Price Limits and Overreaction

Yong H. Kim* and J. Jimmy Yang

University of Cincinnati, Cincinnati, OH 45221, U.S.A.

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Abstract

We test two hypotheses to investigate whether price limits reduce or induce overreaction. The first hypothesis is called the cooling-off hypothesis, which suggests that price limits can reduce overreaction because they provide a cooling-off period for investors to re-evaluate market information and make more rational trading decisions. To test this hypothesis, we identify three different limit hits, namely, closing limit hits, single limit hits, and consecutive limit hits. The cooling-off hypothesis is only supported by consecutive limit hits. The second hypothesis is called the magnet hypothesis, which suggests that price limits induce overreaction because investors may rush to submit orders when prices are approaching the limits disregarding that those orders do not meet their optimal trading strategy. We test this hypothesis by examining return autocorrelations, trading volume, and relative spread. We find support for the magnet hypothesis in our measures of trading volume and relative spread, but no support from the return autocorrelations. Overall we conclude that price limits induce overreaction when the price is approaching the limit, but they also reduce overreaction when the limit price is traded at consecutively.

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*Corresponding author:

Professor Yong H. Kim
Department of Finance
University of Cincinnati
PO Box 210195
Cincinnati, OH 45221-0195
(513) 556-7084(O); (513) 556-0979(F)
E-mail: yong.kim@uc.edu

Price Limits and Overreaction

Behavioral finance has cast doubt on the market efficiency hypothesis and provided empirical evidence as well as theoretical models of market overreaction. Since the 1987 market crash, the Brady Report (1988) and several academic researchers have suggested the imposition of "circuit breakers" to prevent the market from fluctuating excessively due to investor overreaction. Even though the New York Stock Exchange (NYSE) implemented the circuit breaker mechanism on October 19, 1988, because the circuit breakers are rarely activated[1], we cannot be certain whether the circuit breakers actually reduce market overreaction. However, many countries in Asia have been imposing price limits, one form of circuit breakers, for decades. In general, price limits regulate the magnitude of the change in price that can occur for a given asset during a single trading session. The purpose of this paper is to examine whether price limits can reduce market overreaction by investigating a natural experiment from the Taiwan Stock Exchange (TSE), one of the major stock markets in Asia.

The most popular rationale for imposing price limits is to reduce market overreaction. From the proponents' point of view, price limits can provide a cooling-off period that allows investors to re-evaluate market information and make more rational decisions during periods of extreme price changes. Hence, price limits can reduce traders' overreaction and diminish price volatility. However, opponents of price limits argue that they serve no purpose other than to slow or delay the price discovery process (see, e.g., Fama, 1989). Even though price limits can stop the price of a share from falling or rising

[1] Circuit breakers were triggered for the first and only time on Oct. 27, 1997, when the DJIA fell 350 points at 2:35 p.m. and 550 points at 3:30 p.m. That reflected an approximate 7% overall decline and the market was closed for the remainder of the day. See Goldstein and Kavajecz (2000) for more detail.

at the limit on a given trading day, they argue that the price will continue to move in the direction towards equilibrium as new trading limits are established in subsequent trading day(s). Furthermore, rather than generating a stabilizing effect that calms market movements, price limits may have a magnet effect that acts to pull prices toward the limit. When prices move toward the limits, traders may rush to trade for fear that orders might not be executed if the limit is hit. That is, price limits induce investors' overreaction when prices are approaching the limits. The resolution of these two contrary arguments relies on empirical evidence.

The empirical literature does not definitively answer whether price limits reduce or induce overreaction. Studies that test directly for the effect of price limits use relatively small data sets and reach different conclusions. Besides, most studies examine the futures market rather than the stock market because there are price limits on futures markets but not on the stock market in the U.S.[2]. Studies investigating stock markets use data from Asian markets and focus only on daily stock prices. However, to determine whether price limits reduce or induce overreaction, transaction data rather than daily data should be used because the transitory volatility caused by overreaction is more clearly reflected in transaction data. For example, if the significant change in volatility occurs only during the first hour of trading before and/or after a limit hit, the use of daily data would fail to detect the real impact of price limits. Therefore, this paper examines transaction data in an effort to provide insight into the ongoing debate over the relation between price limits and overreaction.

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[2] We cannot generalize the results from futures markets to the stock market because of the different characteristics between them. For example, the difference in the degree of margin requirement, the mark-to-market feature in futures markets, and the market makers' obligation to provide liquidity on NYSE may affect investors' trading behavior between the futures markets and the stock market.

We test two hypotheses to investigate whether price limits reduce or induce overreaction. The first hypothesis is called the cooling-off hypothesis, which suggests that price limits can reduce overreaction because they provide a cooling-off period for investors to re-evaluate market information and make more rational trading decisions. To test this hypothesis, we identify three different limit hits, namely, closing limit hits, single limit hits, and consecutive limit hits. A closing limit hit occurs when a price hits the limit and no other trades occur the remainder of the day. A single limit hit occurs when a limit hit is followed by non-limit-hit transactions. Consecutive limit hits occur when a limit hit is followed by further trades at the limit price. The cooling-off hypothesis is only supported by consecutive limit hits. The second hypothesis is called the magnet hypothesis, which suggests that price limits induce overreaction because investors may rush to submit orders when prices are approaching the limits, even if those orders do not meet their optimal trading strategy. We test this hypothesis by examining return autocorrelations, trading volume, and relative spread.[3] We find support for the magnet hypothesis in our measures of trading volume and relative spread, but no support from the return autocorrelations. Overall we conclude that price limits induce overreaction when prices are approaching the limits, but they also reduce overreaction when the limit price is traded at consecutively.

This paper makes several contributions. This is the first paper to examine the relation between price limits and overreaction using transaction data. We believe that the use of transaction data better captures the transitory volatility caused by price limits than does daily data. Second, the empirical results support opponents' magnet effect argument and

[3] Description and formula are presented in Section IV.

demonstrate that the proponents' cooling-off effect argument is valid only for consecutive limit hits. Third, our method of distinguishing among different types of limit hits provides important insights into the effect of price limits on trading behavior. Lastly, our findings have important regulatory implications. Since price limits can reduce and induce overreaction, policy makers need to evaluate the net effect from price limits and set a rule to optimally reduce overreaction. For example, since the cooling-off hypothesis is supported by the consecutive limit hits, would a hybrid or combination of price limits and trading halts reduce overreaction more efficiently than only price limits or only trading halts?

The remainder of this paper is organized as follows. The next section provides the institutional background of the TSE. Section II discusses the theory and relevant empirical literature. Section III proposes two testing hypotheses. Section IV describes the data and sets out the research design. Section V presents the empirical findings and section VI concludes.

I. Institutional Background

According to the Monthly Bulletin of Statistics of the Republic of China (March, 2001), 531 stocks are listed on the TSE at the end of 2000. The total market value is New Taiwanese Dollar (NT$) 8,191,170 million (or about US$ 248.5 billion at the exchange rate of NT$ 32.96/US$). The average daily trading value is NT$112,640 million (US$ 3.4 billion), with daily trading value being the sum of the product of trading volume and the trading price for every transaction on any given trading day.

The TSE is an order-driven market with no market makers or specialists. Investors can submit either market orders or limit orders. Orders are accumulated and matched against each other via the automated central limit order book. Since there are no official market makers, the bid and ask quotations are the best prices in the limit order book provided by various traders. According to the Taiwan Stock Exchange Corporation (TSEC), the open outcry system has been gradually replaced since August 1985 by a computer-aided trading system (CATS), and was eventually upgraded to a fully automated securities trading (FAST) system in 1993. The trading session of the centralized market is 9:00 a.m. to 12:00 p.m., Monday through Friday. On the first, third, and fifth (if there is one) Saturdays of each month, trading also takes place from 9:00 a.m. to 12:00 p.m. Thirty minutes before the market opens, orders can be submitted via security firms and are ranked based on price-time priority. The opening price is the one that maximizes trading volume. Following the opening, orders are matched on a periodic basis till the closing with each round of clearing taking around one minute. The actual time interval of each round of clearing may vary slightly according to trading intensity.

The TSE has been imposing daily price limits since its inception in 1962. The purpose of the price limits is to avoid excessive volatility and to protect investors by limiting potential daily losses. The TSE sets its daily price limits at a predetermined rate, both upward and downward, based on the previous day's closing price. The price-limit rate has been adjusted up or down several times in accordance with the market conditions. Panel A of Table I provides the price-limit rates during different periods in year 2000. For stocks listed on the TSE, tick sizes (the minimum allowable unit that a stock price may change) vary with market prices. Panel B of Table I reports the tick size for each price range. In addition to the daily price limits, the clearing price in each round of matching cannot exceed two tick sizes from the clearing price in the preceding round. Stocks that hit their price limits are still allowed to trade as long as the transaction prices are within the limits. Thus, the TSE price limits are simply boundaries, not triggers for trading halts.

II. Literature Review

There are two important theoretical studies on price limits and circuit breakers. Brennan (1986) provides a theory of price limits in futures markets. He shows that price limits may act as a partial substitute for margin requirements in ensuring contract performance without resorting to costly litigation. However, the implementation of a daily price limit imposes clear costs on market participants by prohibiting trades at prices outside the limits. Subrahmanyam (1994) provides a model showing that a circuit breaker may actually increase price variability, thus increasing the probability that the price will reach the circuit breaker bounds if it is already very close to the breaker limit. If traders fear that a halt will occur before they can submit their orders, to increase the probability of execution they may submit them earlier than they would otherwise. This is called the gravitation effect or magnet effect.

Because there are no price limits imposed on the U.S. equity markets, most studies examine the futures markets to investigate the effects of price limits. Arak and Cook (1997) examine the U.S. Treasury bond futures market to test whether the daily price limits act as magnets to pull prices toward the limit. They find that the proximity to the limit tends to cause a small price reversal. In other words, the daily price limits act as a stabilizer in the futures markets. Chen (1998) investigates 19 futures contracts to test the overreaction hypothesis. The author finds little evidence to support the hypothesis. By arguing that futures prices are extremely noisy in the opening and closing minute, Chen uses the difference between the closing price on the event day and the average of the opening, closing, daily high and low prices on the next day to measure overreaction. However, Chen points out that transaction data appears to be superior to the average daily price in measuring overreaction.

Several studies examine the effects of price limits on stock prices. Kim and Rhee (1997) examine daily stock price data from the Tokyo Stock Exchange from 1989 to 1992 to test the effectiveness of price limits and find evidence that supports the arguments advanced by the opponents of price limits, i.e. delayed price discovery, volatility spillover, and trading interference. They then conclude that the price limit system of the Tokyo Stock Exchange may be ineffective. Choi and Lee (2001) examine both the inter-day and intra-day data from the Korean market to investigate the transitory and asymmetric properties of price limits. Using variance ratio tests and the modified Kim and Rhee (1997) method, they provide evidence of delayed price discovery due to price limits. They further show that the delayed price discovery and trading interference are transitory because they are resolved once the constraint of price limits is removed at the open on the next day following the limit days. More importantly, they identify the asymmetric feature of price limits by showing that price limits act differently on the upper and lower limit activities. They find that criticisms of price limits are partially supported by upper limit moves while price limits are found effective in the case of lower limit moves. Because of this asymmetric effect, they suggest a price-limit system with an upper limit wider than the lower limit to enhance market efficiency and reduce market volatility. However, the appropriate magnitude of limit rates is left for future studies. While this paper uses intra-day data, its major focus is on the first five transactions after the opening.

Recently, Cho et al. (2003) use the intraday data from Taiwan Stock Exchange to test the magnet effect of price limits. It is the first attempt to test the magnet effect using intraday data. They find a statistically and economically significant tendency for stock prices to accelerate toward the upper bound and weak evidence of acceleration toward the lower bound as the price approaches the limits. That is, the magnet effect is supported. However, their study is limited to the return generating process and has nothing to say about the informed investors' behavior. Besides, similar results from different thresholds used for the proximity to the limits cloud the magnet effect. If different levels of proximity to the limits generate similar results, there is no evidence of magnet effect. Based on Subrahmanyam (1994), if the price is very close to the limit, the price limit may actually increase price variability and the probability of the price crossing the limits because strategic traders may advance their trades to assure their ability to trade. Thus, the magnet effect is supported only if significant results are observed when the price is very close to the limit. Besides, the discarding of limit-hit observations in their study may underestimate the means, standard deviations and correlation coefficients, as pointed out by Chiang, Wei, and Wu (1990).

Several studies examine the effect of trading halts, another form of circuit breakers, using U.S. data. Corwin and Lipson (2000) study the order flow and liquidity around NYSE trading halts. They find that limit order book depth near the quotes is unusually low before, during, and after trading halts, which reflects investors' reduced willingness to supply liquidity at these times. They also find that the quoted spreads are unusually high at the reopen. In addition, they find evidence of a dramatic increase in quoted spreads prior to order imbalance halts. Gerety and Mulherin (1992) investigate NYSE data from 1933-1988 and find that closing volume is positively related to expected overnight volatility, while volume at the open is positively related to both the expected and unexpected volatility from the previous night. They then conclude that the desire of investors to trade prior to market closings indicates a cost of mandating circuit breakers. Lee, Ready, and Seguin (1994) examine the effect of firm-specific NYSE trading halts on volume and price volatility. They find that the period after a trading halt is characterized by higher levels of both volume and volatility. That is, the trading halt is ineffective in reducing price volatility. Like the NYSE studies by Lee, Ready, and Seguin (1994) and Corwin and Lipson (2000), the NASDAQ-based research by Christie, Corwin, and Harris (2002) also finds that even with information transmission during the halt, post-halt volume and volatility are unusually high following NASDAQ halts. This consistency in volume and volatility patterns suggests that the response of investors to trading halts is independent of the market structure and halt mechanisms. In sum, these studies suggest that trading halts are ineffective in reducing volatility and transactions increase after halts.

III. Hypotheses

Two hypotheses emerge from the relationship between price limits and overreaction. The first hypothesis is based on the belief that price limits can provide a cooling-off period for investors to gain more information and re-evaluate market conditions and thus can reduce overreaction. Therefore, it is called the cooling-off hypothesis. The second hypothesis is based on the argument that when prices are approaching the limits, market participants, fearing the inability to trade, will alter their trading strategies to make sure their desired positions are taken before price limits are hit. This is called the magnet hypothesis. Instead of reducing overreaction, this hypothesis suggests that price limits actually induce overreaction.

A. *Cooling-off hypothesis (reduce overreaction)*

For this cooling-off hypothesis, we are more interested in knowing what happens after price limits are hit. If price limits can provide traders a cooling-off period to obtain information, reassess the market price, and avoid overreaction, the degree of return volatility after a limit hit should be less than that before a limit hit. On the other hand, if price limits delay the price discovery process and interfere with trading, the degree of return volatility after a limit hit may be higher than that before a limit hit. Therefore, the hypothesis is supported if we observe lower return volatility after limit hits than before limit hits. Otherwise, it is rejected.

According to Easley and O'Hara (1987) and Stoll (1989), when liquidity providers perceive an increase in the degree of information asymmetry, they tend to widen the bid-ask spread to compensate for expected losses to informed traders. Even though these studies are based on quote-driven markets, Biais, Hillion, and Spatt (1995), Hamao and Hasbrouck (1995), and Ahn, Bae and Chan (2001) investigate major order-driven markets in the world and find similar results. In an order-driven market, such as the Tokyo Stock Exchange and the Paris Bourse, all liquidity is provided by traders who submit limit orders. The difference between the price of the lowest sell limit order and that of the highest buy limit order determines the effective bid-ask spread. The bid-ask spread represents expected compensation for the costs of supplying immediacy. Because limit order prices are fixed, investors face adverse selection risk due to the arrival of informed traders. Glosten (1994) shows that the existence of adverse selection costs generate positive bid-ask spreads in an order-driven trading environment. Therefore, bid-ask spreads can be used as the proxy for the degree of information asymmetry.

If investors overreact and price limits reduce overreaction by providing a cooling-off period for them to obtain more information, the degree of information asymmetry is expected to be lower after limit hits. Consequently, liquidity providers will face less adverse selection risks from informed traders after limit hits and, accordingly, narrow the bid-ask spreads. If we observe lower bid-ask spreads after limit hits than before limit hits, the cooling-off hypothesis is supported. Otherwise, the hypothesis is rejected.

B. *Magnet hypothesis (induce overreaction)*

Theoretical support of this hypothesis is modeled by Subrahmanyam (1994). The model suggests that price limits may increase price variability and the probability that the price will reach the limit if it is already very close to the limit. If the magnet effect holds, we should observe three phenomena. First, the rush of market participants to trade actually exacerbates the problem by pushing the price closer to the price limits. That is, when a price is approaching the limit, the possibility of hitting the limit will increase due to the magnet effect. In other words, instead of reducing overreaction, price limits actually induce overreaction. Second, under this hypothesis, market participants should have an increasing demand for liquidity as prices approach the limits. Accordingly, trading volume should increase. Third, because of the increasing demand of liquidity, the cost of liquidity is expected to rise. Brockman and Chung (1999) examine an order-driven market, the Stock Exchange of Hong Kong, and find that the liquidity costs are realized through both spreads and depths. They demonstrate that the bid-ask spread is positively related to the liquidity costs while depth is negatively related to the liquidity costs. Since TSE is also an order-driven market, we expect to see increasing spreads and decreasing depths as prices approach the limits if the magnet hypothesis holds.

IV. Data and Methodology

A. *Data description*

Transaction data of all TSE-listed stocks in year 2000 are obtained from the Taiwan Economic Journal Data Bank. The data contain time-stamped records of all transactions on the Taiwan Stock Exchange. 541 stocks traded on TSE during year 2000, but only 439 of them traded through the entire year, either due to delisting or IPOs. Trading volume, trading price, and transaction time for each transaction as well as the bid and ask prices are recorded in the transaction data. After August 27, 2000, the bid and ask sizes when the bid price or the ask price is also the limit-hit price are also recorded in the data.

Year 2000 is an ideal period for examining the relation between price limits and overreaction. First of all, the stock market is relatively volatile in 2000, with the index rising from 8756.55 at the beginning of the year to 10202.20 on the 17th of February and then dropping down to 4743.94 at the end of 2000. Given this high volatility, the chance for stocks to hit their limits is also high; so more observations of limit hits can be obtained. Thus, the concern of small sample sizes raised in previous studies is alleviated. Second, some important events, such as the presidential election and the resignation of the prime minister, occurred in Taiwan, so the lower limit rate was adjusted downward from 7% to 3.5% four times during the year while keeping the upper limit rate unchanged at 7% (see Panel A of Table 1 for detail). Therefore, we are able to form comparison groups based on those different price-limit rates during different periods to test our overreaction hypotheses.

B. *Methodology*

For limit hits, we identify three different cases. The first case is called a closing limit hit, which occurs when a price hits the limit and no other trades occur the remainder of the day. In this case, information may not be fully reflected during the day and the remaining information needs to be reflected on the following day. The second case is called a single limit hit, which occurs when a limit hit is followed by non-limit-hit transactions. In this case, the limit hit is transitory and information may be fully reflected during the day. The last case is called a consecutive limit hit, which occurs when a limit hit is followed by additional trades at the limit price. In this case, information may be fully reflected and the price could be the equilibrium price because market participants are willing to trade at the limit price.

B.1. *Cooling-off hypothesis*

For the case of closing limit hits, we compare the percentage of price reversals and price continuations between the limit-hit sample and the comparison sample. The limit-hit sample includes those days when closing prices hit the price limits, while the comparison sample includes all other days with non-zero daily returns. We exclude those days with zero daily returns from the comparison sample in order to make more legitimate comparisons. The event day, t, is the day when the closing price hits the price limit for the limit-hit sample while it is the day when the closing price does not hit the price limit and when the daily return is not zero for comparison sample. Let r_t be the daily return on t, r_t^d be the daytime (open-to-close) return on t, and r_{t+1}^n be the overnight (close-to-open) return from t to $t+1$, one trading day after t.

$$r_t = \lambda n\left(\frac{P_t^c}{P_{t-1}^c}\right) \tag{1}$$

$$r_t^d = \lambda n\left(\frac{P_t^c}{P_t^o}\right) \tag{2}$$

$$r_{t+1}^n = \lambda n\left(\frac{P_{t+1}^o}{P_t^c}\right) \tag{3}$$

where λn is the natural logarithm, P_t^c is the closing price on t, P_t^o is the opening price on t, P_{t-1}^c is the closing price on $t-1$, the trading day prior to t, and P_{t+1}^o is the opening price on $t+1$, the trading day following t. Stock returns can be positive (+), negative (-) or zero (0). For comparison sample, upward (downward) movements include those days when r_t is positive (negative). For all upward movements, we classify the set of {[r_t^d, r_{t+1}^n] | [+, +], [0, +]} as price continuations, the set of {[r_t^d, r_{t+1}^n] | [+, -], [0, -]} as price reversals, and the set of {[r_t^d, r_{t+1}^n] | [+, 0], [0, 0]} as no changes in prices around the closing. As to all downward movements, we classify the set of {[r_t^d, r_{t+1}^n] | [-, -], [0, -]} as price continuations, the set of {[r_t^d, r_{t+1}^n] | [-, +], [0, +]} as price reversals, and the set of {[r_t^d , r_{t+1}^n] | [-, 0], [0, 0]} as no changes in prices around the closing. For the comparison sample, we also add the set of {[r_t^d , r_{t+1}^n] | [-, +], [-, 0], [-, -]} to price reversals for upward movements and the set of {[r_t^d , r_{t+1}^n] | [+, +], [+, 0], [+, -]} to price reversals for downward movements. If more price reversals are observed from the limit-hit sample than from the comparison sample, the cooling-off hypothesis is supported. In this case, the closing limit hit is caused by traders overreacting to news, so a price reversal would support the cooling-off effect. In contrast, if more price continuations are observed from the limit-hit sample than from the comparison sample, which is more likely to happen given the belief that information is not fully reflected on the limit-hit day and the remaining information needs to be reflected on the following day, the cooling-off hypothesis is not supported. In this case, price limits delay the price discovery process.

However, for the case of single limit hit and consecutive limit hit, by definition, price reversals are guaranteed. Hence, the cooling-off effect should be tested using a different methodology. Based on previous discussion, if price limits can provide traders with a cooling-off period to obtain information, reassess the market price, and avoid unnecessary overreaction, the degree of return volatility after a limit hit should be less than that before a limit hit. For return volatility, we calculate the average 3-minute and 5-minute return volatility 30 minutes before and after limit hits to test the cooling-off hypothesis. We obtain the 3-minute returns (R_t^3), 5-minute returns (R_t^5), and the mean return ($\overline{R}$) based on the following calculation.

$$R_t^3 = \lambda n\left(\frac{P_t}{P_{t-3}}\right) \tag{4}$$

$$R_t^5 = \lambda n\left(\frac{P_t}{P_{t-5}}\right) \qquad (5)$$

$$\overline{R} = \frac{1}{n}\sum R_t \qquad (6)$$

where λn is the natural logarithm, P_t is the transaction price at t, P_{t-3} is the transaction price three minutes prior to t, P_{t-5} is the transaction price five minutes prior to t, and R_t is either R_t^3 or R_t^5. In order to gain robust results, we use two different volatility measures. V_1 is the standard deviation of returns and V_2 is the mean of absolute returns. Those measures are calculated as follows:

$$V_1 = \sqrt{\frac{1}{n-1}\sum\left(R_t - \overline{R}\right)^2} \qquad (7)$$

$$V_2 = \frac{1}{n}\sum\left|R_t\right| \qquad (8)$$

where n is the number of observations, R_t is equal to R_t^3 (R_t^5) for 3-minute (5-minute) return volatility, and $\overline{R}$ is the mean of R_t.

If we observe lower return volatility after limit hits than before limit hits, the cooling-off hypothesis is supported. Otherwise, it is rejected. Since the bid-ask bounce might affect the volatility measure, we use the bid-ask midpoint to replace the transaction price for the calculation of returns and volatilities. The bid-ask midpoint (M_t) is defined as follows:

$$M_t = \frac{\left(P_{bt} + P_{at}\right)}{2} \qquad (9)$$

where P_{bt} is the bid price at time t and P_{at} is the ask price at time t.

As to the degree of information asymmetry, we use the bid-ask spread as its proxy. For the purpose of comparison, we calculate the relative spread (RS_t) and the mean of relative spreads ($\overline{RS}$) with the following formula.

$$RS_t = \frac{(P_{at} - P_{bt})}{M_t} \tag{10}$$

$$\overline{RS} = \frac{1}{n}\sum RS_t \tag{11}$$

where P_{at} is the ask price at time t, P_{bt} is the bid price at time t, M_t is the bid-ask midpoint at time t, and n is the number of observations. If we observe lower $\overline{RS}$ after limit hits than before limit hits, the cooling-off hypothesis is supported. Otherwise, the hypothesis is rejected.

To perform a robustness check, we also construct a control sample called “pseudo” limit hits. As Panel A of Table 1 shows, there were periods with 7% upward and 7% downward price limits and periods with 7% upward and 3.5% downward price limits. Pseudo limit hits occur when transaction prices hit the pseudo 3.5% downward price limits during periods with 7% downward price limits. That is, even though the actual downward price limits are 7%, we treat them as 3.5% to identify our pseudo limit hits. We also split pseudo limit hits to single pseudo limit hits and consecutive pseudo limit hits. The methodology used for single limit hits and consecutive limit hits is applied to pseudo limit hits. However, we do not expect to see a significant difference in return volatility and relative spread between the pre- and post- pseudo limit hits.

In sum, the cooling-off hypothesis leads to the following testable implications.

Proposition 1: For the case of closing limit hits, the percentage of price reversals (continuations) is expected to be higher (lower) for the limit-hit sample than for the comparison sample.

Proposition 2: For the cases of single limit hits and consecutive limit hits, the return volatility after limit hits is expected to be lower than that before limit hits.

Proposition 3: For the cases of single limit hits and consecutive limit hits, the relative spread after limit hits is expected to be lower than before limit hits.

Proposition 4: For the case of pseudo limit hits, the return volatility and the relative spread after limit hits are expected to be insignificantly different from those before limit hits.

We perform the normality test of the volatility measures and the relative spread to determine if nonparametric tests are required. The Wilcoxon signed rank test will be used if it is necessary.

B.2. *Magnet hypothesis*

In order to test the magnet hypothesis, it is crucial to find a price that is so close to the price limits that the magnet effect is likely to occur. On TSE, the clearing price in each round of periodic matching cannot exceed two tick sizes from the clearing price in the preceding round. Therefore, a price that is two tick sizes below the upper limit price or a price that is two tick sizes above the lower limit price is the most desirable choice. All qualifying prices are called “magnet prices”. We then calculate the first-order autocorrelations of 3-minute returns (R_t^3) and 5-minute returns (R_t^5) for the 30 minutes after the magnet prices are traded. If the magnet hypothesis holds, we expect to see positive autocorrelations. In order to have a benchmark, a control sample needs to be constructed for the purpose of comparison. The control sample includes the same stocks in the sample, matched by time of day, day of week, and duration, during which no “magnet prices” are observed. Again, the Wilcoxon signed rank test is used to determine the significance level. If we observe higher return autocorrelations from the magnet sample than those from the control sample, the magnet hypothesis is supported. Otherwise, it is rejected. However, according to Roll (1984), the bid-ask bounce may result in negative serial correlation, which will reject the hypothesis. Therefore, we also calculate the first-order autocorrelations of 3-minute and 5-minute returns for the 30 minutes after the magnet prices are traded based on the bid-ask midpoint (M_t) to mitigate the distortion from the bid-ask bounce. The calculation of returns is the same except the transaction prices are replaced by M_t.

If there is magnet effect, trading volume is expected to increase after the magnet prices are reached because investors may rush to place market orders. Total trading volume during the 30 minutes prior to a magnet price is compared to the total trading volume during the 30 minutes after the magnet price. To make valid comparison, we divide the trading volume by its corresponding total daily trading volume. The magnet hypothesis is supported if we observe significantly higher trading volume after the magnet prices than that before the magnet prices for the magnet sample and no significant difference between the trading volume before and after for the control sample.

As mentioned earlier, due to increased demand for liquidity, we expect to see increasing spreads and decreasing depths as prices approach the limits if the magnet hypothesis holds. Since depth data are not available, we focus on only the bid-ask spread. The mean of the relative spreads ($\overline{RS}$) during the 30 minutes prior to the magnet price is compared to that during the 30 minutes after the magnet price. If the $\overline{RS}$ prior to the magnet price is lower than that after the magnet price for the magnet sample and no significant difference between the $\overline{RS}$ before and after for the control sample, the magnet hypothesis is supported; otherwise, it is rejected.

V. Results

A. *Summary Statistics*

Panel A of Table II reports the number of observations and ratios for limit hits, magnet hits, and pseudo limit hits during period 1 and period 2 for all 439 stocks traded through out the whole year 2000 on TSE. Period 1 represents all periods with 7% upward and 7% downward price limits while period 2 includes all periods with 7% upward and 3.5% downward price limits. 17,188,194 transactions occurred during period 1 and 3,539,160 transactions during period 2 for all 439 stocks. Upper (Lower) limit hits occur when transaction prices hit the upward (downward) price limits. Upper (lower) magnet hits occur when transaction prices hit the upper (lower) magnet prices. Upper (lower) magnet prices are defined as the prices that are two ticks below (above) the upward (downward) price limits. Pseudo limit hits occur when transaction prices hit the pseudo 3.5% downward price limits during period 1 when the actual downward price limits are 7%. Ratios, displayed in Panel A of Table II, are defined as the number of observations divided by the number of transactions in each period.

During Period 1, there are more upper limit hits than lower limit hits. The overall limit-hit ratio is about 4%. That is, for every one hundred transactions, 4 hit the price limits. The fact that the sum of the numbers of observations for single, consecutive, and closing limit hits is much less than the total number of limit-hit observations shows that many limit hits are categorized into consecutive limit hits. On average, each consecutive limit hit observation consists of 12 limit-hit transactions. As for magnet hits, there are more lower hits than upper hits and the overall ratio is about 1.55%. The ratio of pseudo limit hits is 1.73%.

Unlike Period 1, there are more lower limit hits than upper limit hits during Period 2. The main reason is the imposition of 3.5% downward price limits. Further, Period 2 is more volatile than Period 1 given the occurrence of several important events such as the Presidential Election and the resignation of Prime Minister. The overall limit-hit ratio is about 10%, with 7% being lower limit hits. As for magnet hits, there are more lower hits than upper hits and the overall ratio is 5.37%.

Panel B of Table II reports the summary statistics of daily market returns during both Periods 1 and 2 based on the TSE Capitalization Weighted Price Index (TAIEX), the most frequently quoted index among the many stock indices published by TSE. Since the standard deviation (S.D.) of daily market returns in Period 2 is higher than that in Period 1, Period 2 is indeed more volatile than Period 1. We also perform the Wilcoxon Rank Sum test to see if the median in Period 1 is significantly different from that in Period 2, but we find no significant difference between them given a P-value of 0.4104. Since the stock market in Period 2 is more volatile than in Period 1, we would expect to see higher limit-hit ratios in Period 2 than those in Period 1. Besides, given the asymmetric price-limit rates during Period 2, we would expect to see more lower limit hits than upper limit hits. The results reported in Panel A of Table II are consistent with our expectations. All ratios in Period 2 are significantly higher than those in Period 1. In Period 2, there are more lower limit hits than upper limit hits and more lower magnet hits than upper magnet hits.

B. *Cooling-off hypothesis*

We report the results from the tests of the cooling-off hypothesis based on the three different limit hits: closing limit hits, single limit hits, and consecutive limit hits. To find a benchmark, we form a comparison group for the closing limit hits. For single limit hits and consecutive limit hits, we compare the results with those from the pseudo limit hits.

B.1. *Closing limit hits*

Table III reports the proportions of price continuations, reversals, and no changes for both upward movements and downward movements for the closing limit-hit group and the comparison group. Panel A reports the results for periods with 7% upward and 7% downward price limits and Panel B reports those for periods with 7% upward and 3.5% downward price limits. The limit-hit sample includes those days when closing prices hit the price limits, while the comparison sample includes all other days when daily returns are not zero. We exclude those zero-return observations from our comparison sample to gain a more legitimate comparison since they do not exist in our limit-hit sample.

As mentioned earlier, if more price reversals are observed from the limit-hit sample than from the comparison sample, the cooling-off hypothesis is supported. In other words, if the closing limit hit is caused by traders overreacting to news, the cooling-off effect from price limits implies a price reversal. Results from both Panels A and B of Table III show that the ratio of continuations for the limit-hit sample is significantly higher than that for the comparison sample. The ratio difference, defined as the ratio of the limit-hit sample minus the ratio of the comparison sample, for continuations is positive and significant based on the standard binomial test. On the other hand, the ratio difference of reversals is negative and significant. That is, the ratio of reversals for the limit-hit sample is significantly less than that for the comparison sample. Therefore, the results from the closing limit hits do not support the cooling-off hypothesis. When the closing price hits the price limits, the price on the next trading day tends to move in the same direction toward its equilibrium level. In fact, this is consistent with the delayed price discovery hypothesis, which states that price limits delay the price discovery process due to the limitations imposed on the price movements.

B.2. *Single limit hits*

Table IV reports the results from various tests of the cooling-off hypothesis for single limit hits. A single limit hit occurs when a limit hit is followed by non-limit-hit transactions. Upper (Lower) limit hits occur when prices hit the upward (downward) price limits. Pseudo limit hits occur when prices hit the pseudo 3.5% downward price limits during Period 1 when actual price limits are 7%. Pre-Hits refer to the period 30 minutes prior to the single limit hit, while Post-Hits refer to the period 30 minutes after the single limit hit. $\overline{R}$ is the mean of the returns, V_1 is the standard deviation of the returns, V_2 is the mean of the absolute returns, and N is the sample size. All figures reported are multiplied by 1000. >> (<<) indicates that the left-side figure is higher (lower) than the right-side figure at the 1% level of significance. > (<) indicates that the left-side figure is higher (lower) than the right-side figure at the 5% level of significance. The Wilcoxon signed rank test is used to determine the level of significance. The sample sizes for upper limit hits, lower limit hits, and pseudo limit hits are much smaller than those reported in Table II because we eliminate many observations in the process of selecting the qualified sample. Basically, we delete the observations that occur during the first and the last 30 minutes of each trading day in order to obtain trading data both 30 minutes prior to and after each selected observation. Further, for each single limit hit, if another limit hit occurs during the period 30 minutes prior to or after the trading took place, the observation is deleted from our sample. The purpose for these strict selection criteria is to obtain a clean sample for testing the cooling-off hypothesis.

Panel A reports the average return, $\overline{R}$, and average volatilities, V_1 and V_2, from both the 3-minute and the 5-minute return analyses based on transaction prices. The average 3-minute return is the average of ten 3-minute returns during the 30-minute period and the average 5-minute return is the average of six 5-minute returns during the 30-minute period. If no trading occurs during the 3-minute and 5-minute interval, the previous trading price is used to determine the return, which is zero in this case. Basically, the results from the 3-minute and the 5-minute return analyses are similar. For upper limit hits, $\overline{R}$ is significantly higher during Pre-Hits than during Post-Hits, but is significantly lower during Pre-Hits than during Post-Hits for lower limit hits. In fact, $\overline{R}$ is positive during Pre-Hits and negative during Post-Hits for upper limit hits. These results are intuitive because prices need to keep going up to hit the upper price limits and then going down to be away from the limits. For lower limit hits, same intuitive argument applies to explain the negative $\overline{R}$ during Pre-Hits and positive $\overline{R}$ during Post-Hits. However, without the actual price limits constraint, no significant difference of $\overline{R}$ between Pre-Hits and Post-Hits is observed for pseudo limit hits.

As to volatility measures, V_1 and V_2 provide similar results. No significant differences for V_1 and V_2 between Pre-Hits and Post-Hits are observed except for the upper limit hits during periods with 7% upward and 3.5% downward price limits. Both volatility measures are significantly higher during Pre-Hits than during Post-Hits for upper limit hits during Period 2. That is, the cooling-off hypothesis is supported only from upper single limit hits during periods with 7% upward and 3.5% downward price limits using transactions prices to determine returns and volatilities. For pseudo limit hits, no significant difference is observed between Pre-Hits and Post-Hits.

Panel B reports the return and volatility from both the 3-minute and 5-minute return analysis based on the bid-ask midpoint to avoid excess return volatility caused by bid-ask bounce. Sample sizes are smaller than those in Panel A because transactions with either zero bid or zero ask prices are excluded from the sample. The results from Panel B are similar to those in Panel A for both returns and volatilities. However, the support of the cooling-off hypothesis from upper single limit hits during Period 2 is not as strong as that in Panel A because the low volatility during Post-Hits is only observed from the 3-minute return analysis, not the 5-minute return analysis.

Panel C reports the mean of the relative spreads for each type of limit hits. The relative spread is defined as the bid-ask spread divided by the bid-ask midpoint. Since the relative spreads are proxies for the degree of information asymmetry, we expect to see lower relative spreads after limit hits to support the cooling-off hypothesis. Results from Panel C show that relative spreads increased from Pre-Hits to Post-Hits for upper limit hits during both Periods 1 and 2. For lower and pseudo limit hits, no significant differences between Pre-Hits and Post-Hits are observed. Therefore, results from the spread analysis do not support the cooling-off hypothesis.

B.3. *Consecutive limit hits*

Table V reports the results from various tests of the cooling-off hypothesis for consecutive limit hits. A consecutive limit hit occurs when a limit hit is followed by additional trades at the limit price. Pre-Hits refer to the period 30 minutes prior to the first limit hit of a consecutive limit hit, while Post-Hits refer to the period 30 minutes after the last limit hit of the consecutive limit hit. All notations used in Table V are the same as those in Table IV. However, unlike the results from Table IV, Panel A of Table V shows that return volatilities decrease from Pre-Hits to Post-Hits for both upper and lower limit hits during Period 1 and for lower limit hits during Period 2. No significant difference is found for pseudo limit hits. Therefore, the cooling-off hypothesis is supported by consecutive limit hits except for the upper limit hits during Period 2. Panel B reports the return and volatility measures from both the 3-minute and 5-minute return analysis based on the bid-ask midpoint to avoid excess return volatility caused by bid-ask bounce. Again, the cooling-off hypothesis is supported because both volatility measures are significantly lower during Post-Hits than during Pre-Hits for all limit hits during all periods except for the pseudo limit hits. Thus, the results from Panel B are stronger than those in Panel A.

As to the spread analysis, similar to single limit hits, we find that the average relative spread is higher during Post-Hits than during Pre-Hits for upper limit hits. However, for lower limit hits during Period 1, we observe lower average relative spreads during Post-Hits than during Pre-Hits. Therefore, the cooling-off hypothesis is supported by lower consecutive limit hits from the spread analysis.

B.4. *Regression analysis*

Since the cooling-off hypothesis is supported by consecutive limit hits, but not by single limit hits, we further examine our sample to find out what features associated with consecutive limit hits may contribute to this result. The most apparent feature is the number of transactions at the limit price. Another feature is the time duration between the first limit hit and the last limit hit for each consecutive limit hit. Panel A of Table VI provides descriptive statistics of duration and the number of limit hit transactions. The mean (median) duration is 293 (131) seconds with the maximum and minimum duration being 2504 and 0 seconds, respectively. There are 27 consecutive limit hits whose durations are 0 because two separate limit hit transactions occur at the same time. The mean (median) number of transactions is 5 (3), with the maximum and minimum being

75 and 2, respectively. The correlation between duration and number of transactions is 0.4922.

To determine whether the duration or the number of transactions can explain the magnitude of the volatility change, we run the following regressions:

$$V(Pre)\text{-}V(Post) = \alpha + \beta_1 \text{ Duration} + \varepsilon \quad (12)$$

$$V(Pre)\text{-}V(Post) = \alpha + \beta_1 \text{ Transaction} + \varepsilon \quad (13)$$

$$V(Pre)\text{-}V(Post) = \alpha + \beta_1 \text{ Duration} + \beta_2 \text{ UP} + \beta_3 \text{ SEVEN} + \varepsilon \quad (14)$$

$$V(Pre)\text{-}V(Post) = \alpha + \beta_1 \text{ Transaction} + \beta_2 \text{ UP} + \beta_3 \text{ SEVEN} + \varepsilon \quad (15)$$

where V(Pre) is the pre-hit volatility multiplied by 1,000, while V(Post) is the post-hit volatility multiplied by 1,000. Duration is the total time (in seconds) from the first to the last limit hit, while transaction refers to the number of limit hit transactions for each consecutive limit hit. UP takes the value 1 for upper limit hits and takes the value 0 for lower limit hits. SEVEN takes the value 1 for periods with 7% upward and downward price limits and takes the value 0 for periods with 7% upward and 3.5% downward price limits.

Panel B of Table VI shows that the coefficients of Duration are negative and significant, which indicates that there is negative relationship between Duration and the magnitude of volatility change. That is, the longer the duration of consecutive limit hits, the less the volatility will be reduced. The result may appear to be counter intuitive. That is, if price limits provide a cooling-off period for market participants to obtain and evaluate information and make rational decisions, we would expect to see a positive relationship between Duration and the magnitude of volatility reduction. However, our regression result is consistent with the time pressure argument widely recognized in psychology literature. Ben Zur and Breznitz (1981) argue that individuals may adapt and accelerate information processing and focus on important information given time pressure. Easterbrook (1959) also points out that with moderate time pressure, decision makers' performance improves as they focus on relevant cues and exclude the peripheral. When price limit is hit, market participants are eager to obtain and evaluate information. If the duration is short, given the time pressure, they make decisions based on important and relevant information. On the other hand, if the duration is long, they may obtain some irrelevant information or slow down the speed of information processing due to the decreased time pressure. Thus, the magnitude of volatility reduction can be negatively related to the duration of limit hits.

Besides volatility, we also perform similar regression analysis for the relative spread. However, unlike the previous analysis, neither duration nor the number of transactions can explain the change in relative spread. The only factor that affects the change in relative spread is the dummy variable UP.

C. *Magnet hypothesis*

We report the results from the tests of the magnet hypothesis regarding three different aspects: return autocorrelations, trading volume, and relative spreads. To find a benchmark for comparison, we form a control sample for our magnet sample. The magnet sample includes transactions whose prices have hit the magnet prices. A magnet price is two ticks below the upper limit price or two ticks above the lower limit price. The control sample includes the same stocks in the magnet sample, matched on time of day, day of week, and duration, during which no "magnet prices" are observed.

C.1. *Return autocorrelations*

Table VII reports the average return autocorrelations from both the 3-minute return analysis and the 5-minute return analysis during Period 1 and Period 2. Results in Panel A are based on the transaction prices, while those in Panel B are based on the bid-ask midpoints. Before refers to the period 30 minutes prior to the trading time of each observation and After refers to the period 30 minutes after the trading time of that observation. After-Before is equal to After minus Before. N is the sample size. The P-value of After-Before is based on the Wilcoxon signed rank test.

Panel A of Table VII reports the sample sizes and return autocorrelations of the magnet sample and the control sample during Period 1 and 2 from the 3-minute and 5-minute return analysis. It should be noted that the sample sizes for the 5-minute return analysis are smaller than those for the 3-minute return analysis. The major reason is because some observations have zero 5-minute returns for the 30-minute periods and thus the autocorrelations are not available. In addition, the sample sizes of the magnet sample are much smaller than those reported in Table II due to our strict sample selection criteria. Basically, we delete the observations that occur during the first and the last 30 minutes of each trading day in order to obtain trading data for 30 minutes prior to and after each selected observation. Besides, when a magnet price is hit, it is possible to have another trade(s) at the magnet price. In order to test the magnet hypothesis, we only select the first magnet price to be in the magnet sample. Therefore, the size of the magnet samples decrease significantly from those reported in Table II. For the control sample, we try to find as many matched observations as possible without losing comparability. The control sample needs to match with the magnet sample in terms of stocks, day of the week, time of the day, and duration, during which no “magnet prices” are observed. To obtain a reasonable number of matched observations, we follow four matching rounds with the first being one week prior to the day of each magnet observation. For those unmatched magnet observations after the first round, we perform the second, third, and fourth matching rounds by examining one week after, two weeks prior to, and two weeks after the day of each magnet observation, respectively. To avoid capturing too much noise, we do not go beyond the fourth matching round. Fortunately, the TSE is a very active market, so we are able to find the majority of the magnet-matched observations in the control sample.

We expect to see positive return autocorrelations for the magnet sample and the magnitude should be higher than that from the control sample if the magnet hypothesis holds. However, as shown in Panel A, all autocorrelations are negative. For the magnet sample, the average autocorrelations during After are significantly lower than those during Before except for the 5-minute return analysis during Period 2. Some similar results are found for the control sample, but mainly caused by downward movements. Therefore, based on the results, the magnet hypothesis is not supported from the return autocorrelations using transaction prices. If these negative autocorrelations are due to the bid-ask bounce suggested by Roll (1984), the use of bid-ask midpoint for determining return autocorrelations should give us more promising results.

Panel B of Table VII reports the sample sizes and return autocorrelations of the magnet sample and the control sample during Period 1 and 2 from the 3-minute and 5-minute return analysis based on bid-ask midpoint. Again, the sample sizes are smaller than those reported in Panel A because observations with zero bid or ask prices are deleted from the sample. The results show that autocorrelations are still negative for both the magnet sample and the control sample. Apparently, the magnet hypothesis is not supported even with those return autocorrelations calculated using the bid-ask midpoints.

C.2. *Trading volume*

Table VIII reports the average trading volume of the magnet sample and control sample during Period 1 and Period 2. Trading volume during each 30-minute period, both Before and After, is scaled by its corresponding daily trading volume. N is the sample size. >> (<<) indicates that the left-side figure is higher (lower) than the right-side figure at the 1% level of significance. > (<) indicates that the left-side figure is higher (lower) than the right-side figure at the 5% level of significance. The Wilcoxon signed rank test is used to determine the level of significance.

If the magnet hypothesis holds, we expect to see higher average trading volume during After than during Before because investors rush to trade when the magnet price is reached. Results in Table VIII show that average trading volumes are actually higher during Before than during After for both the magnet sample and the control sample except during the downward movement of the magnet sample. It seems that the magnet hypothesis is rejected. However, since the same results are found for both the magnet sample and the control sample, we cannot attribute this result to the magnet effect. Instead, we argue that these results might support the magnet hypothesis. The average trading volume reported is actually the proportion of the daily trading volume that occurs during the 30-minute period. If we consider the total proportion of the daily trading volume occurring during the one-hour period (30 minutes before and 30 minutes after each observation) for the magnet sample and the control sample, we find that the proportion (Before+After) is significantly higher for the magnet sample than for the control sample. That is, even though we do not observe higher trading volume during After than during Before, during the one-hour window, the trading volume of the magnet sample is actually higher than that of the magnet sample for both upward and downward movements and during both Periods 1 and 2. Therefore, we feel safe in concluding that the magnet hypothesis cannot be rejected by this trading volume analysis. Furthermore, the results indicate that the intensive trading activity may occur prior to the time when the magnet price is reached.

C.3. Relative spreads

Table IX reports the mean of the relative spreads for the magnet sample and the control sample during Period 1 and Period 2. Relative spread is defined as the bid-ask spread divided by the bid-ask midpoint. All relative spreads reported are multiplied by 1000. If the magnet hypothesis holds, we expect to see higher average relative spreads during After than during Before. Results from Table IX show that the average relative spreads are significantly higher during After than during Before for magnet sample during Period 2 and for upward magnet sample during Period 1. Results for the control sample are simply the opposite, with higher average relative spreads during Before than during After during Period 2 and no difference during Period 1. Therefore, the magnet hypothesis is supported by this relative spread analysis. That is, when investors' demand for liquidity increases, the cost of liquidity is expected to rise and that is reflected in the increasing bid-ask spreads.

VI. **Conclusion**

Given the recent development of behavioral finance and its empirical evidence on market overreaction, this paper intends to answer the question "can price limits, one form of circuit breakers, reduce overreaction"? Even though the most popular rationale for imposing price limits is to reduce market overreaction, opponents of price limits argue that it serves no purpose other than to slow down or delay the price discovery process. Furthermore, rather than generating a stabilizing effect that calms market movements, price limits have a magnet effect that acts to pull prices toward the limit. That is, price limits induce investors' overreaction when prices are approaching the limits. We use transaction data from the Taiwan Stock Exchange to examine the relation between price limits and overreaction. More specifically, we try to investigate whether price limits reduce or induce overreaction.

We test two hypotheses to investigate whether price limits reduce or induce overreaction. The first hypothesis is called the cooling-off hypothesis, which suggests that price limits can reduce overreaction because they provide a cooling-off period for investors to reevaluate market information and form more rational trading decisions. In order to correctly test this hypothesis, we identify three different limit hits, namely, the closing limit hit, the single limit hit, and consecutive limit hits. The cooling-off hypothesis is only supported by consecutive limit hits. The second hypothesis is called the magnet hypothesis, which suggests that price limits induce overreaction because investors may submit sub-optimal orders when prices are approaching the limits. We test this hypothesis from three different aspects, namely, return autocorrelations, trading volume, and relative spread. The magnet hypothesis is supported by trading volume and relative spread, but it is not supported by the return autocorrelations. Therefore, our overall result is that price limits induce overreaction when prices are approaching the limits, but they also reduce overreaction when the price hit the limit consecutively.

This paper makes no attempt to investigate whether investors overreact or not. In fact, we assume that investor overreaction exists and examine the relation between price limits and overreaction. Our findings have important regulatory implications. Since price limits can reduce overreaction after consecutive limit hits and induce overreaction when prices are approaching the limits, policy makers need to evaluate the net effect from price limits and set a rule to optimally reduce overreaction. For example, since the cooling-off hypothesis is supported by consecutive limit hits, would a hybrid or combination of price limits and trading halts perform better than a pure price limits or trading halts in reducing overreaction? That might be a good future research topic.

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Table I
Price-Limit Rates and Tick Size

Panel A reports the price-limit rates during different periods in year 2000. Panel B reports the tick sizes for different price ranges on TSE. NT$ is the Taiwanese currency. Information from Both Panels is obtained from the Taiwan Stock Exchange Corporation.

Panel A: Price limits in year 2000

Periods	Price-limit Rates
01/01/2000 to 03/19/2000	7% upward and 7% downward
03/20/2000 to 03/26/2000	7% upward and 3.5% downward
03/27/2000 to 10/03/2000	7% upward and 7% downward
10/04/2000 to 10/11/2000	7% upward and 3.5% downward
10/12/2000 to 10/19/2000	7% upward and 7% downward
10/20/2000 to 11/07/2000	7% upward and 3.5% downward
11/08/2000 to 11/20/2000	7% upward and 7% downward
11/21/2000 to 12/31/2000	7% upward and 3.5% downward

Panel B: Tick size

Price Range	Tick Size
$P <$ NT$ 5.00	NT$ 0.01
NT$ 5.00 $\leq P <$ NT$ 15.00	NT$ 0.05
NT$ 15.00 $\leq P <$ NT$ 50.00	NT$ 0.10
NT$ 50.00 $\leq P <$ NT$ 150.00	NT$ 0.50
NT$ 150.00 $\leq P <$ NT$ 1,000.00	NT$ 1.00
NT$ 1,000.00 $\leq P$	NT$ 5.00

Table II
Summary Statistics

There are 439 stocks traded through out the whole year 2000 on TSE. Panel A reports the number of observations and ratios for both upper and lower limit hits during period 1 and period 2. Upper (Lower) limit hits occur when transaction prices hit the upward (downward) price limits. Period 1 represents all periods with 7% upward and 7% downward price limits while period 2 represents all periods with 7% upward and 3.5% downward price limits in year 2000. There are 17,188,194 transactions occurred during period 1 and 3,539,160 transactions during period 2 for all 439 stocks. A single limit hit occurs when a limit hit is followed by non-limit-hit transactions. Consecutive limit hits occur when a limit hit is followed by further trades at the limit price. Closing limit hit occurs when a price hits the limit and no other trades occur the remainder of the day. Upper (lower) magnet hits occur when transaction prices reach two ticks below (above) the upper (lower) limit prices. Pseudo limit hits occur when transaction prices hit the pseudo 3.5% downward price limits during Period 1 when actual price limits are 7%. Ratios are defined as the number of observations divided by the number of transactions in each period. $Ratio_2$-$Ratio_1$ is the ratio of period 2 minus the ratio of period 1. Z-value of $Ratio_2$-$Ratio_1$ is based on the standard binomial test. Panel B reports the summary statistics of daily market return during both Periods 1 and 2 based on the TSE Capitalization Weighted Price Index (TAIEX).

Panel A:

	Period 1		Period 2		$Ratio_2$-$Ratio_1$	Z-value
	# of observations	Ratios	# of observations	Ratios		
Upper limit hits	399890	0.0233	104124	0.0294	0.0062	68.46
Single	12455		5528			
Consecutive	26826		9156			
Closing	5343		2114			
Lower limit hits	305466	0.0178	251757	0.0711	0.0534	565.21
Single	15246		14973			
Consecutive	28978		25285			
Closing	4471		4359			
Total limit hits	705356	0.0410	355881	0.1006	0.0595	462.62
Upper magnet hits	119522	0.0070	37549	0.0106	0.0036	72.22
Lower magnet hits	146749	0.0085	152490	0.0431	0.0346	496.19
Total magnet hits	266271	0.0155	190039	0.0537	0.0382	446.05
Pseudo limit hits	298162	0.0173				

Panel B: Daily market return

Period	N	Mean	S.D.	Min	Max	Median
1	213	-0.00375	0.01990	-0.06774	0.04483	-0.00292
2	57	0.00325	0.02518	-0.02757	0.06172	-0.00125

Table III
Cooling-off hypothesis: Closing Limit Hits

There are 439 stocks traded through the whole year 2000 on TSE. This table reports the proportions of price continuations, reversals, and no changes for both upward movements and downward movements for the limit-hit group and the comparison group. Panel A reports the results for periods with 7% upward and 7% downward price limits and Panel B reports those for periods with 7% upward and 3.5% downward price limits. Limit-hit sample includes those days when price hits the limit and no other trades occur the remainder of the day, while the comparison sample includes all other days when daily returns are not zero. Let $r_t = \lambda n(P_t^c / P_{t-1}^c)$, $r_t^d = \lambda n(P_t^c / P_t^o)$ and $r_{t+1}^n = \lambda n(P_{t+1}^o / P_t^c)$, where P_t^c is the closing price on day t, P_t^o is the opening price on day t, P_{t-1}^c is the closing price on $t-1$, the trading day prior to t, and P_{t+1}^o is the opening price on $t+1$, the trading day following t. Stock returns can be positive (+), negative (-) or zero (0). For comparison sample, upward (downward) movements include those days when r_t is positive (negative). For upward movements, we classify the set of {$[r_t^d, r_{t+1}^n]$ | [+, +], [0, +]} as price continuations, the set of {$[r_t^d, r_{t+1}^n]$ | [+, -], [0, -]} as price reversals, and the set of {$[r_t^d, r_{t+1}^n]$ | [+, 0], [0, 0]} as no changes in prices around the closing. As to downward movements, we classify the set of {$[r_t^d, r_{t+1}^n]$ | [-, -], [0, -]} as price continuations, the set of {$[r_t^d, r_{t+1}^n]$ | [-, +], [0, +]} as price reversals, and the set of {$[r_t^d, r_{t+1}^n]$ | [-, 0], [0, 0]} as no changes in prices around the closing. Besides, for comparison sample, we also add the set of {$[r_t^d, r_{t+1}^n]$ | [-, +], [-, 0], [-, -]} to price reversals for upward movements and the set of {$[r_t^d, r_{t+1}^n]$ | [+, +], [+, 0], [+, -]} to price reversals for downward movements. The proportions may not add to 1 due to rounding error. N is the sample size. Ratio difference is the ratio of the limit-hit sample minus the ratio of the comparison sample. Z-value of the ratio difference is based on the standard binomial test.

Price Behavior	Limit-hit Sample	Comparison Sample	Ratio Difference	Z-value
Panel A: Periods with 7% upward and 7% downward price limits				
Upward Movements	N = 5343	N = 30594		
Continuation	0.770	0.410	0.359	48.60
Reversal	0.121	0.382	-0.261	-37.11
No change	0.110	0.208	-0.098	-16.76
Downward Movements	N = 4471	N = 42992		
Continuation	0.740	0.316	0.425	56.48
Reversal	0.143	0.439	-0.295	-38.21
No change	0.116	0.246	-0.129	-19.47
Panel B: Periods with 7% upward and 3.5% downward price limits				
Upward Movements	N = 2114	N = 7589		
Continuation	0.659	0.309	0.350	29.21
Reversal	0.161	0.462	-0.301	-25.01
No change	0.180	0.229	-0.049	-4.80
Downward Movements	N = 4359	N = 8428		
Continuation	0.862	0.494	0.369	40.68
Reversal	0.072	0.383	-0.311	-37.28
No change	0.066	0.123	-0.057	-10.07

Table IV
Cooling-off hypothesis: Single Limit Hits

A single limit hit occurs when a limit hit is followed by non-limit-hit transactions. Upper (Lower) limit hits occur when prices hit the upward (downward) price limits. Pseudo limit hits occur when prices hit the pseudo 3.5% downward price limits during Period 1 when actual price limits are 7%. Pre-Hits (Post-Hits) refers to the period 30 minutes prior to (after) the single limit hit. $\overline{R}$ is the mean of returns, V_1 is the standard deviation of returns, V_2 is the mean of absolute returns, and N is the sample size. Panel A (B) reports the return and volatility from both the 3-minute and the 5-minute return analyses based on transaction prices (bid-ask midpoints). A bid-ask midpoint is the average of the bid price and the ask price. Panel C reports the mean of relative spreads for each type of limit hits. The relative spread is defined as the bid-ask spread divided by the bid-ask midpoint. All figures reported are multiplied by 1000. >> (<<) indicates that the left-side figure is higher (lower) than the right-side figure at the 1% level of significance. > (<) indicates that the left-side figure is higher (lower) than the right-side figure at the 5% level of significance. Wilcoxon signed rank test is used to determine the level of significance.

Panel A: Transaction Prices

	3-minute return analysis			5-minute return analysis		
Return and Volatility	Pre-Hits		Post-Hits	Pre-Hits		Post-Hits
Period 1: Periods with 7% upward and 7% downward price limits						
Upper Limit Hits (N=118)						
$\overline{R}$	0.3983	>>	-0.3259	0.6639	>>	-0.5431
V_1	1.6317		1.5667	1.9643		1.8659
V_2	1.0340		1.0364	1.3808		1.3847
Lower Limit Hits (N=143)						
$\overline{R}$	-0.7157	<<	0.5414	-1.1928	<<	0.9013
V_1	3.3569		3.4969	4.2144		3.9736
V_2	2.2017		2.0722	2.9353		2.5949
Pseudo Limit Hits (N=202)						
$\overline{R}$	0.0282		-0.1223	0.0466		-0.2039
V_1	5.2701		4.7803	6.5890		5.9899
V_2	2.8853		2.5975	4.1788		3.7041
Period 2: Periods with 7% upward and 3.5% downward price limits						
Upper Limit Hits (N=62)						
$\overline{R}$	0.8787	>>	-0.2769	1.4646	>>	-0.4614
V_1	3.6914	>>	2.3930	4.5217	>	3.1066
V_2	2.2616	>>	1.4642	3.1053	>>	2.1293
Lower Limit Hits (N=238)						
$\overline{R}$	-0.2903	<<	0.1594	-0.4827	<<	0.2655
V_1	2.0171		1.8801	2.4277		2.2391
V_2	1.1288		1.0827	1.5010		1.4282

Panel B: Bid-ask Midpoint						
	3-minute return analysis			5-minute return analysis		
Return and Volatility	Pre-Hits		Post-Hits	Pre-Hits		Post-Hits
Period 1: Periods with 7% upward and 7% downward price limits						
Upper Limit Hits (N=31)						
$\bar{R}$	0.4880	>>	-0.7623	0.8133	>>	-1.2705
V_1	2.3426	<	3.0134	3.1317		3.5451
V_2	1.3533		1.6317	2.0771		2.2642
Lower Limit Hits (N=67)						
$\bar{R}$	-1.1690	<<	0.8662	-1.9484	<<	1.4384
V_1	4.5048		3.7463	5.7715		4.7064
V_2	2.7800		2.2478	4.1423		3.1706
Pseudo Limit Hits (N=182)						
$\bar{R}$	-0.0410		0.0266	-0.0684		0.0459
V_1	3.2173		3.2034	3.9324		4.0927
V_2	1.7044		1.7688	2.3977		2.5660
Period 2: Periods with 7% upward and 3.5% downward price limits						
Upper Limit Hits (N=26)						
$\bar{R}$	1.0226	>>	-0.7115	1.7044	>>	-1.1858
V_1	4.8535	>	3.4506	5.7173		4.6499
V_2	2.8110	>	2.0825	4.1422		3.1856
Lower Limit Hits (N=88)						
$\bar{R}$	-0.4638	<<	0.4708	-0.7729	<<	0.7842
V_1	2.3820		2.7875	2.8717		3.3517
V_2	1.1428		1.4623	1.6151		1.9184

Panel C: Spread Analysis			
Relative spread	Pre-Hits		Post-Hits
Period 1: Periods with 7% upward and 7% downward price limits			
Upper Limit Hits (N=31)	6.1196	<<	6.9006
Lower Limit Hits (N=67)	6.6736		6.2861
Pseudo Limit Hits (N=182)	8.1815		8.1926
Period 2: Periods with 7% upward and 3.5% downward price limits			
Upper Limit Hits (N=26)	5.6894	<<	7.2423
Lower Limit Hits (N=88)	7.9950		8.0124

Table V
Cooling-off hypothesis: Consecutive Limit Hits

A consecutive limit hit occurs when a limit hit is followed by further trades at the limit price. Upper (Lower) limit hits occur when prices hit the upward (downward) price limits. Pseudo limit hits occur when prices hit the pseudo 3.5% downward price limits during Period 1 when actual price limits are 7%. Pre-Hits (Post-Hits) refers to the period 30 minutes prior to (after) the consecutive limit hit. $\overline{R}$ is the mean of returns, V_1 is the standard deviation of returns, V_2 is the mean of absolute returns, and N is the sample size. Panel A (B) reports the return and volatility from both the 3-minute and the 5-minute return analyses based on transaction prices (bid-ask midpoints). A bid-ask midpoint is the average of the bid price and the ask price. Panel C reports the mean of relative spreads for each type of limit hits. The relative spread is defined as the bid-ask spread divided by the bid-ask midpoint. All figures reported are multiplied by 1000. >> (<<) indicates that the left-side figure is higher (lower) than the right-side figure at the 1% level of significance. > (<) indicates that the left-side figure is higher (lower) than the right-side figure at the 5% level of significance. Wilcoxon signed rank test is used to determine the level of significance.

Panel A: Transaction Prices	3-minute return analysis			5-minute return analysis		
Return and Volatility	Pre-Hits		Post-Hits	Pre-Hits		Post-Hits
Period 1: Periods with 7% upward and 7% downward price limits						
Upper Limit Hits (N=57)						
$\overline{R}$	2.3547	>>	-0.7674	3.8669	>>	-1.2611
V_1	7.4748	>>	5.8039	9.1085	>>	6.7072
V_2	4.8599	>>	3.4322	6.6792	>>	4.4696
Lower Limit Hits (N=73)						
$\overline{R}$	-1.6768	<<	0.8633	-2.7693	<<	1.4036
V_1	6.0690		5.5990	7.8158	>>	6.7025
V_2	4.0367	>>	3.4978	5.6827	>>	4.4097
Pseudo Limit Hits (N=188)						
$\overline{R}$	-0.1583		-0.0621	-0.2643		-0.1014
V_1	5.3638		5.4315	6.4599		6.5119
V_2	3.1867		3.3306	4.2856		4.3149
Period 2: Periods with 7% upward and 3.5% downward price limits						
Upper Limit Hits (N=43)						
$\overline{R}$	2.2480	>>	-0.8816	3.6450	>>	-1.4420
V_1	6.3728		5.8240	7.5904		6.7219
V_2	4.5270		3.8124	6.1482	>>	4.7127
Lower Limit Hits (N=79)						
$\overline{R}$	-0.5787	<<	0.4430	-0.9400	<<	0.7275
V_1	3.2999	>	2.5113	4.1017	>	3.1997
V_2	1.8538	>>	1.3789	2.6104	>>	1.9431

Panel B: Bid-ask Midpoint						
	3-minute return analysis			5-minute return analysis		
Return and Volatility	Pre-Hits		Post-Hits	Pre-Hits		Post-Hits
Period 1: Periods with 7% upward and 7% downward price limits						
Upper Limit Hits (N=46)						
$\overline{R}$	2.1220	>>	-0.9059	3.5000	>>	-1.4966
V_1	6.0377	>>	3.8467	7.7632	>>	4.7720
V_2	3.7023	>>	2.1944	5.4156	>>	3.1013
Lower Limit Hits (N=59)						
$\overline{R}$	-1.4521	<<	0.6110	-2.3987	<<	0.9983
V_1	4.3616	>>	3.2918	5.7606	>>	4.3748
V_2	2.6990	>>	1.8570	4.0645	>>	2.6812
Pseudo Limit Hits (N=176)						
$\overline{R}$	-0.2420		-0.0722	-0.3996		-0.1184
V_1	3.6263		4.0527	4.4683		5.1234
V_2	2.0950		2.3681	3.0097		3.3631
Period 2: Periods with 7% upward and 3.5% downward price limits						
Upper Limit Hits (N=40)						
$\overline{R}$	1.8471	>>	-0.6215	3.0236	>>	-1.0215
V_1	4.6791	>>	3.6199	6.3065	>>	4.5991
V_2	3.0389	>>	2.3388	4.7691	>>	3.2652
Lower Limit Hits (N=51)						
$\overline{R}$	-0.5047	<<	0.1628	-0.8399	<<	0.2639
V_1	2.9013	>>	1.8206	3.6082	>>	2.1514
V_2	1.4998	>>	0.9471	2.1131	>>	1.2626

Panel C: Spread Analysis			
Relative spread	Pre-Hits		Post-Hits
Period 1: Periods with 7% upward and 7% downward price limits			
Upper Limit Hits (N=46)	4.5300	<<	6.8566
Lower Limit Hits (N=59)	6.7229	>>	6.0832
Pseudo Limit Hits (N=176)	7.2175		7.3315
Period 2: Periods with 7% upward and 3.5% downward price limits			
Upper Limit Hits (N=40)	5.3758	<	5.8027
Lower Limit Hits (N=51)	7.5973		7.1410

Table VI
Regression Analysis

This table reports the results of regression equations in which the dependent variable is the difference between Pre-Hit volatility and Post-Hit volatility for consecutive limit hits. A consecutive limit hit occurs when a limit hit is followed by further trades at the limit price. Pre-Hit (Post-Hit) refers to the period 30 minutes prior to (after) each consecutive limit hit. Panel A provides descriptive statistics of duration and transactions. Duration is the total time (in seconds) from the first to the last limit hit, while transaction refers to the number of limit hit transactions for each consecutive limit hit. Panel B reports the regression results of the regression: V(Pre)-V(Post) = $\alpha + \beta_1$ Duration + β_2 Up + β_3 Seven + ε as well as its simplified specification. V(Pre) is the pre-hit volatility multiplied by 1,000, while V(Post) is the post-hit volatility multiplied by 1,000. Up takes the value 1 for upper limit hits and takes the value 0 for lower limit hits. Upper (Lower) limit hits occur when prices hit the upward (downward) price limits. Seven takes the value 1 for periods with 7% upward and downward price limits and takes the value 0 for periods with 7% upward and 3.5% downward price limits. The numbers in parentheses are *p*-values.

Panel A: Descriptive Statistics

	Duration (in seconds)	Transaction
Mean	293	5
Median	131	3
Maximum	2504	75
Minimum	0	2

Panel B: Regressions

	3-minute return		5-minute return	
Independent Variables	[1]	[2]	[1]	[2]
Constant	***0.80593	0.44802	***1.55304	*0.92042
	(0.0002)	(0.1817)	(0.0001)	(0.0716)
Duration	**-0.00057	**-0.00053	***-0.00109	***-0.00103
	(0.0200)	(0.0320)	(0.0037)	(0.0067)
Up		0.51852		0.7786
		(0.1965)		(0.2021)
Seven		0.26444		0.57907
		(0.4981)		(0.3294)
R-square	0.0226	0.0319	0.0349	0.0462
Number of Observations	252	252	252	252

***Significance at the 1 percent level; **significance at the 5 percent level; *significance at the 10 percent level.

Table VII
Magnet hypothesis: Return Autocorrelations

This table reports the average return autocorrelations from both the 3-minute return analysis and the 5-minute return analysis during Period 1 and Period 2. Results in Panel A are based on the transaction prices, while those in Panel B are based on the bid-ask midpoints. A bid-ask midpoint is the average of the bid price and the ask price. Magnet sample includes transactions whose prices hit the magnet prices. A magnet price is two ticks below the upper limit price or two ticks above the lower limit price. Control sample includes same stocks in the magnet sample, matched on time of day, day of week, and duration, during which no "magnet prices" are observed. Before (After) refers to the period 30 minutes prior to (after) the trading time of each observation. After-Before is equal to After minus Before. N is the sample size. P-value of After-Before is based on the Wilcoxon signed rank test.

Panel A: Transaction Prices

	3-minute return analysis					5-minute return analysis				
Autocorrelations	N	Before	After	After-Before	P-value	N	Before	After	After-Before	P-value
Period 1: Periods with 7% upward and 7% downward price limits										
Magnet Sample										
Upward movement	2855	-0.1153	-0.1954	-0.0801	0.0000	2846	-0.1458	-0.1930	-0.0472	0.0000
Downward movement	3574	-0.1652	-0.2019	-0.0368	0.0000	3534	-0.1899	-0.2199	-0.0301	0.0000
Control Sample										
Upward movement	2481	-0.2153	-0.2224	-0.0071	0.3160	2426	-0.2331	-0.2340	-0.0010	0.9890
Downward movement	2928	-0.2049	-0.2320	-0.0271	0.0000	2874	-0.2330	-0.2379	-0.0049	0.3370
Period 2: Periods with 7% upward and 3.5% downward price limits										
Magnet Sample										
Upward movement	803	-0.1284	-0.1836	-0.0552	0.0000	798	-0.1921	-0.2061	-0.0140	0.4650
Downward movement	1693	-0.1619	-0.1964	-0.0345	0.0000	1660	-0.2137	-0.2130	0.0006	0.9030
Control Sample										
Upward movement	597	-0.1851	-0.1762	0.0089	0.7000	592	-0.2180	-0.2101	0.0079	0.6400
Downward movement	1436	-0.1849	-0.2052	-0.0202	0.0440	1400	-0.2163	-0.2335	-0.0172	0.0720

Panel B: Bid-ask Midpoint

	3-minute return analysis					5-minute return analysis				
Autocorrelations	N	Before	After	After-Before	P-value	N	Before	After	After-Before	P-value
Period 1: Periods with 7% upward and 7% downward price limits										
Magnet Sample										
Upward movement	2679	-0.0490	-0.1124	-0.0634	0.0000	2661	-0.1046	-0.1550	-0.0505	0.0000
Downward movement	3161	-0.1064	-0.1439	-0.0375	0.0000	3131	-0.1455	-0.1823	-0.0368	0.0000
Control Sample										
Upward movement	2202	-0.1280	-0.1291	-0.0012	0.7580	2160	-0.1746	-0.1734	0.0012	0.7810
Downward movement	2554	-0.1256	-0.1418	-0.0163	0.0290	2507	-0.1803	-0.1955	-0.0152	0.0230
Period 2: Periods with 7% upward and 3.5% downward price limits										
Magnet Sample										
Upward movement	712	-0.0702	-0.1133	-0.0431	0.0020	706	-0.1421	-0.1650	-0.0229	0.0980
Downward movement	1410	-0.1179	-0.1374	-0.0195	0.0310	1388	-0.1746	-0.1854	-0.0108	0.3130
Control Sample										
Upward movement	533	-0.1003	-0.0990	0.0014	0.9760	529	-0.1626	-0.1597	0.0029	0.9510
Downward movement	1188	-0.1227	-0.1208	0.0018	0.9970	1167	-0.1911	-0.1816	0.0094	0.5270

Table VIII
Magnet hypothesis: Trading Volume

This table reports the average trading volume of magnet sample and control sample during Period 1 and Period 2. Magnet sample includes transactions whose prices hit the magnet prices. A magnet price is two ticks below the upper limit price or two ticks above the lower limit price. Control sample includes same stocks in the magnet sample, matched on time of day, day of week, and duration, during which no "magnet prices" are observed. Before (After) refers to the period 30 minutes prior to (after) the trading time of each observation. Before+After is equal to Before plus After. Trading volume during each 30-minute period is scaled by its corresponding daily trading volume. N is the sample size. >> (<<) indicates that the left-side figure is higher (lower) than the right-side figure at the 1% level of significance. > (<) indicates that the left-side figure is higher (lower) than the right-side figure at the 5% level of significance. The superscript a (b) indicates that the figure is higher than that in the control sample with same type of movement at the 1% (5%) level of significance. Wilcoxon signed rank test is used to determine the level of significance.

Trading Volume	N	Before		After	Before+After
Period 1: Periods with 7% upward and 7% downward price limits					
Magnet Sample					
Upward movement	2995	0.2232	>>	0.2024	0.4256[a]
Downward movement	3869	0.1727		0.1698	0.3425[a]
Control Sample					
Upward movement	2732	0.1452	>>	0.1273	0.2725
Downward movement	3439	0.1391	>>	0.1230	0.2621
Period 2: Periods with 7% upward and 3.5% downward price limits					
Magnet Sample					
Upward movement	854	0.1948	>>	0.1720	0.3668[a]
Downward movement	2205	0.1578	>>	0.1373	0.2951[b]
Control Sample					
Upward movement	763	0.1361	>	0.1282	0.2643
Downward movement	1776	0.1472	>>	0.1210	0.2682

Table IX
Magnet hypothesis: Relative spreads

This table reports the mean of relative spreads of magnet sample and control sample during Period 1 and Period 2. Magnet sample includes transactions whose prices hit the magnet prices. A magnet price is two tick sizes below the upper limit price or two tick sizes above the lower limit price. Control sample includes same stocks in the magnet sample, matched on time of day, day of week, and duration, during which no "magnet prices" are observed. Before (After) refers to the period 30 minutes prior to (after) the trading time of each observation. Relative spread is defined as the bid-ask spread divided by the bid-ask midpoint. A bid-ask midpoint is the average of the bid price and the ask price. N is the sample size. All relative spreads reported are multiplied by 1000. >> (<<) indicates that the left-side figure is higher (lower) than the right-side figure at the 1% level of significance. > (<) indicates that the left-side figure is higher (lower) than the right-side figure at the 5% level of significance. Wilcoxon signed rank test is used to determine the level of significance.

Relative spreads	N	Before		After
Period 1: Periods with 7% upward and 7% downward price limits				
Magnet Sample				
Upward movement	2866	5.335	<<	5.525
Downward movement	3582	7.304		7.308
Control Sample				
Upward movement	2549	5.691		5.688
Downward movement	3100	6.475		6.431
Period 2: Periods with 7% upward and 3.5% downward price limits				
Magnet Sample				
Upward movement	787	5.670	<<	5.976
Downward movement	1929	7.115	<<	7.210
Control Sample				
Upward movement	624	5.962	>>	5.790
Downward movement	1501	6.625	>>	6.446