trading.

the total market capitalization for the converted share might vary. Therefore, it is appropriate to work with market values in terms of a share (prices) rather than total shares (market cap) in the *RS* treatment.

Hypothesis 2: *The order imbalance is zero pre- and post-split across both treatments.*

Following the previous hypothesis, if the market perfectly adjusts to the new FVs, then there should be no systematic order imbalance across periods. Order imbalance is defined using the difference in the number of bid and ask orders, adjusted for the distance from the market price.

Hypothesis 3: *Asset turnover pre- and post-split is the same across both treatments.*

If traders are rational, then asset turnover, or the average market quantity transacted each period, should not change following a stock (reverse) split, given that the volume is adjusted for the new number of shares in the market. We adjust for the increase (decrease) in the number of shares in the split (reverse split) case in order to make the volume of trade comparable across the two assets.

Hypothesis 4: *Lower CRT scores of traders are associated with larger departures from the FV of the assets.*

CRT scores serve as a proxy for the subjects' cognitive abilities and capture the extent to which they employ system 1 (reactive) versus system 2 (reflective) thinking. There is already experimental evidence that markets populated by traders with low CRT scores result in greater mispricing of assets than do markets populated by traders with higher CRT scores (see, e.g., Bosch-Rosa et al., 2018). We conjecture that this phenomenon will also apply to the orders submitted after the split announcement, which require that subjects adjust to *changes* in asset values per share. Indeed, there is related evidence that subjects fail to track relative prices in money illusion experiments (e.g., Fehr and Tyran, 2001, Noussair et al., 2012) and in field data (Shue and Townsend, 2021).

While we cannot provide an exact prediction on whether the subjects will overreact or underreact to the conversion announcements, we conjecture that subjects with lower CRT scores will submit orders that do not capture the change in FVs.

2.5 Asset market measures

We first present the measures we employ for testing the hypotheses. Regarding *Hypothesis 1*, we follow the tradition in the experimental asset market literature and study the behavior of prices relative to their FVs by first computing the relative deviation (RD) of the price of each asset j, p_j, with respect to its FV. In Table 2 we provide the formula employed to calculate the RD, as well as a number of other relevant measures. RD is computed as the average dispersion per period. In field data, such a measure cannot be easily computed since the FV is not observable. As noted in Figure 1, we classify the 15 periods per call market into pre-announcement, short-term, and long-term periods, inspired by the approach used in the field. Since our environment consists of two assets, we also incorporate the relative price deviation with respect to relative FVs ($\text{RD}_{j/-j}$), following the approach of Duffy et al. (2021).

Table 2: Market measures per asset j at time τ

Measure	Formula
RD: relative deviation of asset j • Measures the difference between price p and fundamental value FV.	$p_{j,\tau}/FV_{j,\tau} - 1$
$\text{RD}_{j/-j}$: RD of relative prices • Extends the measure of RD to two assets.	$\frac{p_{j,\tau}/p_{-j,\tau}}{FV_{j,\tau}/FV_{-j,\tau}} - 1$
z Order imbalance (of asset j) • $\delta = 0.98$ • p^* is the market price. • $Q(p,t)$ is a number of + sell (− buy) orders in the book at price p at period t.	$-\sum_p Q(p)_{j,\tau}\delta^{\lvert p_{j,\tau}-p^*_{j,\tau}\rvert}$
Asset turnover: units transacted • $q_{j,\tau}$ is the market quantity. • $\phi = 1$ before the announcement and $\phi \in (1/2, 2)$ after the announcement.	$q_{j,\tau}/\phi$

To study order imbalance (*Hypothesis 2*), we assume that $\delta \in (0, 1]$ is a weight parameter which discounts limit orders more heavily the further they are away from the market price p^*, and $Q(p)_{j,\tau}$ is a number of + sell (− buy) orders in the book at price p in period t; we can then specify the order imbalance as

$$z_{j,\tau} := -\sum_p Q(p)_{j,\tau}\delta^{\lvert p_{j,\tau}-p^*_{j,\tau}\rvert} \tag{4}$$

A negative order imbalance indicates downward price pressure due to an increasing number of sell orders relative to buy orders (increasing supply), while a positive order imbalance indicates upward price pressure due to an increasing number of bid orders relative to sell orders (increasing demand).

Finally, we study asset turnover (*Hypothesis 3*) for each asset j as the market quantity transacted per period. Following the announcement of a share conversion, we adjust the market quantity by $\phi \in (1/2, 2)$ so that market units are comparable in the periods before and after the split announcement.

3 Laboratory procedures

The experiment was conducted online using oTree (Chen et al., 2016). Subjects were undergraduate students recruited from Monash University (Australia), who had no prior experience with our game. Subjects were assigned to participate in just one of the two treatments: $\{SS, RS\}$. At the start of each session, subjects were asked to read some written instructions.[9] The instructions made clear to subjects that there was that possibility that a share conversion could occur for either asset A or B. They were *not* told that a conversion would occur for asset A only and that this would occur in period $t = 6$. Further, they were instructed on what a share conversion would mean for both assets in terms of the terminal value TV_j, and the dividend d_j, for the converted asset j, depending on the treatment (SS or RS) using several illustrative examples. Thus, subjects had *all* of the information needed to adjust the share price of either asset following a conversion.

After reading the instructions, subjects were asked to complete a comprehension quiz to check their understanding of the instructions.[10] After completing the quiz, subjects received feedback on whether their answers were correct, and the experimenter answered any remaining questions privately via a chat room. Subjects then participated in two, 15 period markets. Following completion of the second market, subjects answered three cognitive reflection test (CRT) questions taken from Toplak et al. (2014). The precise questions are

1. Jerry received both the 13th highest and the 13th lowest mark in the class. How

[9] Copies of these instructions are provided in the online appendix. See Appendix A for the user-interface.

[10] Specifically, in the SS (RS) treatment we asked, (i) If a conversion of shares of 2-for-1 (1-for-2) is announced for asset B but not for A, what happens with the dividends and price that the experimenter will pay for each share of asset B? (ii) Can I buy/sell an unlimited number of assets?, and (iii) Do the payments or holding costs (dividends) of asset A and asset B move together?

many students are in the class? [Correct Answer: 25, Intuitive Wrong Answer: 26]

2. Simon decided to invest $8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has: (i) broken even in the stock market, (ii) is ahead of where he began, or (iii) has lost money. [Correct Answer: iii) Lost Money. Intuitive Wrong Answer: (ii)]

3. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together? [Correct Answer: 4 days. Intuitive Wrong Answer: 9 days.]

In each period, participants had the option to input buy and/or sell orders, subject to the constraints that buy orders did not exceed cash endowments and sell orders were for assets currently in possession (i.e., no borrowing or short selling was allowed). Any holding costs in treatment SS or any dividends in treatment RS that subjects accrued over the course of the market were put into a separate account that was paid out or deducted from their earnings at the end of the session. Subjects' endowments of cash and assets at the start of sessions are presented in Table 1, which also reports on other parameters of the two treatments (SS and RS). In total, we conducted 14 online sessions with 7 sessions for each of the 2 treatments. Each session had between 10 and 14 subjects. We present an overview of all sessions in Table 3.

Table 3: Overview of experimental sessions

Treatment	Sessions	Participants	Payoff (AUD, without show-up fee)
split (SS)	7	85	24.64
reverse (RS)	7	94	24.21
Total	14	179	24.41

Note: Each session consisted of 10-14 participants. All sessions were conducted online using the subject pool at Monash University.

At the end of the experiment, one of the two markets was randomly selected and subjects' total point earnings from the selected market were converted into Australian dollars (AUD) at the fixed and known exchange rate of AUD 1.25 per 100 points. Subjects' market earnings were equal to the sum of their dividends (holding costs) over all 15 rounds from assets held plus their remaining cash balance and the value of their asset position at the end of the 15th round. On average, each session lasted about 1 hour and 45 minutes, and the average earnings were AUD 24.78. In addition to these market earnings, subjects also received a show-up fee of AUD 5.

4 Results

4.1 Stock split treatment

We begin our discussion of results for the SS treatment with Figure 2 which shows the market value (using median prices) of assets S and B over the course of 15 periods for the second market using data from all 7 sessions.[11] The market value of the S asset increases relative to the baseline asset, B, despite the fact that the fundamental market capitalization does not change, as depicted by the dashed dark line in Figure 2.[12]

We classify the periods of trading into three time intervals: (i) pre-announcement, which corresponds to periods $\tau \in [1, 5]$, (ii) the short-run, which are the 5 periods immediately following the announcement $\tau \in [6, 10]$, and (iii) the long-run, which are the last 5 periods of trading, $\tau \in [11, 15]$. During the pre-announcement stage, we observe that the price of asset B (the asset with the lower FV) closely follows its FV. By contrast, the price of asset S (the asset with the higher FV) is significantly below its FV, trading at a discount. Undervaluation of assets is commonly observed in single asset markets where the FV is upward sloping (see Noussair and Powell, 2010). In period 6, following the announcement, asset S becomes immediately overvalued, while asset B continues to be priced close to its FV. This suggests a short-run under-reaction to the split announcement by traders: prices are not sufficiently revised downward. In the long-run, both shares S and B converge to their respective FVs, though there is some dispersion at the beginning of the long-run phase for asset B. The reversal to FV is commonly observed toward the end of asset lifetimes in asset market experiments.

[11] In Appendix B, we provide complete graphs showing data for market 1 and market 2 for all sessions. Appendix B shows that while asset B is priced closer to its FV in the second market, there are important deviations in the first market, which is consistent with the idea that participants are learning to trade using the features of the platform and about the FV process. Therefore, we focus our analysis on the second market after subjects have gained some trading experience. Appendix D provides our main regression results controlling for the session effects. Our main results do not qualitatively change for the SS treatment.

[12] While the FV per share drops after the split announcement as described in equation (2), the market capitalization of the asset should remain the same. We calculate the market capitalization by multiplying the FV per share in equation (2) by $2n$ after the split announcement.

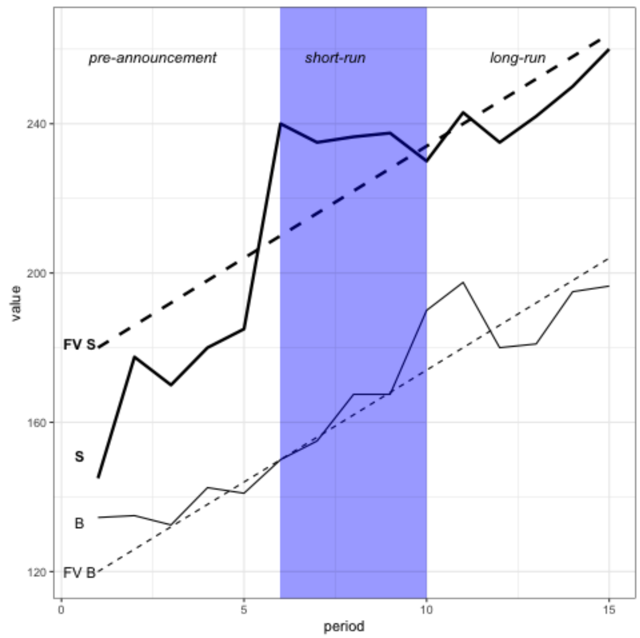


Figure 2: Fundamental and market value in the *SS* treatment. The fundamental market value of each asset (dashed lines) is normalized to one pre-announcement, and following the conversion period (period 6) is adjusted based on the new number of shares in the market (2) such that the total fundamental market value is not altered by the conversion. The short-run, periods 6-10, are shaded. B is the benchmark share and S the converted share. The solid lines represent the price per share (adjusted).

Table 4: Summary of results for *SS* treatment

	pre-announcement $1 \leq \tau \leq 5$		short-run $6 \leq \tau \leq 10$		long-run $11 \leq \tau \leq 15$	
	S	B	S	B	S	B
RD	-0.13	0.06	0.09	0.03	-0.05	-0.06
$RD_{S/B}$	-0.18	–	0.08	–	0.00	–
Order imbalance	2.40	1.25	-5.32	1.38	-6.30	-1.21
Asset turnover	2.17	2.11	1.33× 2	1.51	0.94× 2	1.17

Note: S is the converted share, and B is the benchmark share. All variables of study are defined in Table 2, and are presented using averages per period. In our statistical analysis, volume is divided by 2 in the short-run and long-run periods in order to have a fair comparison with respect to B after the announcement period.

Next, we report the various measures of deviations, order imbalance and asset turnover first introduced in Table 2, and then we formally test the impact of a share conversion on these measures. Overall, asset B shows a very little deviation with respect to its FV, as measured by RD, in all three stages of the *SS* treatment according to Table 4 which presents per period averages of the measures presented in Table 2. By contrast, the RD for asset S suggests a difference in pricing behavior across the three stages. In the periods leading up to the split announcement, asset S is undervalued by about 13 percent on average. Then, it is overvalued by about 9 percent in the short-run periods, and in the long-run, S approaches its FV. The RD of *relative* prices, $RD_{S/B}$, which looks at the relative pricing of both assets with respect to their FVs, confirms that both assets approach the FV in the long-run. In the pre-announcement periods, this relative measure shows a nearly 18 percent deviation suggesting that asset S is initially underpriced relative to asset B, and in the short-run it suggests that asset S is overvalued by 8 percent. In the long-run, the relative mispricing of both assets decreases and approaches zero.

The order imbalance measure in Table 4 reveals whether there is any upward or downward pressure on the price of an asset by taking stock of the relative numbers of bid versus ask orders. We see that for both assets in the pre-announcement periods, the order imbalance is positive which means that there is an excess of buy orders relative to sell orders. One can explain the larger imbalance observed for asset S (2.40) compared to asset B (1.25) by the relative underpricing of asset S in these pre-announcement periods: asset S is selling at a discount. The adjustment of prices generally follows the order imbalance: a positive imbalance indicates that prices will adjust upwards, as is the case in the pre-announcement period.

In the immediate short-run period we observe the reverse pattern for asset S. Given that asset S has become overpriced with the split, there should be a downward pressure on prices, which is confirmed by a negative order imbalance of -5.32. Further, we do not observe any significant changes in the sign of the order imbalance for asset B, which serves as a benchmark. In the long-run, the order imbalance decreases for both assets, which suggests lower demand as prices converge to fundamentals. Asset turnover, defined as the average market quantity transacted each period, is about 2 for assets S and B in the pre-announcement periods, and decreases to about 1 in the long-run. This follows the tradition in SSW experiments where as prices converge to fundamentals, there is less incentive to trade.

Result 1: *There is an increase in the total market value of the split S asset in the short run of the SS treatment as compared to the baseline asset B.*

Table 5 reports on a regression analysis of various market measures for the SS treatment. Specifically, we study the impact of stock splits on: (1) overpricing as measured by RD, (2) relative overpricing, as measured by $RD_{S/B}$, (3) order imbalance, and (4) asset turnover. The independent variables include SR, which is a dummy variable equal to 1 for the immediate post-split *short-run* period where $\tau \in [6, 10]$, LR which is a dummy variable for the *long-run* period $\tau \in [11, 15]$, S which takes the value of 1 for asset S, and 0 otherwise, and lastly 2 interaction terms. The constant across all specifications shows the relationship between the aforementioned measures and asset B in the pre-announcement periods.

Table 5: Market measures for the SS treatment (OLS)

	(1) RD	(2) $RD_{S/B}$	(3) order imbalance	(4) asset turnover
constant	0.060	-0.180***	1.253	2.114***
	(0.045)	(0.035)	(1.365)	(0.344)
SR	-0.033	0.261***	0.130	-0.600**
	(0.064)	(0.041)	(1.128)	(0.247)
LR	-0.119*	0.180***	-2.462*	-0.943***
	(0.071)	(0.016)	(1.467)	(0.204)
S	-0.192***	—	1.147	0.057
	(0.044)		(0.779)	(0.208)
$S \times SR$	0.255***	—	-7.875***	-0.243
	(0.046)		(1.366)	(0.206)
$S \times LR$	0.199***	—	-6.237**	-0.286
	(0.034)		(2.459)	(0.285)
N	174	75	210	210
R^2	0.264	0.465	0.240	0.128

Notes: S is the converted asset, and B is the benchmark asset (captured by the constant). All dependent variables are defined in Table 2. In our statistical analysis, volume is divided by 2 in the short-run (SR, periods 6-10) and long-run (LR, 11-15) periods to have a fair comparison with respect to B. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

In specification (1) we find that asset S is underpriced in the pre-announcement period, and overpriced in the short-run (p-value of 0.001 using a Wald test). In the long-run, we fail to reject that the relative deviation is different from zero (p-value of 0.716 using a Wald test). For the baseline asset B, which does not undergo a conversion, we fail to reject that the relative deviation of prices with respect to the FV is zero for all time periods. The overpricing of asset S in the short-run is confirmed by specification (2), which studies the RD of relative prices, and shows that the sum of coefficients is 0.081 (p-value < 0.001). This suggests that the relative price of S/B is higher than the relative FVs.

Result 2: *The order imbalance for the split asset S is significantly negative following the split announcement.*

We fail to reject that order imbalance for asset B is significantly different than zero (p-value < 0.05). However we find that for asset S, the order imbalance is significantly negative in both the short-run and long-run periods. As mentioned above, a negative order imbalance means that the number of sell orders (asks) is greater than the number of buy orders (bids). This suggests that adjustment of prices for asset S should be downward following the split announcement. Study of the order imbalances for the two assets suggests that, despite the different fundamental structure between them, asset B serves as a good benchmark for capturing the changes in the order imbalance driven by the conversion.

Result 3: *Asset turnover is not significantly affected by the split in the SS treatment.*

According to Table 5 asset turnover tends to decrease over time for the benchmark asset, and the split asset, when adjusted for the increased number of shares. Overall, we do not see a major difference in turnover across both assets. The convergence of prices to FV in the long-run creates less incentive to trade.

4.2 Reverse stock split treatment

Figure 3 provides an overview of the effect of a reverse split in the RS treatment, showing the market value (using median prices) of assets $\tilde{S}$ and $\tilde{B}$ per period over the 15 periods of the second market for all 7 sessions. As in the analysis of treatment SS, we observe that the announcement affects the trajectory of the market value for $\tilde{S}$ even though the fundamental market value was not altered.[13]

[13] In Appendix C, we provide complete graphs showing prices in *both* markets for each session, and Appendix D provides our main regression results controlling for the session effects. Given the larger departures of prices with respect to fundamentals in the first market, we do not observe an impact of

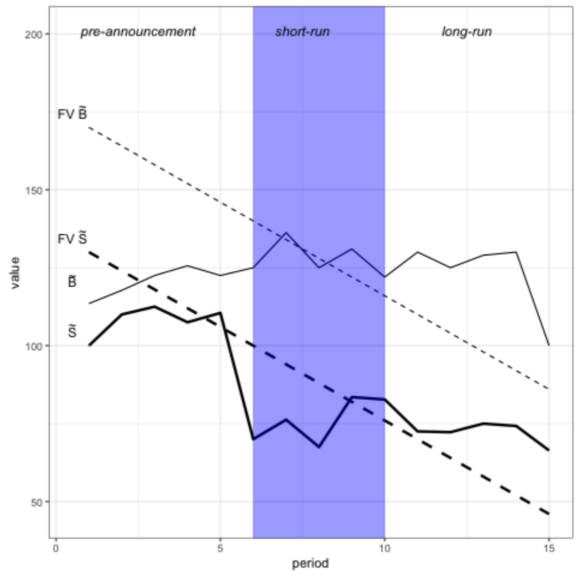


Figure 3: Fundamental and market value in the *RS* treatment. The fundamental value of each asset (dashed lines) is normalized to one in pre-announcement, and following the conversion period (period 6) is adjusted based on the new number of shares in the market (1/2) such that the total fundamental market value is not altered by the conversion. The short-run, periods 6-10, are shaded. B is the benchmark share and S the converted share. The solid lines represent the price per share (adjusted).

Consistent with the initial price dynamics observed in the *SS* treatment, the asset with the higher FV, in this case asset $\tilde{B}$, is underpriced relative to its FV in the pre-announcement periods. In the short-run periods following the reverse split (periods 6-10), we observe that asset $\tilde{B}$ is closer to its FV while asset $\tilde{S}$, which undergoes a reverse split, becomes underpriced relative to the FV.

Table 6: Summary of results for *RS* treatment

	pre-announcement $1 \leq \tau \leq 5$		short-run $6 \leq \tau \leq 10$		long-run $11 \leq \tau \leq 15$	
	$\tilde{S}$	$\tilde{B}$	$\tilde{S}$	$\tilde{B}$	$\tilde{S}$	$\tilde{B}$
RD	-0.06	-0.21	-0.10	0.03	0.27	0.26
$RD_{\tilde{S}/\tilde{B}}$	0.17	–	-0.13	–	0.00	–
Order imbalance	3.24	4.87	2.78	1.37	1.57	-0.76
Asset turnover	2.43	2.29	1.82÷2	1.94	2.63÷2	1.71

Note: $\tilde{S}$ is the converted asset, and $\tilde{B}$ is the benchmark asset. All variables are defined in Table 2, and are presented using averages per period. In the short-run and long-run periods, volume is multiplied by 2 for the converted share $\tilde{S}$ for a fair comparison with respect to $\tilde{B}$.

reverse splits on RD or relative RD.

Table 6 presents per period averages of the various asset market measures. The RD measure suggests that in the pre-announcement period, the asset with the lower FV (asset $\tilde{S}$) is priced closer to the FV (-0.06), while the asset with the higher FV (asset $\tilde{B}$) is underpriced (-0.21). In the short-run period following the reverse split announcement, $\tilde{B}$ is now priced closer to FV (0.03), while $\tilde{S}$ is underpriced (-0.10). Bubbles appear in the long-run for both assets $\tilde{S}$ and $\tilde{B}$ (as measured by the long-run RDs of 0.27 and 0.26, respectively). The RD of relative prices shows that while asset $\tilde{S}$ is overpriced relative to asset $\tilde{B}$ in the pre-announcement periods, it becomes underpriced in the immediate short-run periods following the reverse split. In the long-run, we observe that the relative price dispersion decreases significantly.

The order imbalance, which indicates whether there is price pressure on an asset, is positive for all periods and both assets in the *RS* treatment, except for $\tilde{B}$ in the long-run. Positive imbalance suggests that prices should move in an upward direction, as there is an excess of bids relative to asks. In the short-run, we observe that order imbalance decreases for asset $\tilde{B}$ compared to the pre-announcement periods, but it does not change much for asset $\tilde{S}$. Thus, the direction of price adjustment for asset $\tilde{S}$ is mostly upward, but less so than for the benchmark asset. It should be noted that the price for asset $\tilde{S}$ should increase following the reverse split, but we do not observe a sufficient adjustment as evident by the negative RD measure. In the long-run, the order imbalance decreases for both assets, and becomes negative for asset $\tilde{B}$. It is important note that the order imbalance is greater than zero for the benchmark asset in the pre-announcement and short-run periods, which is consistent with the documented pattern of bubbles (and later crashes) in the SSW environment when the FV has a downward trend.

The measure of asset turnover is generally similar for both assets in the *RS* treatment. In the pre-announcement period, asset turnover is 2.43 for $\tilde{S}$ and 2.29 for $\tilde{B}$ and in the short-run and long-run, we multiply the turnover in asset $\tilde{S}$ by two to account for the conversion (in this case, a reduction of shares). The adjusted asset turnover is 1.82 for $\tilde{S}$ and 1.94 for $\tilde{B}$ in the short-run, and 2.63 for $\tilde{S}$ and 1.71 for $\tilde{B}$.

Result 4: *The relative price of $\tilde{S}$ (with respect to $\tilde{B}$) is close to the FVs of the assets after the announcement in the RS treatment.*

We formally test the impact of a reverse split on the relative deviation (RD) measure

Table 7: Market measures for the *RS* treatment (OLS)

	(1) *RD*	(2) $RD_{\tilde{S}/\tilde{B}}$	(3) order imbalance	(4) asset turnover
constant	-0.208***	0.167**	4.866***	2.286***
	(0.033)	(0.073)	(0.873)	(0.296)
SR	0.235***	-0.299**	-3.493***	-0.343
	(0.044)	(0.133)	(0.823)	(0.268)
LR	0.466***	-0.168**	-5.627***	-0.571**
	(0.048)	(0.068)	(1.053)	(0.263)
$\tilde{S}$	0.146***	—	-1.627	0.143
	(0.048)		(1.013)	(0.211)
$\tilde{S} \times SR$	-0.271**	—	3.029**	-0.257
	(0.106)		(1.411)	(0.416)
$\tilde{S} \times LR$	-0.132***	—	3.962***	0.771
	(0.043)		(0.959)	(0.593)
N	164	67	210	210
R^2	0.548	0.248	0.121	0.037

Note: $\tilde{S}$ is the converted asset, and $\tilde{B}$ is the benchmark share, captured by the constant. All dependent variables are defined in Table 2. In our statistical analysis, volume is multiplied by 2 in the short-run (SR, periods 6-10) and long-run (LR, 11-15) periods in order to have a fair comparison with respect to *B*. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

in the first specification of Table 13, using OLS regressions. In the first regression we see that in the pre-announcement period the asset with the higher FV, $\tilde{B}$, is significantly undervalued while the asset with the lower FV, $\tilde{S}$, is priced closer to its FV.[14] In the short-run period, following the reverse split, we fail to reject that asset $\tilde{B}$ is priced at its FV when we test whether the sum of the coefficients $(0.230 - 0.208)$ is different from zero (p-value of 0.66). For asset $\tilde{S}$ in the short-run, there is weak evidence that it is under-priced (p-value of 0.07). In the long-run, we find that asset $\tilde{B}$ is over-priced (p-value < 0.001) as is asset $\tilde{S}$ (p-value < 0.001).

In specification (2), which uses the RD of relative prices as the dependent variable, we observe that asset $\tilde{S}$ is overvalued with respect to asset $\tilde{B}$ (p-value < 0.05) in the pre-announcement period, and that the prices are closer to fundamentals in the short-run (p-value of 0.14) and long-run (p-value of 0.89).

[14] A Wald test of whether the value of the constant coefficient plus the coefficient on $\tilde{S}$ is equal to zero yields a p-value of 0.26.

Result 5: *The order imbalance is strongly positive in the pre-announcement and short-run periods for asset* $\tilde{S}$*, and decreasing in the long-run.*

The benchmark asset $\tilde{B}$ has a higher initial FV, and therefore its price adjusts upwards in the short-term due to an excess of bid orders. In later periods, we observe that prices move closer relative to their FVs, and the order imbalance decreases (all p-values < 0.001). For the asset that undergoes a conversion $\tilde{S}$, we also observe a strongly positive order imbalance in the pre-announcement periods (p-value < 0.001) and in the short-run periods (p-value of 0.02), as prices continue to adjust upwards. In the long-run, the order imbalance of asset $\tilde{S}$ is not different from zero (p-value of 0.11).

Result 6: *Asset turnover does not change in the short-run, and decreases for all assets in the long-run in the RS treatment*

In the pre-announcement period we observe that an average of two units are transacted per period. In the long run, the number of units transacted for both assets decreases by 0.57 (p-value < 0.05) according to specification (4) in Table 13, which reflects less trading activity as relative prices move closer to fundamental values.

5 Cognitive ability and price adjustment

As noted earlier, following the completion of the two asset markets, subjects in both treatments answered three CRT questions taken from Toplak et al. (2014). For both treatments, the percentage of correct responses is about 60% for each question, with 40% of subjects answering all three questions correctly. On average, subjects answered about two of the three questions correctly.[15]

In order to better understand the under-reaction of asset prices to stock (reverse) split announcements, we use regression analysis to study the relationship between a subject's cognitive ability (proxied by their CRT score) and the deviations in their bids and asks relative to the FV. These results are presented in Table 8 for the *SS* treatment, and Table 9 for the *RS* treatment. We report the results of OLS regressions with standard errors clustered at the session level, where the dependent variable is the

[15]Using the Spearman's rank correlation, we also find that there is a weak positive correlation between final earnings and CRT scores of 0.1 (0.2) for the *SS* (*RS*) treatment.

absolute value of the bid order for asset S relative to the FV in specification (1), and the absolute value of the ask order relative to the FV for asset S in specification (2). Specifications (3) and (4) employ the same approach for asset B. For independent variables we use period dummies SR (to capture the short-run periods 6-10) and LR (to capture the long run periods 11-15); each subject's CRT score; and interaction terms.

Table 8: CRT and orders relative to the FV for SS treatment (OLS regression)

	(1)	(2)	(3)	(4)
	|Bid S/FV S-1|	|Ask S/FV S-1 |	|Bid B/FV B -1 |	|Ask B/FV B -1 |
constant	0.53***	0.42***	0.49***	0.39***
	(0.034)	(0.081)	(0.044)	(0.061)
SR	0.05	0.12	-0.083**	-0.032
	(0.052)	(0.108)	(0.042)	(0.063)
LR	-0.072	-0.068	0.014	-0.034
	(0.048)	(0.108)	(0.091)	(0.085)
CRT	-0.078***	-0.046	-0.069**	-0.003
	(0.020)	(0.028)	(0.029)	(0.027)
$SR \times CRT$	-0.036***	-0.010	0.014	-0.032
	(0.013)	(0.059)	(0.015)	(0.028)
$LR \times CRT$	0.005	-0.002	-0.006	-0.055*
	(0.0271)	(0.0525)	(0.0346)	(0.0291)
N	643	678	657	546
R^2	0.085	0.045	0.068	0.045

Note: S is the split asset, and B is the benchmark asset. The CRT score uses all three questions. SR includes periods 6-10 and LR includes periods 11-15. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

The constant term in all regression specifications can be interpreted as the absolute deviation from the FV for subjects who answer all CRT questions incorrectly (have a score of zero) for the pre-announcement period. We find that subjects who score zero on the CRT submit orders which are far from the FV, as demonstrated by the statistically and economically significant coefficients of about 0.40-0.50. It is also interesting to see that generally the deviations do not decrease in the short-run or the long-run, since the coefficients on the SR and LR dummies are not statistically different from zero for the most part. A higher CRT score (for a maximum of 3) leads to smaller deviations from the FVs for the bid orders, but not for the ask orders. The coefficient on CRT and the interaction term $SR \times CRT$ is negative in specification (1). For the benchmark asset

B, we observe a negative coefficient on the CRT for the bid orders (specification 3), but it is not statistically different than zero for the ask orders (specification 4). Thus, we conclude that subjects with higher CRT scores adapt more readily to changes in fundamentals. These findings may help explain the order imbalances presented in Tables 5: subjects with low CRT scores slow the convergence to new the FV for the split asset, S. The fact that the interaction term $SR \times CRT$ score does not play a very important role in bids for the benchmark asset B, which does not undergo a conversion, supports this intuition.

Table 9: CRT and orders relative to FV for RS treatment (OLS)

	(1) $\lvert$Bid $\tilde{S}$/FV $\tilde{S}$-1$\rvert$	(2) $\lvert$Ask $\tilde{S}$/FV $\tilde{S}$-1 $\rvert$	(3) $\lvert$Bid $\tilde{B}$/FV $\tilde{B}$ -1 $\rvert$	(4) $\lvert$Ask $\tilde{B}$/FV $\tilde{B}$ -1 $\rvert$
constant	0.58***	0.67***	0.59***	0.65***
	(0.052)	(0.078)	(0.058)	(0.059)
SR	0.05*	0.21*	-0.08**	-0.00
	(0.027)	(0.115)	(0.043)	(0.066)
LR	0.05	0.32**	0.06	0.19
	(0.032)	(0.147)	(0.048)	(0.123)
CRT	-0.11***	-0.15***	-0.10***	-0.13***
	(0.026)	(0.028)	(0.021)	(0.022)
$SR \times CRT$	-0.00	-0.04	-0.01	-0.00
	(0.015)	(0.040)	(0.016)	(0.040)
$LR \times CRT$	-0.02	-0.02	-0.04*	0.03
	(0.020)	(0.062)	(0.022)	(0.043)
N	814	508	763	647
R^2	0.159	0.091	0.182	0.052

Note: $\tilde{S}$ is the split asset, and $\tilde{B}$ is the benchmark asset. The CRT score uses all three questions. SR includes periods 6-10 and LR includes periods 11-15. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

To analyze subject behavior in the RS treatment, we present similar OLS regressions in Table 9. We also observe important deviations from the orders submitted relative to the FV by subjects who answered all CRT questions incorrectly; as the constant term is positive and statistically different than zero for all specifications. We find that subjects with higher CRT scores tend to submit orders closer to the FVs, as the coefficient on CRT is negative and statistically different than zero for all specifications. Compared to the SS treatment, the evidence of adjustment in the short-run is less clear in the RS treatment as demonstrated by the lack of a statistically significant coefficient on the interaction term $SR \times CRT$. We summarize our results as follows,

Result 7: *Subjects with a higher CRT scores submit orders that are closer to the FV.*

6 Conclusion

We report on a controlled laboratory experiment with the aim of better understanding asset pricing anomalies in the immediate aftermath of a stock market split or reverse split. As a counterfactual exercise, we also consider the pricing of a similar asset that do es not experience a split (or reverse split). In the SS treatment (a 1 for 2 share split) we find that the split asset is overpriced relative to its FV in the short-run period immediately following the split announcement while the non-converted asset is fairly priced. In the long run, the price of the split asset reverts to its FV. In the RS treatment (a 2 for 1 *reverse* share split) the price of the split asset falls below the FV in the immediate aftermath of the reverse split announcement, while the non-converted asset is priced more fairly. Thus, we show that under both settings markets *underreact* to splits, or that there is no full adjustment necessary to be consistent with the new fundamental value. The measure of order imbalance helps us understand the nature of price adjustments in the aftermath of the split announcement. In the SS treatment, the split asset has a negative order imbalance, suggesting that prices adjust downwards. Further, for both treatments, we find no evidence of a change in asset turnover following the split announcements.

The laboratory provides an ideal environment to study market reactions to stock splits because it allows us to control the FVs of the assets pre- and post- split and to account for survival bias (Brown et al., 1995). Moreover, our results capture some of the anomalies observed in field data.[16] Our design further allows us to highlight the importance of heterogenity of individual behavior for explaining market phenomena (see also Daniel et al., 2020 and references therein) while controlling for the signaling effects of such events. We provide further evidence of the relationship between cognitive ability and the bids and asks of market participants. Our findings show that subjects with higher CRT scores submit orders that are closer to the fundamental values as compared to subjects with lower CRT scores. In the SS treatment, we clearly observe that subjects with higher CRT score adjust their orders in response to the split

[16] Fink et al. (2020) also provide evidence of abnormal returns following earnings announcements.

announcement suggesting that such subjects are able to easily adapt to the event.

In studying the market's reaction to stock splits in a laboratory experiment, we have tremendous internal validity (causal inference) but our findings might be viewed more skeptically on the external validity dimension in that our student subjects are not professional market traders. Further, there may be important elements of financial markets that we abstract from in our experimental design. For instance, it may be that stock splits provide market signals attracting traders from the sidelines and/or speculators who would not otherwise be present.[17]

Nevertheless, we believe there are good reasons to think that our results should generalize to the field. For example, using archival data, Grinblatt et al. (2011) finds that higher-IQ investors achieve better performance (Sharpe ratios). Furthermore, Weitzel et al. (2020) find that financial market professionals are also susceptible to asset market bubbles and crashes in experimental asset markets of the SSW variety and that these professionals do not differ from student subjects in their performance on CRT tests (their questions are similar to those used in our experiment).[18] While our results are consistent with the literature studying the role of cognitive ability on trader performance, our finding that market reactions to events such as splits and reverse splits can also be explained by individual characteristics provides a greater context for the cognitive-biases explanation for financial market behavior. For all of these reasons, we think that our experimental findings are relevant to understanding the market's reactions to stock splits, and that laboratory methods should continue to play a complementary role with archival data in understanding this phenomenon.

[17] As noted earlier, investors can now easily buy fractions of shares. Thus, it is not clear why splitting a stock and lowering its price should attract investors who were sitting on the sidelines waiting for a price cut, though we cannot rule out this possibility.

[18] More generally, Frechette (n.d.) surveys experimental studies comparing professionals versus students and finds, remarkably, that in only 1 study out of 13 is the behavior of professionals closer to theoretical predictions than that of students.

Appendix A: User Interface

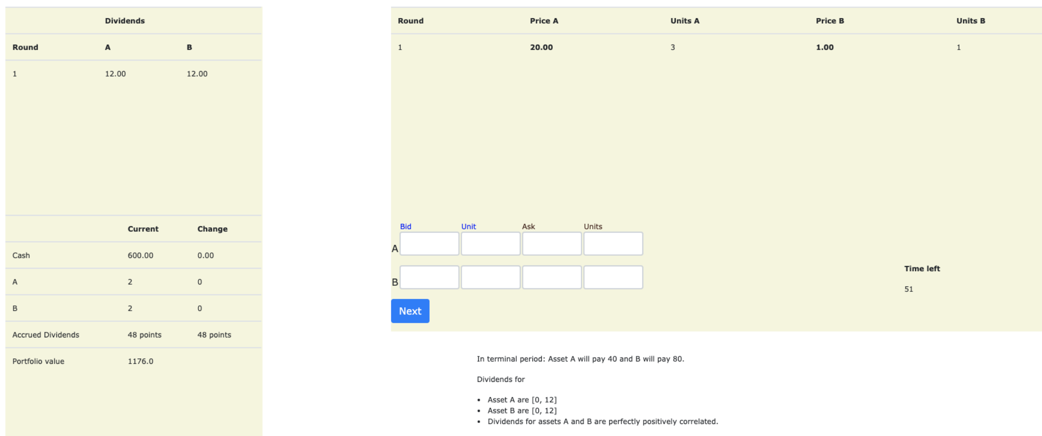
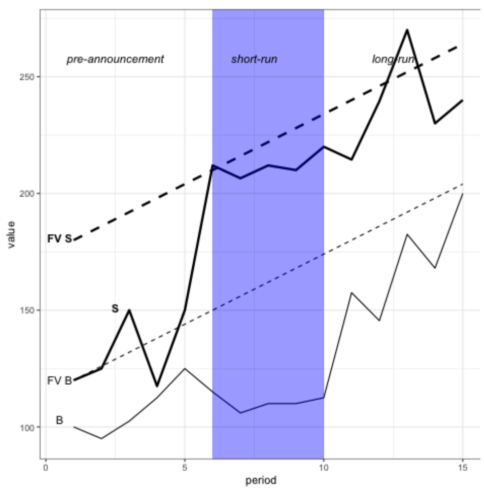


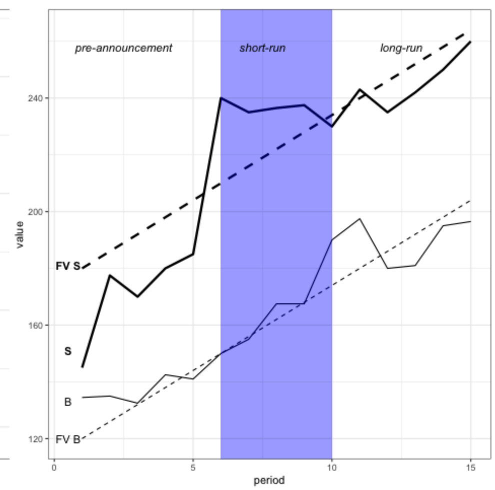
Figure 4: User interface for the *RS* treatment.

Notes: The top right panel of the screen displays the market clearing prices and the volume of trade in the two assets while the top left panel displays the dividends earned per share of each asset in each period (in this example, both assets earned a dividend of \$12). The bottom left panel shows the trader's asset holdings and cash. The Accrued Dividends (in this example $48 = 12 \times 2 + 12 \times 2$) are put into a separate account which is not available for trading. The column labeled 'change' refers to recent flows of variables. The Portfolio value use cash and the terminal value per asset plus the sum of expected dividends for the future periods ($1176 = 600 + 2 \times [40 + 6 \times 14 + 80 + 6 \times 14]$). The bottom center panel displays white input boxes where subjects entered their buy/sell orders: how much they wanted to bid per unit of Asset A or B, the number of units to bid for, how much they wanted to ask per unit of Asset A or B and how many units they wanted to sell of each. At the bottom right is a timer counting down the time remaining in the market.

Appendix B: Price plots for the SS treatment



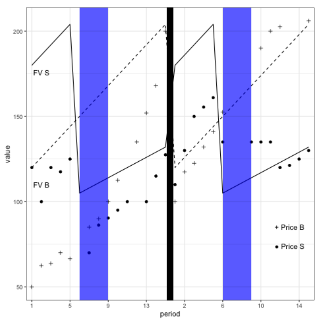
(a) First market



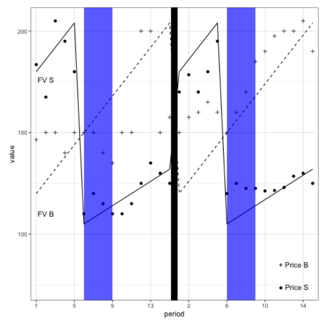
(b) Second market

Figure 5: Fundamental and market value in the SS treatment

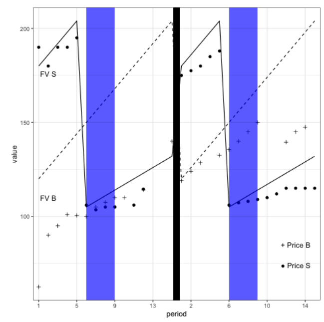
Note: The fundamental market value of each asset (dashed lines) is normalized to one pre-announcement, and following the conversion period (period 6) is adjusted based on the new number of shares in the market (2) such that the total fundamental market value is not altered by the conversion. The short-run, periods 6-10, are shaded. B is the benchmark share and S the converted share. The solid lines represent the price per share (adjusted).



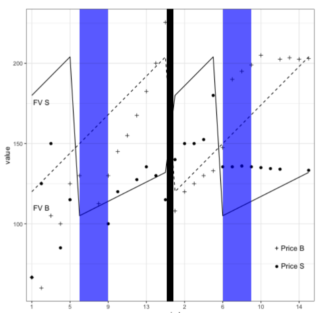
(a) Session 1



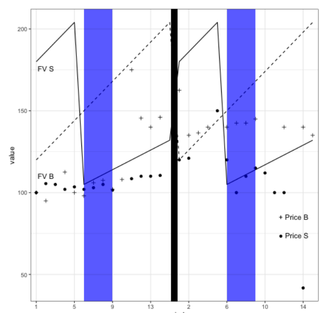
(b) Session 2



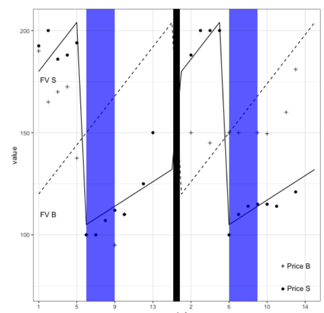
(c) Session 3



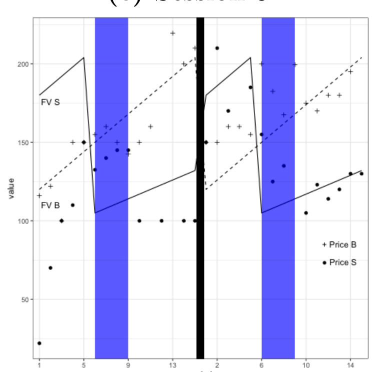
(d) Session 4



(e) Session 5



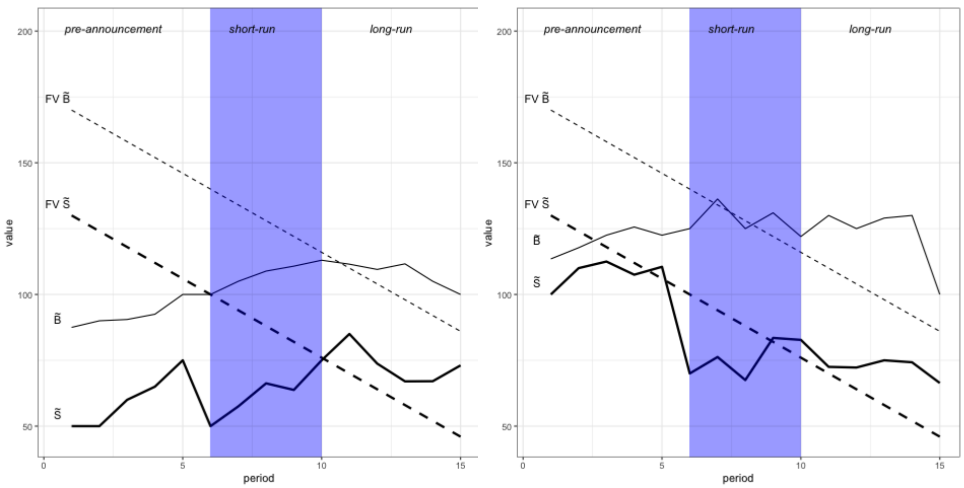
(f) Session 6



(g) Session 7

Figure 6: Asset prices and fundamental values per period (2 markets).

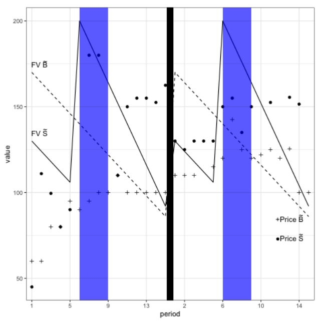
Appendix C: Price plots for the RS treatment



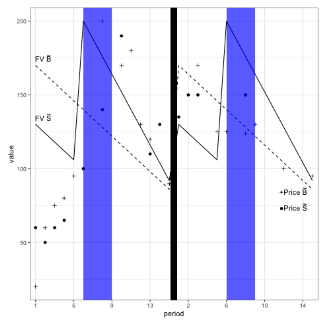
(a) First market **(b)** Second market

Figure 7: Fundamental and market value in the RS treatment

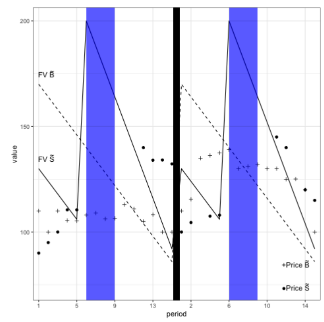
Note: The fundamental value of each asset (dashed lines) is normalized to one pre-announcement, and following the conversion period (period 6) is adjusted based on the new number of shares in the market (1/2) such that the total fundamental market value is not altered by the conversion. The short-run, periods 6-10, are shaded. B is the benchmark share and S the converted share. The solid lines represent the price per share (adjusted).



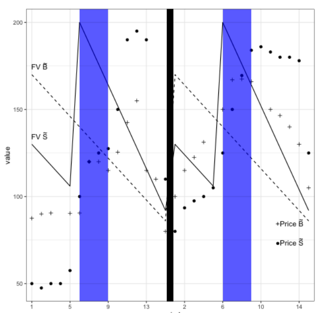
(a) Session 1



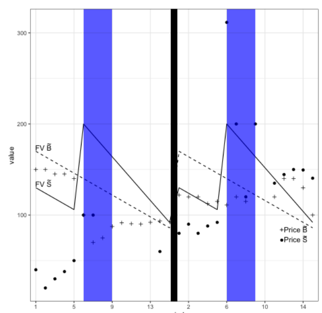
(b) Session 2



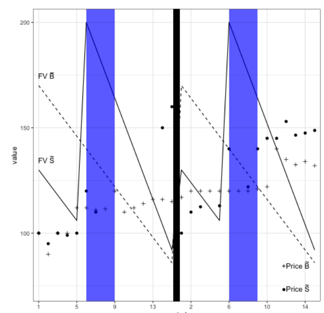
(c) Session 3



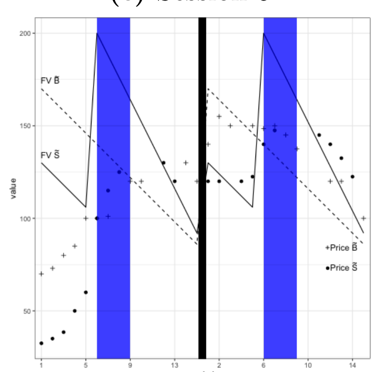
(d) Session 4



(e) Session 5



(f) Session 6



(g) Session 7

Figure 8: Asset prices and fundamental values per period (2 markets).

Appendix D: Additional regressions

Table 10: Market measures for the *SS* treatment (OLS) adding market fixed effects

	(1) RD	(2) $RD_{S/B}$	(3) order imbalance	(4) asset turnover
constant	0.682***	-0.0753*	2.92*	2.308***
	(0.164)	(0.0402)	(1.499)	(0.301)
SR	-0.596***	0.0923**	-2.147*	-0.714***
	(0.206)	(0.0450)	(1.276)	(0.250)
LR	-0.650***	0.0249	-4.161**	-1.257***
	(0.210)	(0.0284)	(1.486)	(0.205)
S	-0.829***	—	1.147	0.707
	(0.168)		(1.124)	(0.131)
$S \times SR$	0.449***	—	-7.181***	-0.429**
	(0.157)		(1.328)	(0.186)
$S \times LR$	0.392**	—	-7.672***	-0.364***
	(0.159)		(1.124)	(0.130)
N	351	310	420	420
R^2	0.428	0.689	0.246	0.207

Notes: S is the converted asset, and B is the benchmark asset (captured by the constant). All dependent variables are defined in Table 2. In our statistical analysis, volume is divided by 2 in the short-run (SR, periods 6-10) and long-run (LR, 11-15) periods to have a fair comparison with respect to B. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

Table 11: Market measures for the *RS* treatment adding market fixed effects (OLS)

	(1) RD	(2) $RD_{\tilde{S}/\tilde{B}}$	(3) order imbalance	(4) asset turnover
constant	-0.171***	-0.0986	6.649***	2.562***
	(0.0242)	(0.0707)	(1.172)	(0.308)
SR	0.175***	0.0959	-5.547***	-0.814***
	(0.0396)	(0.122)	(1.328)	(0.195)
LR	0.333***	0.279***	-7.215***	-0.971***
	(0.0274)	(0.0866)	(1.858)	(0.228)
$\tilde{S}$	0.0376	—	-1.572	0.500***
	(0.0518)		(1.240)	(0.125)
$\tilde{S} \times SR$	-0.00520	—	1.473	-0.643**
	(0.0706)		(1.537)	(0.298)
$\tilde{S} \times LR$	0.150***	—	1.935	0.171
	(0.0475)		(1.434)	(0.257)
N	331	266	420	420
R^2	0.760	0.137	0.183	0.088

Note: $\tilde{S}$ is the converted asset, and $\tilde{B}$ is the benchmark share, captured by the constant. All dependent variables are defined in Table 2. In our statistical analysis, volume is multiplied by 2 in the short-run (SR, periods 6-10) and long-run (LR, 11-15) periods in order to have a fair comparison with respect to B. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

Table 12: Robustness check Order Imbalance (OLS) for *SS* treatment

	(1) $\delta = 0.96$	(2) $\delta = 0.97$	(3) $\delta = 0.98$	(4) $\delta = 0.99$
constant	-0.06	0.27	1.25	4.68**
	(1.033)	(1.144)	(1.365)	(2.132)
SR	-0.41	-0.37	0.13	3.39
	(1.017)	(1.050)	(1.128)	(2.228)
LR	-1.50	-1.80	-2.462*	-3.65*
	(1.209)	(1.303)	(1.467)	(1.893)
S	1.38**	1.41**	1.15	-0.25
	(0.546)	(0.606)	(0.779)	(1.378)
$S \times SR$	-6.44***	-6.91***	-7.875***	-11.68***
	(1.204)	(1.227)	(1.366)	(2.991)
$S \times LR$	-6.351**	-6.54**	-6.237**	-5.01
	(2.042)	(2.146)	(2.459)	(3.232)
N	174	210	210	210
R^2	0.27	0.27	0.24	0.11

Notes: S is the converted asset, and B is the benchmark asset (captured by the constant). SR, periods 6-10, and long-run, LR, periods 11-15 periods. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

Table 13: Robustness check Order Imbalance (OLS) for *RS* treatment

	(1) $\delta = 0.96$	(2) $\delta = 0.97$	(3) $\delta = 0.98$	(4) $\delta = 0.99$
constant	3.16***	3.78***	7.34***	2.286***
	(0.903)	(0.926)	(0.873)	(0.765)
SR	-2.63**	-2.94***	-3.493***	-4.82***
	(0.782)	(0.798)	(0.823)	(1.000)
LR	-4.43***	-4.87***	-5.627***	-7.41***
	(0.968)	(1.017)	(1.053)	(1.281)
$\tilde{S}$	-1.62	-1.68*	-1.627	-1.33
	(0.954)	(0.987)	(1.013)	(1.158)
$\tilde{S} \times SR$	2.36**	2.64**	3.029**	3.93**
	(1.161)	(1.281)	(1.411)	(1.592)
$\tilde{S} \times LR$	3.25***	3.55***	4.79***	3.93***
	(0.923)	(0.921)	(0.959)	(1.145)
N	210	210	210	210
R^2	0.12	0.12	0.12	0.11

Note: $\tilde{S}$ is the converted asset, and $\tilde{B}$ is the benchmark share, captured by the constant. All dependent variables are defined in Table 2. In our statistical analysis, volume is multiplied by 2 in the short-run (SR, periods 6-10) and long-run (LR, 11-15) periods in order to have a fair comparison with respect to B. Standard errors are clustered at the session level and computed via bootstrapping. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.1$

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