Limit Hits and Informationally Related Stocks

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ABSTRACT

This paper examines the liquidity and price impacts of limit hits on informationally related stocks within different industry concentrations. Information relatedness is implied from correlations of returns, volatilities, and volumes between stocks in the same industry. Trade-based liquidity is significantly higher when either limit is hit, but quote-based liquidity at lower limit hits may behave differently from that at upper limit hits. We observed an augmented total price impact in high concentration industries, though both the total and temporary price impacts of limit hits are significantly different from those during the benchmark period.

JEL Classification: G14, G18, G19

Keywords：Price Limit; Liquidity Impact; Price Impact; Industry Concentration; Asymmetry Information;

1. Introduction

Price limit rules are used in many financial markets to prevent stock prices from fluctuating too much. The goal of price limits is to serve as a circuit breaker. In 2012, the Securities and Exchange Commission (SEC) introduced the limit up/limit down rule to restrain excessive volatility and provide time for reassessment. Many countries, including Japan, China, Korea, Taiwan, Thailand, Malaysia, South Africa, Mexico, Peru, Turkey, and most European Union countries, presently have imposed or have ever imposed price limits on publicly traded stocks. Different stock markets have their own ways of giving investors time to assess new information and avoid crashing in the short term. The Brady Report (1988) suggests two circuit-breaking mechanisms, such as trading halts and price limits, to prevent wild swings in stock prices and provide a time-out period.

Previous studies have focused on the overreaction hypothesis and investigate the price reversals based on abnormal returns (see e.g. Ma, Rao, and Sears (1989a, 1989b) in U.S. future markets; Huang (1998) and Huang, Fu, and Ke (2001) in the Taiwan Stock Exchange (TWSE); and Diacogiannis, Patsalis, Tsangarakis, and Tsiritakis (2005) in the Athens Stock Exchange. Kim and Rhee (1997) provide an investigation regarding price limit hit events in the Tokyo Stock Exchange; their paper compares stocks that hit price limits to stocks that almost hit price limits. They summarize the three negative effects of price limits—the delayed price discovery hypothesis, the volatility spillover hypothesis, and the trading interference hypothesis—and conclude the ineffectiveness of the price limit mechanism.

Based on a similar approach, Bildik and Gulay (2006) show consistent results in the Istanbul Stock Exchange, as do Henke and Voronkova (2005) in the Warsaw Stock Exchange.

Chen, Rui, and Wang (2005) and Kim, Liu, and Yang (2013) both study the regulatory price limits imposed in China's stock markets and find evidence of volatility reduction of the price limit mechanism for A shares in China. Li, Zheng, and Chen (2014) test three hypotheses (delayed price discovery hypothesis, volatility spillover hypothesis, and trading interference hypothesis) using daily data of cross-listed stocks and analyze the shares of the same company stocks across different markets when price limits are hit in the A share market. Yeh and Yang (2013) use a different approach: they test the same three hypotheses based on an artificial stock market composed of bounded rational and heterogeneous traders. Recent research has used intraday data to investigate the effect of price limits, such as Kim and Yang (2008); Lee and Chou (2004); and Sovan Deb, Kalev, and Marisetty (2013). In this paper, we use both intraday and daily data to analyze the impact of price limit hits from informationally related and continually trading stocks.

The mechanisms, such as trading halts and price limits, may act as signals to investors that substantial asymmetric information exists in the market. Bhattacharya and Spiegel (1991) indicate that trading halts arise when the degree of information asymmetry outweighs other motivations for trading, and Shen and Wang (1998) show that informed traders' private information will become public information in the process of trading. What kind of impact does a trading halt or price limit have on the stock market? These issues have been studied over the last two decades; however, most previous studies have investigated the impact of trading halts or price limits on the halted or limit-hitting stock itself. Instead of examining direct impact on limit-hitting stocks, this paper will focus on the liquidity and price impacts of limit hits on informationally related stocks.

Measuring the cross-firm information relationship is a concern in the literature. For example, Caballe and Krishnan (1994) provide a model to measure the information relationship between securities from their trading volumes, returns, and spreads in the market. Lo and Wang (2000) show that a factor structure of trading volume can be implied from portfolio rebalancing and liquidation under certain assumptions. Hasbrouck and Seppi (2001) find that there are common factors in cross-firm returns, order flows, and market liquidity. Spiegel and Subrahmanyam (2000) propose a model in which informationally related equities have a positive correlation in their volatilities; they show that the mechanism giving investors more time to reassess new information is a necessary component of markets. The cessation of trading is regarded as a signal of asymmetric information, and there is a reduction in liquidity for informationally related stocks as a result. Tookes (2008) demonstrates that an informational event in one stock in an industry can trigger informed trading in informationally related stocks in the same industry, which implies an increase in trading. Jiang, McInish, and Upson (2009) investigate the information content of trading halts in New York Stock Exchange (NYSE)-listed stocks through informational relationships with other securities within the same industry. They first establish the informational relationships between halted stocks and non-halted stocks and then conduct analyses on both the liquidity and price impacts of trading halts on informationally related equities. Therefore, these studies establish the informational relationship between stocks by their volumes, volatilities, and returns separately. Hence, this paper extends the analysis framework of Jiang, McInish, and Upson's (2009) study, which ranges from trading halts to price limits in the TWSE market data[1] and investigates the information content of limit hits from the view of informational

[1] Normally, the TWSE sets its daily price limit for each stock at 7%, which is based on the

relationships. From 2004 to 2013, a stock is regarded as a limit-hitting stock if it reached its daily price limit within one day. For each limit-hitting stock, its informationally related stocks are identified in the same industry. The distribution of limit hits, including both upper and lower price limits, is shown in Figure 1.

[Figure 1 is about here.]

Resembling trading halts, price limits provide a cooling off period for investors to digest new information. Even though trading halts and price limits are considered to be circuit breakers, they are not quite the same. Kim, Yagüe, and Yang (2008) assert that investors can more easily observe when a price will hit limits than predict when a trading halt will be called. There remain questions about limit hits that are not applicable to trading halts. Two instances are as follows: (1) the fact that limit prices are known in advance and (2) the fact that limit-hitting stocks can continue to trade (either at the limit price or away from the limit price). In the first instance, we might expect there to be anticipatory changes in the market that precede the limit hit, which could be addressed in the empirical work. The second fact suggests that the empirical work should also account for the post-limit hit environment, since presumably, some stocks that hit the limit continue to trade actively while others may not trade at all.

This paper examines the informational relationship of the stocks listed in the TWSE from the aspects of liquidity and the price impacts of limit hits on informationally related stocks at the lower and upper limits. The sample data is further classified by industry concentration to investigate whether the informational spillover effect of limit hits is

previous day's closing price of each stock. However, daily price limits have been temporarily adjusted to 3.5% to stabilize stock markets when unusual events occurred, such as the 921 Earthquake of 1999, the September 11 attacks, and the 2008 credit crunch.

influenced by industry concentration. Beside investigating the liquidity impact during the whole period of limit hits, the liquidity impact in the post-limit hit environment is further examined by dividing the whole period of limit hits into two sub-periods: the continually trading period and the trading cessation period. It is noteworthy that limit hits can be classified into lower limit hits and upper limit hits and that they may have different liquidity impacts on informationally related stocks. We determine whether quote-based liquidity has a different impact at the lower and upper limits and then verify whether these differences can be explained by investors' sentiments. We also explore how stocks that almost hit price limits for surveying anticipatory changes influence the liquidity impact. In spite of the liquidity impact, Spiegel and Subrahmanyam (2000) state that trades of informationally related stocks have a larger price impact during a trading halt period than during a non-trading halt period. However, Admati and Pfleiderer (1988) demonstrate that informed traders intend to conceal what they privately know from the market. Therefore, in order to investigate the price impact of limit hits on informationally related stocks, we use two price impact measures as defined by Holthausen, Leftwich, and Mayers (1987)—temporary and total price impacts—to observe the price changes during the period of limit hits. A contrary finding in high concentration industries indicates that buyer-initiated trade prices of informationally related stocks rise more during periods of lower limit hits than during periods of upper limit hits. Intuitively, we rank limit-hitting stocks in the high concentration industries by their market shares and then compare their price impacts on informationally related stocks.

The remainder of the paper is organized as follows: Section 2 describes our hypotheses, Section 3 introduces the data and defines informationally related stocks, Section 4 presents the methodology to test the hypotheses, Section 5 discusses empirical results, and Section 6

concludes.

2. Hypotheses

Trading halts in Spiegel and Subrahmanyam's (2000) model act as a signal that the level of information asymmetry increases for stocks that are informationally related to the halted stock, such as stocks in the same industry. The liquidity suppliers observe this signal and then widen the spread and reduce the quoted depths to compensate for the potential losses to the informed traders. That is to say, stocks in the same industry that are informationally related and continue to trade have reduced liquidity during the halt period.

The informed trading model proposed by Tookes (2008) shows informed traders' propensity to make information-based trades in the stocks of competitors. In other words, informed traders seek other venues to obtain arbitrage opportunities because they cannot trade the halted stock directly. For example, informed traders may have incentives to trade stocks that are informationally related to the halted stock; this is also called a substitution effect and implies an increase in trading volume of informationally related stocks.

Because there are some similarities between trading halts and limit hits, this paper investigates the market liquidity impact of limit hits from both quote-based liquidity and trade-based liquidity measures according to the following hypothesis:

Hypothesis 1. During the period of limit hits for a stock, stocks in the same industry that are informationally related and continue to trade have higher trade-based liquidity and lower quote-based liquidity.

As the empirical study conducted by Rourke (2009) suggests, one can estimate the

supply of market liquidity by the shares of the best quotes on the limit book; the order flows indicate the demand of market liquidity. The trade-based liquidity measures, representing the liquidity demand in the market, will increase because of the additional volume of informed traders. The quote-based liquidity measures, representing the liquidity supply in the market, will decrease because of the compensation of the existence of asymmetric information on the market to the liquidity suppliers. We will explain the empirical results of Hypothesis 1 from the perspective of liquidity supply and demand.

Aside from the liquidity impact, the price impact of limit hits is another interesting point to discuss. Proposition eight in Spiegel and Subrahmanyam's (2000) model demonstrates that stocks in the same or related industries will experience an increase in the price impact of market orders during the trade cessation period. That is to say, the price impact on the informationally related stocks should be more positive or more negative during the cessation of trading. Analogous to trading halts, the price impact on the related stocks should be significantly larger during the period of limit hits. The hypothesis of limit hits is as follows:

Hypothesis 2. During the period of limit hits for a stock, the price impact on stocks in the same industry that are informationally related and continue to trade will be significantly different from the price during the benchmark period; prices will rise more (and fall less) at the upper limit than at the lower limit.

Because Tookes (2008) indicates market share or market capitalization of a company as important determinants of the liquidity impact, we expect impacts of limit hits on informationally related stocks in high concentration industries to be stronger than those in low concentration industries.

3. Data

3.1 Data

In order to examine how limit hits affect market liquidity and the informationally related stocks' prices, we use Taiwan Economic Journal (TEJ) data for all the stocks listed in the TWSE (which employs a 7% price limit) between 2004 and 2013 (about 2,475 business days).[2] As in previous studies, we determine the informational relationship between stocks in the same industry from their correlations of trading volumes, volatilities, and returns. We determine the informational relationship between securities in each year by the previous year trading data. Except for common stocks, other securities traded in the TWSE at the same time are excluded, such as ETFs, closed-end funds, beneficial securities, and Taiwan depositary receipts.

[Table 1 is about here.]

The new industry clarification in the TWSE is used to identify each stock's corresponsive industry. There were 28 different industries listed in the TWSE in 2013 (the details of these 28 industries are listed in Table 1). After exclusion, the number of remaining sample stocks and the number of trading days for each year is shown in Table 2. Data used in this study include both daily and intraday frequency.

[Table 2 is about here.]

The descriptive statistics for limit-hitting stock are shown in Table 3. The mean values of time periods of lower limit hits and upper limit hits are 1,141.43 seconds and 1,742.67

[2] There are 10 trading days that are excluded with the 3.5% upper price limit and the 7% lower price limit from 2008/10/13 to 2008/10/24.

seconds, respectively. We define the trading cessation period as the time period during which the bid depth of the lower limit-hitting stock is equal to zero or the time period during which the offer depth of the upper limit-hitting stock is equal to zero. Different from the complete cessation of trading activity in trading halts, trading is still permissible as long as it is within the pre-set trading range in the case of price limits. We observe that the mean percentage of the trading period at the lower price limit is 26% and at the upper price limit is 37%. The mean of the trading period at the lower price limit is 246.71 seconds and at the upper price limit is 159.70 seconds. The mean of the trading volume at limit prices before the cessation of trading is 547.69 thousand shares per five minutes for lower limits and 912.87 thousand shares per five minutes for upper limits.

[Table 3 is about here.]

3.2 Reference group clarification

Based on Jiang, McInish, and Upson's framework (2009), the informational relationship between stocks in the same industry is determined from their correlations of trading volumes, volatilities, and returns. The reference stocks in our paper are also clarified by the concentration of their industries as defined by the Herfindahl–Hirschman Index[3] (HHI), shown in Table 4. The U.S. Department of Justice considers a market with a result of less than 1,000 to be a lowly concentrated marketplace; a result of 1,000~1,800 to be a moderately concentrated marketplace; and a result of 1,800 or greater to be a highly concentrated marketplace.

[3] HHI is often defined as HHI = $10{,}000 \times \sum_{i=1}^{n} s_i^2$, where s_i is the market share of the i-th firm. The HHI number can range from close to zero to 10,000.

[Table 4 is about here.]

Accordingly, we first group the sample by concentration industries. Within each industry, we then recognize the informationally related stocks of each limit-hitting stock by the correlation of their trading volumes, returns, and volatilities in the previous year.

3.2.1 Volume reference group

To separate the industry- and firm-specific informational effects from macroeconomic effects, the volume reference group is formatted by running Ferris, Haugen, and Makhija's (1988) volume model:

$$V_{i,D} = \alpha_i + \beta_i V_{m,D} + \varepsilon_{i,D} \quad (1),$$

where

$V_{i,D}$ = the turnover for stock i on day D,

$$= \frac{\text{the number of shares of stock } i \text{ traded on day } D}{\text{the number of shares of stock } i \text{ outstanding on day } D},$$

$$V_{m,D} = \frac{\text{the number of shares of all stocks traded on day } D}{\text{the number of shares of all stocks outstanding on day } D}, \text{ and}$$

$\varepsilon_{i,D}$ = the abnormal turnover for stock i on day D.

Intraday trading volume for stocks in the TWSE is obtained from intraday data on the *TEJ*'s database. For each stock, a Pearson correlation between the abnormal turnovers of the limit-hitting stock and of the remaining stocks in the same industry is estimated; then, the hypothesis of informational relatedness is accepted or rejected with a 10% significance level. Based on the regression residuals, a stock that has a statistically significant correlation with the limit-hitting stock is classified into the reference group of the limit-hitting stock. A

limit-hitting stock will be excluded from the sample if there is no stock in its own reference group.

1.2.2 Return reference group and volatility reference group

Similarly, the market model is adopted to separate the macroeconomic effects from each stock's adjusted return for return reference groups:

$$R_{i,D} = \alpha_i + \beta_i R_{m,D} + \varepsilon_{i,D} \quad (2),$$

where

$R_{i,D}$ = the adjusted return of stock i on day D,

$R_{m,D}$ = the adjusted return of TWSE's total return index on day D, *and*

$\varepsilon_{i,D}$ = the abnormal return for stock i on day D.

For each stock, a Pearson correlation between the abnormal returns of the limit-hitting stock and that of the remaining stocks in the same industry is estimated; then, the hypothesis of informational relatedness is accepted or rejected with a 10% significance level.

As for the volatility reference group, the square of the residual from the market model (i.e., $\varepsilon_{i,D}^2$) is regarded as the daily volatility of the stock. Based on the correlation of $\varepsilon_{i,D}^2$, a stock is included in the volatility reference group of the limit-hitting stock if it is significantly correlated with the limit-hitting stock.

4. Methodology

This section explains how to measure the impact of the limit hits on informationally related stocks in the same industry. Section 4.1 describes the definitions of the liquidity

measures used and the details of the analysis process of liquidity impact. The analysis process of price impact is shown in Section 4.2.

4.1 Liquidity impacts of price limits on informationally related stocks

4.1.1 Liquidity measures

Many studies use liquidity measures to study the liquidity of the market, such as Chan and Pinder (2000) and Elyasiani, Hauser, and Lauterbach (2000). Six quote-based market liquidity measures of different aspects are used in liquidity impact analysis. The absolute spread, relative spread, offer depth, bid depth, and total depth extracted from the *TEJ*'s intraday data belong to directly quote-based liquidity measures. In addition, Fernandez (2000) emphasizes the need to use different liquidity measures to capture different aspects of liquidity. Hence, the quote slope measure, such as the spread/depth presented by Hasbrouck and Seppi (2001), is also used. These six liquidity measures are classified by three aspects—tightness (absolute spread and relative spread), depth (offer depth, bid depth, and total depth), and quote slope. Depth has the same direction as market liquidity change; for example, depth increases when market liquidity increases. However, tightness and quote slope decrease when market liquidity increases. Any changes in these quote-based liquidity measures, such as spreads, may indicate that the level of asymmetric information changes in the market.

While quote-based liquidity measures represent the liquidity supply changes; trade-based liquidity measures represent the liquidity demand changes. When the limit-hitting stock stops trading, informed traders may deal instead with informationally related stocks to

gain from their private knowledge. As a result, changes in trade-based liquidity measures indicate that there may be a substitution effect between informationally related stocks and limit-hitting stocks. For trade-based measures of liquidity, the volume, value, and number of trades are used to analyze whether the substitution effect exists between the limit-hitting stocks and their informationally related stocks. The empirical results will be presented in Section 5.

4.1.2 Liquidity impact analysis process

The entire limit-hitting interval is further divided into two sub-periods (trading and trading cessation) for the assessment of the liquidity impact on informationally related stocks. The liquidity impact is investigated by comparing the short-term liquidity measure (during day *D* that a limit hit takes place) to the liquidity measure of the benchmark period (the benchmark period of the window between day *D*-5 to day *D*-1, excluding day *D*, is shown in Figure 2). An obvious change between the short-term liquidity measure and the liquidity measure of the benchmark period indicates that the limit hit has an impact on informationally related stocks and that information-asymmetry signals may spread around the market.

Quote-based liquidity measures, including the short-term liquidity measure and the liquidity measure of the benchmark period, are evaluated using the *TEJ*'s intraday market data. At the time of limit hitting, quote-based liquidity measures are calculated by their time-weighted average over the period. A time-weighted average liquidity impact that a limit-hitting stock k has on an informationally related stock k_j is defined as follows:

$$x_{k_j} = \frac{1}{\sum_{i=1}^{m_j} \Delta t_i} \sum_{i=1}^{m_j} x_{k_j,i} \times \Delta t_i \quad (3),$$

where

$k_j =$ the j-th informationally related stock with the limit-hitting stock k,

$x_{k_j} =$ the liquidity measure of stock k_j,

$m_j =$ the number of trade records for stock k_j during the limit-hitting period of stock k,

$\Delta t_i =$ the time interval between the i-th trade record and the $(i+1)$-th trade record for stock k_j, and

$x_{k_j,i} =$ the liquidity measure of stock k_j at the i-th trade record.

In addition, trade-based liquidity measures during the day *D* that a limit hit occurs are also evaluated by the *TEJ*'s intraday market data. These short-term liquidity measures are estimated by the aggregation of trade-based liquidity impacts per five minutes. However, trade-based liquidity measures of the benchmark period are calculated based on the *TEJ*'s daily market data and are further transformed into the liquidity measure per five minutes for comparison.

[Figure 2 is about here.]

To assess liquidity impact in more detail, we consider that a stock on day *D*, denoted by stock k, which hits its price limit boundary, has J informationally related stocks. For a liquidity measure x, the liquidity impact of the limit hit of stock k on an informationally related stock k_j is defined as follows:

$$\alpha_{k_j}^{x} = x_{k_j} / \bar{x}_{k_j} \quad (4),$$

where

$x_{k_j} =$ the liquidity measure of the j-th related stock k_j during the limit-hitting period of stock k, and

$\bar{x}_{k_j} =$ the liquidity measure of stock k_j during the benchmark period.

After assessing all $\alpha^{x}_{k_j}$, the liquidity impact of the limit hit of stock k on its J informationally related stocks is defined as follows:

$$\alpha_k^x = \frac{1}{J}\sum_{k_j=1}^{J} \alpha_{k_j}^x \quad (5).$$

These processes are repeated with limit hits; then, a *t*-test is conducted to evaluate whether the liquidity impact of the sample of limit hits is statistically significantly different from the value 1.

This analysis is repeated for all of the liquidity measures within each reference group. A significant difference existing among those with liquidity impact indicates that stocks hitting the price limit affect significantly informationally related equities. If the trade-based liquidity measures increase based on Hypothesis 1, then the liquidity impact results from the substitution effect on stocks in the market. In other words, informed traders may not buy or sell the limit-hitting stock directly during the period of limit hits; however, they may use their own superior knowledge about the market or the industry to trade and to earn abnormal profits from the market. Meanwhile, if quote-based liquidity measures significantly change (lower quote-based liquidity), the level of asymmetric information is so high that non-informed traders (acting as the liquidity supplier) in the market widen the spread to compensate for losses to informed traders. The quote-based measures of liquidity then decrease. The results of liquidity impact are shown and discussed in Section 5.1.

4.2 Price impacts of price limits on informationally related stocks

Spiegel and Subrahmanyam (2000) show that trades have a larger price impact during a trading halt period compared to a period of continuous trading. To analyze the price impact

before and after the time of a limit hit, the temporary and total price[4] impact proposed by Holthausen, Leftwich, and Mayers (1987) are used. Their definitions are as follows:

$$P_{t,total} = D_t \ln\left(\frac{P_t}{P_{open}}\right) \quad (6),$$

and

$$P_{t,temp} = D_t \ln\left(\frac{P_{close}}{P_t}\right) \quad (7),$$

where

$P_t =$ the price at time t,

$P_{open} =$ the price at the opening,

$P_{close} =$ the price at the closing, and

$D_t =$ 1 if the trade is buyer-initiated and -1 if the trade is seller-initiated.

The direction of the trades is investigated through the trade inference algorithm Lee and Ready (1991) present. In a tick test, if the trade price is larger than or equal to the preceding trade price (uptick or zero uptick), the trade is buyer-initiated; if the trade price is lower than or equal to the preceding trade price (downtick or zero downtick), the trade is seller-initiated. Both the opening and closing prices are obtained from the first and the last equilibrium prices every day in the *TEJ*'s intraday data. If the private information influences market prices, it will be indicated by these two price impact components.

The private information itself decides the direction of price impact on each trade. If informed traders enter into the market for trading informationally related stocks, the price impact of limit hits on these informationally related securities can be significantly detected during the period of limit hits, compared with a period of continuously trading. An upper

[4] Keim and Madhavan (1996) used these price impact measures to investigate the impact of large block trades on price and liquidity measures.

limit hit is regarded as a positive information event and a lower limit hit is regarded as a negative information event in the industry. Hence, the analysis of price impact is partitioned into four aspects: buyer-initiated positive information events, seller-initiated positive information events, buyer-initiated negative information events, and seller-initiated negative information events. The benchmark period here excludes all the trades after the limit hit, which is shown in Figure 3.

[Figure 3 is about here.]

Both $P_{t,total}$ and $P_{t,temp}$ are calculated once a trade is completed in the market during the limit hit period or during the benchmark period on day D; then, a *t*-test is conducted to examine the difference of their averages between the limit hit period and the benchmark period. The empirical results of price impacts of limit hits on informationally related stocks are shown in Section 5.2.

5. Empirical Results

5.1 Liquidity impact of limit hits on informationally related stocks

The results of the liquidity impact of limit hits on informationally related stocks in the same industry are shown in Table 5. There are several interesting findings among the three reference groups of volume, volatility, and return. The empirical results in our analysis are qualitatively similar among all the informational groupings, and we focus only on the return reference group results for conciseness.

[Table 5 is about here.]

First, the spread measures, including the absolute spread and the relative spread of informationally related stocks, significantly increase during the entirely lower limit-hitting period, but they significantly decrease during the entirely upper limit-hitting period. For instance, the absolute spread measure increases by 9% at the lower limit hit and decreases by 5.38% at the upper limit hit. This result indicates that it may be reasonable to treat a lower limit hit as a signal of an increase in information asymmetry, but this may not be the case for an upper limit hit. These observations seem to be reasonable because corporate managers may have different attitudes toward bad news and good news and investors may have different sentiments at lower limit hits and upper limit hits. Although investors are eager to seek private information, especially when price limits are hit,[5] informed parties such as corporate managers may treat bad news very differently than good news. They may be glad and actively announce or confirm good news, but they may tend to hide or delay the propagation of bad news. Meanwhile, a lower limit hit is often regarded as a signal of negative information and an upper limit hit is often regarded as a signal of positive information. Second, the spread measures of informationally related stocks in the trading sub-period of the entirely limit-hitting period are larger than those in the trading cessation sub-period of the entirely limit-hitting period. For instance, the absolute spread measure for the lower limit-hitting period increases by 8.92% in the trading sub-period but decreases by

[5] Lee, Mucklow, and Ready (1993) point out that any probability of information leakage prior to the formal announcement of an event increases information asymmetry. However, even in the absence of leakage, information asymmetry risk may increase before the announcement for two reasons. First, the liquidity supplier faces the risk that other traders may receive and trade on the public news before he/she has a chance to revise his/her quotes, and thus may incur potential losses. Another risk is that the expectation of an imminent event may stimulate some traders to search for information immediately prior to the announcement. In either case, the liquidity supplier is at greater risk prior to news releases.

4.91% in the trading cessation sub-period. For the upper limit-hitting period, the absolute spread measure decreases by 2.79% in the trading sub-period and decreases by 9.58% in the trading cessation sub-period. Because the trading sub-period often precedes the trading cessation sub-period, the quote spread decline in the post-limit hit environment may be explained by information leakage; this is consistent with Shen and Wang's (1998) argument that informed traders reveal their information through trades.[6] Third, offer and bid depths do not always increase, which Jiang, McInish, and Upson (2009) observed in trading halt markets. However, the total depths during a lower limit hit period and an upper limit period hit both increase, even though the offer depth during the period of a lower limit hit decreases.[7] There is an observed asymmetry response to limit hits: the bid depth during the period of lower limit hits dramatically increases (by 42.01%), whereas the offer depth during the period of upper limit hits dramatically increases (by 36.92%). Jiang, McInish, and Upson (2009) conjecture that the quoted depth increase reflects a shift in the sources of liquidity supply, helping to explain these quoted depth puzzles. Hedge funds and proprietary trading desks (HFPTD) may add enormous amounts of liquidity to markets. HFPTD investment strategies may be time-sensitive and concern the execution of orders that exceed the specific

[6] Kim and Verrecchia (1991) suggest that information asymmetry should be higher after the earnings news because the announcement is a noisy signal, and certain traders have a superior ability to process the earnings news. Alternatively, Lee, Mucklow, and Ready (1993) hypthesize that the earnings news reduces the information advantage of the informed trader, so spreads (depths) should decrease (increase) during this time. Our findings about the decline of information asymmetry during the period of an upper limit hit may partially support this alternative hypothesis, as market participators' positive anticipatory of earnings releases sometimes result in an upper limit hit—a signal of an upcoming positive information release.

[7] Lee, Mucklow, and Ready (1993) investigate liquidity changes in response to incoming earnings announcements and show that quoted spreads widen and depths drop in response to an increase in volume. In this study, our findings during the period of a lower limit hit may partially support their argument if the depth is replaced with the offer depth.

execution price. Waiting for informational events to be fully impounded into market prices is considered to undercut the statistical expectations and risk distribution of the overall investment strategy. Higher liquidity demand will allow for quicker execution for passive trading, resulting in higher quoted depths. A dramatic increase in the bid (offer) depth indicates higher liquidity demand during the period of lower (upper) limit hits. While quoted depths increase, we think this may be a response by liquidity suppliers to increased transaction demand from informed traders. This is consistent with our finding of extremely large increases in trading activity during the whole period of limit hits. Fourth, the composite measure of quoted slope (spread/depth) during the period of lower limit hits increases by 17.66%, but during the period of upper limit hits, it only decreases by 11.06%. However, the increase (decrease) of the quoted slope during the period of lower (upper) limit hits is not statistically significant, though it may indicate an overall reduction (augment) of quoted market liquidity during the period of lower (upper) limit hits. Fifth, while the liquidity impact of limit hits is mixed for quote-based measures of liquidity, trade-based measures of liquidity show dramatic increases. Informationally related stocks' trade volume, trade value, and number of trades respectively increase by 25.82%, 16.62%, and 9.52% during the whole period of lower limit hits. These measures also respectively increase by 21.99%, 22.07%, and 10.05% during the whole period of upper limit hits. These findings are consistent with those of Jiang, McInish, and Upson (2009) regarding trading halts. However, the significant increases in trade-based liquidity measures for informationally related stocks during the trading sub-period of the limit-hitting stock clearly show that the substitution effect of limit hits may not only occur during the period of trading cessation. Our results show that the liquidity impacts of limit hits on informationally related stocks are dramatic. The large

increase in the trade-based measure of liquidity, coupled with a mixed quote-based liquidity during the period of limit hits, partially support Hypothesis 1.

Alternatively, the mixed quote-based liquidity of limit hits may result from investor behavior. That is to say, investors will be more conservative when negative information is revealed. On the contrary, investors will be more active when positive information is spread around. Li, Zheng, and Chen (2014) find a similar but not quite the same liquidity asymmetry in the lower limit hit and upper limit hit cases and argue that China's irrational investors tend to be overly optimistic and buy stocks even after the upper limit hits but tend to be more hesitant to sell stocks that incur losses and wait for government's intervention to raise the stock's price. Baker and Wurgler (2007) show that investor sentiment has a stronger reaction regarding the high volatility of stocks; therefore, informationally related stocks for a limit-hitting stock are further classified according to their volatilities to analyze the liquidity impacts of limit hits. Table 6 shows that informationally related stocks with high volatility have augmented liquidity impacts. For instance, in the return reference group, the absolute spread measure at lower limit hits increases by 9.15% for informationally related stocks with high volatility and increases by 8.5% for those with low volatility. Similarly, the absolute spread measure at upper limit hits decreases by 5.5% for informationally related stocks with high volatility and decreases by 4.91% for those with low volatility. Other liquidity measures have similar observations.

[Table 6 is about here.]

Lemma 2 of Tookes' (2008) model indicates that companies with lower market shares simply lack enough product market impact to affect the market liquidity of other stocks in the same industry. A reasonable inference is that the liquidity impact of limit hits on related

stocks is augmented in the market share of the limit-hitting company and weakened in the market share of the related stock; therefore, we investigated the effect of the industry concentration on the liquidity impact of limit hits, and Table 7 shows the results. Only the results of the return reference group are shown for conciseness, because they are qualitatively similar for all of the informational groups. However, the industry concentration seems to have little impact on the liquidity impact of limit hits on information-related stocks; this seems to differ little from those findings in Table 5.

[Table 7 is about here.]

In addition, we analyze the impact of the sequence of limit hits on the liquidity impact of limit hits on informationally related stocks. We collected subsample data of stocks that hit the price limit more than three times in a day for investigation and then examined the liquidity impact of the first three limit-hitting sequences on informationally related stocks. The empirical results are shown in Table 8. Only the return reference group results are shown for conciseness, as they are qualitatively similar for all of the informational groups. The first limit hit has the strongest impact on liquidity measures of informationally related stocks. The information asymmetry and the substitution effect both seem to decline with the sequence of limit hits. For instance, absolute spread measures at the lower limit in the return reference group respectively increase by 14.86%, 10.95%, and 6.51% in the first, second, and third limit hits during the whole period of limit hits. Those at the upper limit respectively decrease by 2.77%, 3.45%, and 7.54% in the first, second, and third limit hits. Instead, trade volume measures at the lower limit respectively increase by 52.02%, 27.54%, and 16.09% in the first, second, and third limit hits during the whole period of limit hits; those at the upper limit respectively increase by 39.54%, 32.74%, and 9.65% in the first, second, and third limit hits.

[Table 8 is about here.]

In contrast to the unpredictable property of trading halts is the fact that limit prices are set in advance; there may be anticipatory changes in the market that precede limit hits. The TWSE sets its daily price limits for each stock at 7%, based on its closing price of the previous day. Therefore, we investigate the liquidity impacts of anticipatory limit hits on informationally related stocks based on three price ranges: 5.5%~6%, 6%~6.5%, and 6.5%~7%. We hypothesize that liquidity suppliers will anticipate upcoming limit hits by actively adjusting quotes of price and quantity; further, we anticipate that the substitution effect from liquidity demanders will gradually affect informationally related stocks. Our empirical results are shown in Table 9. There seems to be an obvious tendency that the liquidity impacts of anticipatory limit hits on informationally related stocks are gradually pronounced until limit hits. For instance, absolute spread measures in the return reference group respectively increase by 5.76%, 6.04%, and 6.68% in cases where stock prices respectively decrease by 5.5%~6%, 6%~6.5%, and 6.5%~7%. The same measures respectively decrease by 8.67%, 9.02%, and 10.78% in cases where stock prices respectively increase by 5.5%~6%, 6%~6.5%, and 6.5%~7%. Trade volume measures gradually increase from -5.52% to 4.1% in response to stock prices that gradually decrease from -5.5%~-6% to -6.5%~-7%. The same measures also gradually increase from 2.32% to 4.98% in response to stock prices that gradually increase from 5.5%~6% to 6.5%~7%. Therefore, our findings support the liquidity impacts of anticipatory limit hits on informationally related stocks.

[Table 9 is about here.]

5.2 Price impact of limit hits on informationally related stocks

We investigate the price impacts of limit hits on informationally related stocks by measuring the temporary and total price impacts, which are respectively related to the closing and opening price. Table 10 shows these results.

[Table 10 is about here.]

Unlike Jiang, McInish, and Upson's (2009) findings in markets with trading halts, both the temporary and total price impacts here are found to be significant at the 1% level for all three reference groups in markets with price limits. According to Admati and Pfleiderer's (1988) informed trader models, informed traders attempt to hide their information from the market. If they succeed in hiding their trades, the total price impact (relative to the opening price) will not be significant; moreover, if informed traders are truly informed and have sufficient resources, the temporary price impact (relative to the closing price) will be significant. The significance of the total price impact of limit hits may indicate that it is easier to be aware of informed trades within the pre-set price range than with the mechanism of trading halts. The leakage of private information could result in price movements toward limits, and the following limit hit may justify the situation of information asymmetry.[8] Because limit hits do not necessarily imply the release of important information,[9] informed traders may have more opportunity to gain from the trades in informationally related stocks during the period of limit hits compared with a trading halt. This might help to explain the significance of the total price impact of limit hits on informationally related stocks.

[8] This could indicate the presence of anticipatory behavior, information leakages, or insider trading.

[9] Firms are not often required to release information related to the cause of a limit hit.

Table 10 indicates that the increase in buyer-initiated trades is greater (stock prices rise more) at the upper limit and lesser (stock prices rise less) at the lower limit, whereas the decrease in seller-initiated trades is lesser (stock prices fall less) at the upper limit and larger (stock prices fall more) at the lower limit compared with their opening prices. For instance, the total price impact of limit hits for buyer-initiated trades in informationally related stocks in the return reference group is 0.0077 for upper limit hits and 0.0053 for lower limit hits. Positive signs of these two numbers denote that, on average, the prices of informationally related stocks during the period of limit hits are higher than their opening prices; however, a higher value at an upper limit hit than at a lower limit hit implies that the prices of informationally related stocks rise more during the period of upper limit hits than during the period of lower limit hits compared with their opening prices. In contrast to buyer-initiated trades, the total price impact of limit hits for seller-initiated trades in informationally related stocks in the return reference group is, on average, 0.0019 for upper limit hits and 0.0109 for lower limit hits. Instead, the positive signs of these two numbers denote that, on average, the prices of informationally related stocks during the period of limit hits are lower than their opening prices. A higher value at a lower limit hit than that at an upper limit hit implies that, compared with their opening prices, prices of informationally related stocks fall more during the period of lower limit hits than during the period of upper limit hits. All of these numbers during the period of limit hits are different at a statistically significant level from those during the benchmark period.

Meanwhile, the temporary price impact of limit hits for buyer-initiated trades in informationally related stocks in the return reference group is 0.0039 at upper limit hits and -0.0096 at lower limit hits. A positive sign at upper limit hits implies that closing prices

of informationally related stocks are, on average, larger than those during the period of upper limit hits. Instead, a negative sign at lower limit hits implies that the closing prices of informationally related stocks are, on average, smaller than those prices during the period of lower limit hits. Similarly, the temporary price impact of limit hits for seller-initiated trades in informationally related stocks in the return reference group is -0.0022 for upper limit hits and 0.0148 for lower limit hits. A negative sign at upper limit hits implies that closing prices of informationally related stocks are, on average, larger than those during the period of upper limit hits. Further, a positive sign at lower limit hits implies that the closing prices of informationally related stocks are, on average, smaller than prices during the period of lower limit hits. These numbers show that limit hits may continually affect the closing prices of informationally related stocks. Our empirical results also show that the temporary price impact at lower limit hits is larger than at upper limit hits because the absolute value of the temporary price impact for lower limit hits is higher than at upper limit hits. In other words, traders react to negative information (lower limit hits) more fiercely than to positive information (upper limit hits). All of these numbers during the period of limit hits are different at the statistically significant level from those during the benchmark period. Our empirical findings for the temporary price impact of limit hits on informationally related stocks are consistent with those that Jiang, McInish, and Upson (2009) found in markets with trading halts; they support Hypothesis 2.

In order to investigate the influence of firms' market share on the price impacts of limit hits on informationally related stocks,[10] industries are further classified into subsamples by their concentration; the empirical results are shown in Table 11.

[10] Companies with a lower market share simply lack the product market impact to affect the

[Table 11 is about here.]

The empirical findings in Table 11 from industries with different concentrations are quite similar to those in Table 10. However, limit hits in high concentration industries seem to incur more pronounced total price impacts on informationally related stocks than those in low or medium concentration industries. For example, the total price impact of limit hits in high concentration industries for buyer-initiated trades on informationally related stocks is 0.0131 at lower limit hits and 0.0089 at upper limit hits. Meanwhile, the total price impact of limit hits in medium concentration industries for buyer-initiated trades on informationally related stocks is 0.0030 at lower limit hits and 0.0074 at upper limit hits. Further, the total price impact of limit hits in low concentration industries for buyer-initiated trades on informationally related stocks is 0.0044 at lower limit hits and 0.0074 at upper limit hits. Obviously, total price impacts in high concentration industries for buyer-initiated trades on informationally related stocks are the largest, compared with those in low or medium concentration industries for both lower and upper limit hits. Similar results are also found in total price impacts for seller-initiated trades. Interestingly, Lemma 2 of Tookes' (2008) model indicates that companies with lower market share simply lack the product market impact to affect the market liquidity of other stocks in the same industry. We find that the result of the total price impact of limit hits on informationally related stocks is similar to the result of Lemma 2 of Tookes' (2008) model, but that the result of the market liquidity of limit hits on informationally related stocks is not similar to the result of Lemma 2 of Tookes' (2008) model.

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market liquidity of other stocks in the same industry.

A contrary finding in high concentration industries is that the total price impact of lower limit hits for buyer-initiated trades on informationally related stocks is larger than that at upper limit hits (0.0131 vs. 0.0089). This finding indicates that buyer-initiated trade prices of informationally related stocks rise more during the period of lower limit hits than during the period of upper limit hits. It is probable that the individual bad news of a company in a high concentration industry may usually be good news to other companies in the same industry. For example, the news of a factory fire in a company with a higher market share usually incurs the transfer of a great deal of business orders to other companies in the same industry. Therefore, lower limit hits may result in the rising prices of informationally related stocks in high concentration industries, especially for those with brightening prospects.

In order to verify this argument, we further rank the stock sample in high concentration industries by the market share of the limit-hitting stock; then, we compare the price impact of limit-hitting stocks ranked in the top third of the market share on informationally related stocks to those ranked in the bottom third of the market share in high concentration industries. Table 12 shows that the total price impact of limit-hitting stocks ranked in the top third of the market share is more pronounced than that ranked in the bottom third of the market share. For instance, the total price impact of lower limit-hitting stocks ranked in the top third of the market share on informationally related stocks in buyer-initiated trades is, on average, 0.0251, and the total price impact of lower limit-hitting stocks ranked in the bottom third of the market share is 0.0074. Particularly, the contrary total price impact of limit hits on informationally related stocks in buyer-initiated trades is augmented in the top third of the market share; it becomes 0.0251 at lower limit hits and 0.0093 at upper limit hits. Nevertheless, the contrary total price impact of limit hits on informationally related stocks

in buyer-initiated trades disappears in the bottom third of the market share, becoming 0.0074 at lower limit hits and 0.0083 at upper limit hits. Therefore, we find some empirical evidence to explain the observed contrary total price impact of limit hits on informationally related stocks in buyer-initiated trades in high concentration industries.

[Table 12 is about here.]

In fact, we also observe a contrary temporary price impact of limit hits on informationally related stocks in buyer-initiated trades in high concentration industries. For example, in Table 11, the temporary price impact of lower limit hits on informationally related stocks in buyer-initiated trades in high concentration industries is 0.0038 for the volatility reference group and 0.0011 for the volume reference group. In Table 12, the contrary temporary price impact of limit hits on informationally related stocks in buyer-initiated trades is augmented in the top third of the market share and disappears in the bottom third of the market share.

6. Conclusion

This paper performs an empirical analysis on the information content of limit hits on informationally related stocks in the TWSE. Information relatedness is implied from correlations of returns, volatilities, and volumes between stocks in the same industry. During the period of lower limit hits, overall, the quote-based liquidity of informationally related stocks is lower (e.g., it has a wider bid-ask spread, and the quote slope is positive, whereas their trade-based liquidity is higher, such as an increase in trading volume). However, during the period of upper limit hits, the quote-based liquidity on informationally related stocks trivially becomes higher, as does the trade-based liquidity (e.g., a narrower bid-ask spread, a

negative quote slope, and an increase in trading volume); hence, a lower limit hit may signal a rise in information asymmetry, but an upper limit hit may not. These results are robust for all three reference groups and are pronounced for informationally related stocks with high volatility. In response to anticipatory changes, the liquidity impacts of limit hits on informationally related stocks are observed to be the sharpest when price limits are first hit. However, a contrary finding is that liquidity impacts of limit hits on informationally related stocks in the post-limit hit environment are not augmented during the period of trading cessation.

As for the price impact, our empirical results show that both the total and temporary price impacts are significant at the 1% level for all three reference groups in markets with price limits. The significance of the total price impact of limit hits may indicate that informed trades are easier to be aware of within the pre-set price range than with the mechanism of trading halts. During the period of limit hits, the increase in buyer-initiated trades is greater (stock prices rise more) at the upper limit and lesser (stock prices rise less) at the lower limit, whereas the decrease in seller-initiated trades is lesser (stock prices fall less) at the upper limit and greater (stock prices fall more) at the lower limit compared with their opening prices. Our empirical results also show that the temporary price impact at lower limit hits is larger than at upper limit hits. In other words, traders react to negative information (lower limit hits) more fiercely than to positive information (upper limit hits). In addition, limit hits in high concentration industries seem to incur more pronounced total price impacts on informationally related stocks than those in low or medium concentration industries. However, a contrary finding in high concentration industries indicates that buyer-initiated trade prices of informationally related stocks rise more during the period of lower limit hits

than those during the period of upper limit hits. It is probable that the individual bad news of a company in a high concentration industry may usually be good news to other companies in the same industry; therefore, lower limit hits may result in the rising prices of informationally related stocks in high concentration industries, especially for those with brightening prospects.

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Tables

Table 1. Industries in the TWSE in 2013

No.	Industry Name	Number of Stocks
01	Cement	7
02	Food	24
03	Plastics	23
04	Textiles and Fiber	47
05	Electrical Machinery	39
06	Electric Appliances, Wire, and Cable	17
08	Class	4
09	Pulp and Paper	7
10	Iron and Steel	29
11	Rubber	10
12	Automobile	5
14	Construction	46
15	Transportation	19
16	Tourist	8
17	Banking and Insurance	42
18	Department Store	12
20	Others	41
21	Chemical	24
22	Biotechnology and Health Care	20
23	Gas and Electricity	8
24	Semiconductor	70

25	Computer and Peripheral Equipment	61
26	Optoelectronics	78
27	Communications and Internet	43
28	Electronic Parts	86
29	Electronic Communications	27
30	Electronic Information Service	17
31	Other Electronics	35

Resource: Taiwan Economic Data Center website

New industry categories of common stocks in the TWSE are shown in the table along with the industry number and the number of stocks in each industry.

Table 2. Number of Trading Days and Analysis Stocks for Each Year

Year	Number of Trading Days	Number of Analysis Stocks
2004	250	606
2005	247	619
2006	248	641
2007	247	637
2008	249	650
2009	251	684
2010	251	714
2011	247	728
2012	250	746
2013	246	769

Because there is one day missing data in 2005, only the data from the remaining 246 days is used for analysis. In addition, we excluded 10 extra trading days from 2008/10/13 to 2008/10/24 due to a temporary adjustment of lower price limits from 7% to 3.5%. Consequently, there are 2,475 trading days remaining for analysis.

Table 3. Descriptive Statistics for Limit Hits

	Lower Limit Hits		Upper Limit Hits	
	Mean	Std. Dev.	Mean	Std. Dev.
Whole Period of Limit Hits (sec)	1141.43	2905.01	1742.67	3800.14
Trading Sub-Period (sec)	246.71	788.38	159.70	528.47
Trading Cessation Sub-Period (sec)	894.72	2770.77	1582.97	3767.27
Percentage of Trading	0.26	0.39	0.37	0.43
Percentage of Trading Cessation	0.74	0.39	0.63	0.43
Trading Volume (1000 shares/5 mins)	547.69	3068.39	912.87	4791.15

The whole time period of limit hits can be further subdivided into two periods: trading sub-period and trading cessation sub-period. The trading cessation sub-period is defined by the time during which the quoted bid depth of a lower limit-hitting stock is equal to zero or when the quoted offer depth of an upper limit-hitting stock is equal to zero.

Table 4. Concentration of Industries

	Number of Industries in Each Year		
Industry Concentration	Low	Medium	High
Range of HHI	HHI $<$ 1000	1000 $\leq$ HHI $<$ 1800	HHI $\geq$ 1800
2004	8	7	13
2005	8	9	11
2006	8	9	11
2007	9	8	11
2008	8	9	11
2009	9	9	10
2010	8	9	11
2011	7	10	11
2012	9	7	12
2013	8	8	12

There are 28 industries total in each year. The corresponding industry names are shown in Table 1.

Table 5. Liquidity Impact of Limit Hits on Informationally Related Stocks.

	Lower Limit Hits			Upper Limit Hits		
	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel A: Return Reference Group						
Absolute Spread (%)	9.00***	8.92***	-4.91***	-5.38***	-2.79***	-9.58***
Relative Spread (%)	15.04***	15.08***	0.46***	-8.58***	-5.59***	-12.65***
Bid Depth (%)	42.01***	36.90***	23.76***	4.68***	-0.64***	0.05***
Offer Depth (%)	-15.77***	-16.43***	-27.32***	36.92***	28.77***	30.10***
Depth (%)	14.56***	11.48***	-0.51***	18.33***	11.85***	12.80***
Spread/Depth (%)	17.66	18.17	2.86	-11.06	-6.15	-15.14
Trade Volume (%)	25.82***	30.87***	13.99***	21.99***	50.81***	18.59***
Trade Value (%)	16.62***	21.99***	5.19***	22.07***	50.47***	18.49***
Number of Trades (%)	9.52***	14.84***	-3.79***	10.05***	19.33***	5.33***
Panel B: Volatility Reference Group						
Absolute Spread (%)	8.97***	8.89***	-4.96***	-5.50***	-2.78***	-9.57***
Relative Spread (%)	15.00***	15.04***	0.41***	-8.58***	-5.58***	-12.64***
Bid Depth (%)	41.85***	36.64***	23.70***	4.74***	-0.58***	0.14***
Offer Depth (%)	-15.72***	-16.42***	-27.26***	36.85***	28.63***	30.03***
Depth (%)	14.50***	11.34***	-0.53***	18.31***	11.80***	12.81***
Spread/Depth (%)	17.61	18.11	2.78	-11.13	-6.21	-15.16
Trade Volume (%)	25.98***	31.06***	14.25***	21.93***	50.47***	18.52***
Trade Value (%)	16.74***	22.16***	5.41***	21.99***	50.16***	18.40***
Number of Trades (%)	9.53***	14.77***	-3.75***	10.01***	19.25***	5.28***

Table 5 (continued). Liquidity Impact of Limit Hits on Informationally Related Stocks.

	Lower Limit Hits			Upper Limit Hits		
	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel C: Volume Reference Group						
Absolute Spread (%)	9.01***	8.93***	-4.93***	-5.80***	-3.18***	-9.87***
Relative Spread (%)	15.02***	15.06***	0.44***	-8.60***	-5.60***	-12.67***
Bid Depth (%)	42.13***	36.86***	23.97***	4.77***	-0.53***	0.16***
Offer Depth (%)	-15.76***	-16.49***	-27.29***	36.94***	28.80***	30.08***
Depth (%)	14.63***	11.44***	-0.39***	18.37***	11.91***	12.84***
Spread/Depth (%)	17.66	18.19	2.84	-11.17	-6.25	-15.19
Trade Volume (%)	25.88***	30.82***	14.17***	21.96***	50.59***	18.53***
Trade Value (%)	16.64***	21.97***	5.34***	21.98***	50.20***	18.36***
Number of Trades (%)	9.53***	14.80***	-3.76***	9.98***	19.18***	5.26***

For each reference group, we present the percentage increase (decrease) for each liquidity measure for three time periods: the whole period of limit hits, trading sub-period, and trading cessation sub-period. The liquidity impact is investigated by comparing the short-term liquidity measure (during the day *D* that the limit hit takes place) to the liquidity measure of the benchmark period (the benchmark period of *D*-5 to *D*-1 day window, excluding day *D*). Only trade-based liquidity measures of the benchmark period are calculated based on the daily market data of the *TEJ*. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 6. Liquidity Impact of Limit Hits on High Volatility Stocks vs. Low Volatility Stocks

Return	Lower Limit Hits			Upper Limit Hits		
Reference Group	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel A: High Volatility Informationally Related Stocks						
Absolute Spread (%)	9.15***	9.05***	-4.10***	-5.50***	-2.96***	-9.43***
Relative Spread (%)	15.33***	15.35***	1.42***	-8.77***	-5.78***	-12.57***
Bid Depth (%)	43.98***	38.53***	26.20***	4.75***	-0.46***	0.42***
Offer Depth (%)	-16.32***	-17.00***	-27.13***	38.47***	30.05***	31.86***
Depth (%)	15.37***	12.10***	0.88***	19.03***	12.50***	13.76***
Spread/Depth (%)	18.06	18.56	3.90	-11.15	-6.25	-14.99
Trade Volume (%)	26.76***	32.23***	15.60***	22.99***	52.11***	19.90***
Trade Value (%)	17.32***	23.27***	6.46***	23.13***	51.78***	19.91***
Number of Trades (%)	9.69***	15.26***	-2.94***	10.26***	19.65***	5.83***
Panel B: Low Volatility Informationally Related Stocks						
Absolute Spread (%)	8.50***	8.48***	-7.66***	-4.91***	-2.19***	-10.10***
Relative Spread (%)	14.07***	14.15***	-2.79***	-7.89***	-4.91***	-12.95***
Bid Depth (%)	35.32***	31.36***	15.45**	4.42***	-1.32***	-1.32***
Offer Depth (%)	-13.88***	-14.47***	-27.98***	31.16***	23.96***	23.57***
Depth (%)	11.81***	9.38***	-5.24***	15.72***	9.40***	9.23***
Spread/Depth (%)	16.30	16.83	-0.69	-10.69	-5.80	-15.69
Trade Volume (%)	22.60***	26.24***	8.53**	18.23***	45.96***	13.73***
Trade Value (%)	14.27***	17.66***	0.87	18.12***	45.57***	13.18***
Number of Trades (%)	8.93***	13.40***	-6.68***	9.28***	18.17***	3.46***

Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 7. Liquidity Impact of Limit Hits Across Industry Concentration

Return	Lower Limit Hits			Upper Limit Hits		
Reference Group	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel A: In High Concentration Industries						
Absolute Spread (%)	11.00***	11.50***	-2.81***	-5.27***	-2.90***	-8.87***
Relative Spread (%)	19.34***	19.71***	4.56***	-7.99***	-5.13***	-11.57***
Bid Depth (%)	43.63***	37.74***	26.23***	4.61***	-0.40***	0.51***
Offer Depth (%)	-18.41***	-18.85***	-29.48***	42.80***	32.93***	36.37***
Depth (%)	14.23***	10.78***	-0.17***	20.63***	13.59***	15.61***
Spread/Depth (%)	23.51	24.13	8.38	-10.93	-6.10	-14.40
Trade Volume (%)	35.59***	43.04***	23.64***	39.97***	92.01***	37.67***
Trade Value (%)	26.50***	33.99***	15.03***	40.42***	88.42***	37.77***
Number of Trades (%)	10.98***	16.35***	-2.19***	16.97***	29.69***	12.88***
Panel B: In Medium Concentration Industries						
Absolute Spread (%)	7.30***	6.97***	-4.44***	-5.55***	-3.05***	-9.15***
Relative Spread (%)	14.12***	14.05***	1.82***	-8.18***	-5.09***	-11.71***
Bid Depth (%)	50.98***	44.90***	33.49***	3.81***	-2.36***	-0.16***
Offer Depth (%)	-13.49***	-14.42***	-23.75***	39.32***	30.70***	33.36***
Depth (%)	20.26***	16.51***	6.23***	18.66***	11.57***	13.88***
Spread/Depth (%)	16.69	17.34	4.22	-11.19	-5.82	-14.67
Trade Volume (%)	25.22***	30.50***	14.49***	15.27***	39.61***	12.33***
Trade Value (%)	15.62***	21.41***	5.18***	14.34***	38.13***	11.16***
Number of Trades (%)	8.01***	13.76***	-3.52***	7.36***	16.43***	3.30***

Table 7 (continued). Liquidity Impact of Limit Hits Across Industry Concentration

Return	Lower Limit Hits			Upper Limit Hits		
Reference Group	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel C: In Low Concentration Industries						
Absolute Spread (%)	9.78***	9.71***	-6.12***	-5.28***	-2.54***	-10.21***
Relative Spread (%)	14.26***	14.27***	-2.29***	-9.15***	-6.19***	-13.86***
Bid Depth (%)	33.36***	29.41***	14.11***	5.42***	0.67***	0.04***
Offer Depth (%)	-16.82***	-17.32***	-29.71***	32.58***	25.50***	24.89***
Depth (%)	9.58***	7.23***	-6.69***	17.13***	11.38***	10.79***
Spread/Depth (%)	16.34	16.68	-0.43	-11.00	-6.45	-15.82
Trade Volume (%)	22.73***	26.70***	9.99***	20.28***	43.49***	16.08***
Trade Value (%)	13.87***	18.08***	1.57***	21.04***	45.37***	16.76***
Number of Trades (%)	10.33***	15.23***	-4.61***	9.48***	17.56***	3.97***

For each reference group, we present the percentage increase (decrease) for each liquidity measure for three time periods: the whole period of limit hits, the trading sub-period, and the trading cessation sub-period. The liquidity impact is investigated by comparing the short-term liquidity measure (during the day *D* that limit hit takes place) to the liquidity measure of the benchmark period (the benchmark period of *D*-5 to *D*-1 day window, excluding day *D*). Only trade-based liquidity measures of the benchmark period are calculated based on daily market data of the *TEJ*. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 8. Liquidity Impact of Limit Hits in Limit Hit Order

Return	Lower Limit Hits			Upper Limit Hits		
Reference Group	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel A: First Limit Hit Period						
Absolute Spread (%)	14.86***	13.52***	-1.53	-2.77***	1.83***	-6.44***
Relative Spread (%)	20.84***	19.25***	3.99*	-5.98***	-0.95***	-9.50***
Bid Depth (%)	22.93***	18.04***	3.86	1.72	-6.22***	-1.91***
Offer Depth (%)	-14.65***	-14.37***	-29.51***	25.22***	17.45***	20.76***
Depth (%)	4.94***	2.37***	-12.11***	11.87***	4.14***	7.97***
Spread/Depth (%)	25.81	24.55	8.66	-7.29	0.51	-10.82
Trade Volume (%)	52.02***	48.54***	40.07***	39.54***	99.84***	36.91***
Trade Value (%)	41.71***	41.26***	29.75***	39.13***	98.42***	36.15***
Number of Trades (%)	16.68***	20.08***	0.36***	14.42***	27.01***	10.54***
Panel B: Second Limit Hit Period						
Absolute Spread (%)	10.95***	11.18***	-8.71***	-3.45***	-2.22***	-7.87***
Relative Spread (%)	17.48***	17.83***	-3.44***	-6.09***	-4.73***	-10.33***
Bid Depth (%)	35.36***	31.92***	9.89	0.39	-1.26***	-4.42***
Offer Depth (%)	-16.48***	-17.30***	-31.85***	27.52***	23.74***	18.78***
Depth (%)	10.85	8.64	-9.99***	11.84***	9.20***	5.39***
Spread/Depth (%)	21.34	21.97	0.13	-5.59	-3.66	-11.09
Trade Volume (%)	27.54***	34.14***	9.31***	32.74***	50.84***	28.07***
Trade Value (%)	18.18***	24.54***	1.14*	32.59***	49.88***	28.50***
Number of Trades (%)	15.08***	16.87***	-3.42***	18.21***	21.67***	12.95***

Table 8 (continued). Liquidity Impact of Limit Hits in Limit Hit Order

Return	Lower Limit Hits			Upper Limit Hits		
Reference Group	Whole Period	Trading Period	Trading Cessation Period	Whole Period	Trading Period	Trading Cessation Period
Panel C: Third Limit Hit Period						
Absolute Spread (%)	6.51***	6.62***	-5.33***	-7.54***	-6.72***	-12.29***
Relative Spread (%)	12.68***	13.03***	0.16***	-10.80***	-9.63***	-15.44***
Bid Depth (%)	51.50***	46.13***	34.86***	7.22***	4.43***	1.66**
Offer Depth (%)	-16.18***	-17.02***	-25.68***	48.00***	40.01***	39.17***
Depth (%)	19.38***	16.09***	6.14***	24.41***	19.36***	17.45***
Spread/Depth (%)	14.29	15.06	1.58	-14.47	-12.11	-18.93
Trade Volume (%)	16.09***	22.78***	5.54	9.65***	15.76***	5.79***
Trade Value (%)	7.20***	13.30***	-2.94***	10.14***	16.33***	6.07*
Number of Trades (%)	6.30***	12.21***	-4.93***	6.67***	13.02***	1.18***

For each reference group, we present the percentage increase (decrease) for each liquidity measure for three time periods: the whole limit hit period, the trading period, and the trading cessation period during the limit hitting. The liquidity impact is investigated by comparing the short-term liquidity measure (during the day *D* that the limit hit takes place) to the liquidity measure of the benchmark period (the benchmark period of *D*-5 to *D*-1 day window, excluding day *D*). Only trade-based liquidity measures of the benchmark period are calculated based on daily market data of the *TEJ*. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 9. Liquidity Impact around Limit Hits: Anticipatory Changes

	Price Down			Price Up		
	6.5%~7%	6%~6.5%	5.5%~6%	6.5%~7%	6%~6.5%	5.5%~6%
Panel A: Return Reference Group						
Absolute Spread (%)	6.68***	6.04***	5.76***	-10.78***	-9.02***	-8.67***
Relative Spread (%)	12.62***	11.56***	10.75***	-11.96***	-11.22***	-10.77***
Bid Depth (%)	32.64***	23.58***	16.58***	5.27*	6.56***	6.19***
Offer Depth (%)	-12.58***	-13.41***	-13.02***	63.14***	46.29***	41.15***
Depth (%)	10.95***	5.61	2.13***	29.16***	23.02***	20.79***
Spread/Depth (%)	14.48	14.11	13.49	-15.45	-14.90	-14.52
Trade Volume (%)	4.10***	-1.21***	-5.52***	4.98	3.04***	2.32***
Trade Value (%)	-3.00***	-6.19***	-9.52***	5.92***	3.64***	2.90***
Number of Trades (%)	4.78***	2.16***	0.82***	7.27***	6.84***	6.33***
Panel B: Volatility Reference Group						
Absolute Spread (%)	6.74***	6.10***	5.77***	-10.79***	-9.05***	-8.69***
Relative Spread (%)	12.68***	11.58***	10.74***	-11.98***	-11.24***	-10.76***
Bid Depth (%)	32.81***	23.63***	16.63***	5.26*	6.65***	6.29***
Offer Depth (%)	-12.48***	-13.46***	-13.01***	62.86***	46.35***	41.50***
Depth (%)	11.09***	5.62	2.15***	29.11	23.08***	20.98***
Spread/Depth (%)	14.56	14.13	13.48	-16.09	-15.12	-14.48
Trade Volume (%)	4.23***	-1.35***	-5.49***	5.30***	3.12***	2.18***
Trade Value (%)	-2.90***	-6.41***	-9.56***	6.19***	3.71***	2.79***
Number of Trades (%)	4.85***	2.17***	0.86***	7.34***	6.87***	6.29***

Table 9 (continued). Liquidity Impact around Limit Hits: Anticipatory Changes

	Price Down			Price Up		
	6.5%~7%	6%~6.5%	5.5%~6%	6.5%~7%	6%~6.5%	5.5%~6%
Panel C: Volume Reference Group						
Absolute Spread (%)	6.73***	6.11***	5.77***	-10.78***	-9.07***	-8.69***
Relative Spread (%)	12.64***	11.58***	10.74***	-11.95***	-11.27***	-10.75***
Bid Depth (%)	32.77***	23.61***	16.59***	5.23*	6.61***	6.27***
Offer Depth (%)	-12.56***	-13.47***	-12.98***	63.16***	46.42***	41.32***
Depth (%)	11.04***	5.60*	2.14***	29.17***	23.11***	20.92***
Spread/Depth (%)	14.52	14.14	13.47	-16.00	-13.54	-14.47
Trade Volume (%)	4.13***	-1.31***	-5.55***	5.06	3.09***	2.25***
Trade Value (%)	-2.98***	-6.38***	-9.56***	5.99***	3.63***	2.85***
Number of Trades (%)	4.82***	2.17***	0.83***	7.29***	6.84***	6.31***

For each reference group, we present the percentage increase (decrease) for each liquidity measure for three time periods: the whole limit hit period, the trading period, and the trading cessation period during the limit hitting. The liquidity impact is investigated by comparing the short-term liquidity measure (during the day *D* that the limit hit takes place) to the liquidity measure of the benchmark period (the benchmark period of *D*-5 to *D*-1 day window, excluding day *D*). Only trade-based liquidity measures of the benchmark period are calculated based on daily market data of the *TEJ*. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 10. Price Impact of Limit Hits on Informationally Related Stocks

	Lower Limit Hits			Upper Limit Hits		
Reference Group	Return	Volatility	Volume	Return	Volatility	Volume
Total Price Impact						
Buyer-Initiated	0.0053***	0.0061***	0.0057***	0.0077***	0.0079***	0.0077***
Seller-Initiated	0.0109***	0.0110***	0.0107***	0.0019***	0.0021***	0.0019***
Temporary Price Impact						
Buyer-Initiated	-0.0096***	-0.0087***	-0.0091***	0.0039***	0.0041***	0.0039***
Seller-Initiated	0.0148 ***	0.0148 ***	0.0146 ***	-0.0022***	-0.0020***	-0.0022***

The total price impact is measured by $P_{t,total} = D_t\, ln(P_t/P_{open})$; the temporary price impact is measured by $P_{t,temp} = D_t\, ln(P_{close}/P_t)$, where D_t is 1 for buyer-initiated and -1 for seller-initiated. All trades occurring after limit hits are excluded from the benchmark. We report the mean of price impacts over the period of limit hits. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 11. Price Impact of Limit Hits Across Industry Concentration

	Lower Limit Hits			Upper Limit Hits		
Reference Group	Return	Volatility	Volume	Return	Volatility	Volume
Panel A: In High Concentration Industries						
Total Price Impact						
Buyer-Initiated	0.0131***	0.0174***	0.0149***	0.0089***	0.0096***	0.0087***
Seller-Initiated	0.0129***	0.0140***	0.0125***	0.0047***	0.0054***	0.0044***
Temporary Price Impact						
Buyer-Initiated	-0.0006***	0.0038***	0.0011***	0.0059***	0.0067***	0.0057***
Seller-Initiated	0.0158***	0.0169***	0.0154***	-0.0001***	0.0006***	-0.0004***
Panel B: In Medium Concentration Industries						
Total Price Impact						
Buyer-Initiated	0.0030***	0.0032***	0.0033***	0.0074***	0.0074***	0.0074***
Seller-Initiated	0.0109***	0.0107***	0.0106***	0.0007***	0.0008***	0.0007***
Temporary Price Impact						
Buyer-Initiated	-0.0130***	-0.0128***	-0.0127***	0.0037***	0.0037***	0.0037***
Seller-Initiated	0.0164***	0.0162***	0.0161***	-0.0029***	-0.0028***	-0.0029***
Panel C: In Low Concentration Industries						
Total Price Impact						
Buyer-Initiated	0.0044***	0.0044***	0.0045***	0.0074***	0.0075***	0.0075***
Seller-Initiated	0.0103***	0.0102***	0.0102***	0.0018***	0.0018***	0.0018***
Temporary Price Impact						
Buyer-Initiated	-0.0099***	-0.0098***	-0.0098***	0.0032***	0.0033***	0.0033***
Seller-Initiated	0.0130***	0.0130***	0.0130***	-0.0025***	-0.0024***	-0.0024***

The total price impact is measured by $P_{t,total} = D_t\, ln(P_t/P_{open})$; the temporary price impact is measured by $P_{t,temp} = D_t\, ln(P_{close}/P_t)$, where D_t is 1 for buyer-initiated and -1 for seller-initiated. All trades occurring after limit hits are excluded from the benchmark. We

report the mean of price impacts over the period of limit hits. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

Table 12. Price Impact of Limit Hits in High Concentration Industries

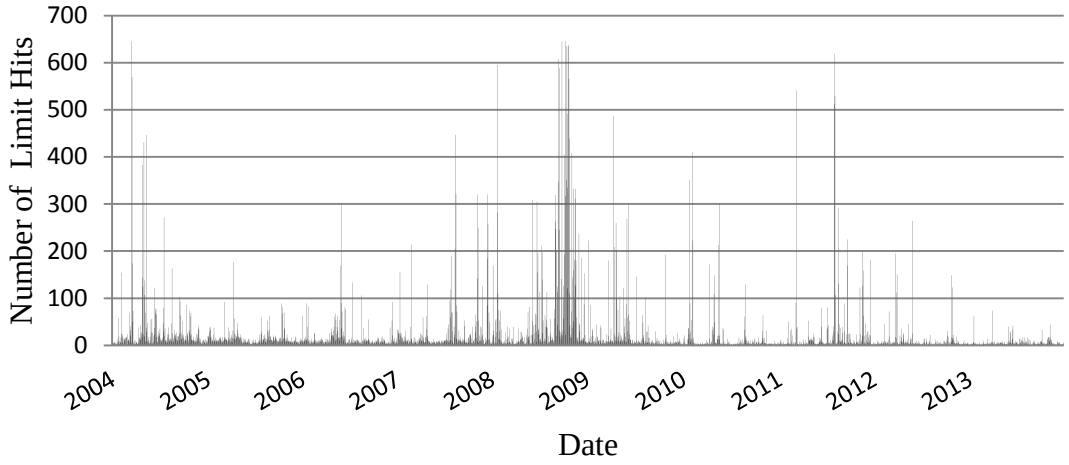
	Lower Limit Hits			Upper Limit Hits		
Reference Group	Return	Volatility	Volume	Return	Volatility	Volume
Panel A: Top One-Third of Limit Hitting Stocks Ranked by Market Share						
Total Price Impact						
Buyer-Initiated	0.0251***	0.0295***	0.0275***	0.0093***	0.0105***	0.0094***
Seller-Initiated	0.0167***	0.0149***	0.0149***	0.0041***	0.0052***	0.0041***
Temporary Price Impact						
Buyer-Initiated	0.0106***	0.0152***	0.0133***	0.0077***	0.0087***	0.0076***
Seller-Initiated	0.0195***	0.0175***	0.0176***	-0.0025***	-0.0015***	-0.0025***
Panel B: Bottom One-Third of Limit Hitting Stocks Ranked by Market Share						
Total Price Impact						
Buyer-Initiated	0.0074***	0.0125***	0.0105***	0.0083***	0.0088***	0.0080***
Seller-Initiated	0.0110***	0.0115***	0.0107***	0.0024***	0.0035***	0.0025***
Temporary Price Impact						
Buyer-Initiated	-0.0058***	-0.0007***	-0.0027***	0.0050***	0.0055***	0.0047***
Seller-Initiated	0.0137***	0.0142***	0.0135***	-0.0019***	-0.0008***	-0.0017***

The total price impact is measured by $P_{t,total} = D_t\ ln(P_t/P_{open})$; the temporary price impact is measured by $P_{t,temp} = D_t\ ln(P_{close}/P_t)$, where D_t is 1 for buyer-initiated and -1 for seller-initiated. All trades occurring after limit hits are excluded from the benchmark. We report the mean of price impacts over the period of limit hits. Asterisks (***, **, *) denote that coefficient is significant at 1%, 5%, and 10% respectively.

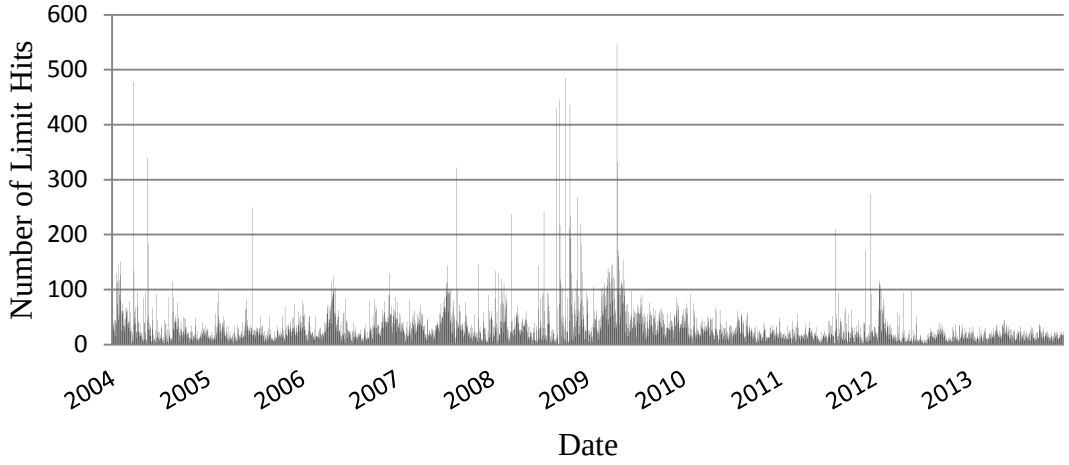
Figures

Figure 1. Distribution of Limit Hits from 2004 to 2013

Panel A: Lower Limit Hits

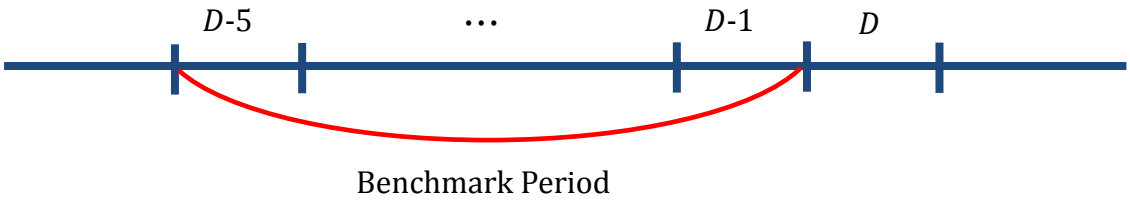


Panel B: Upper Limit Hits



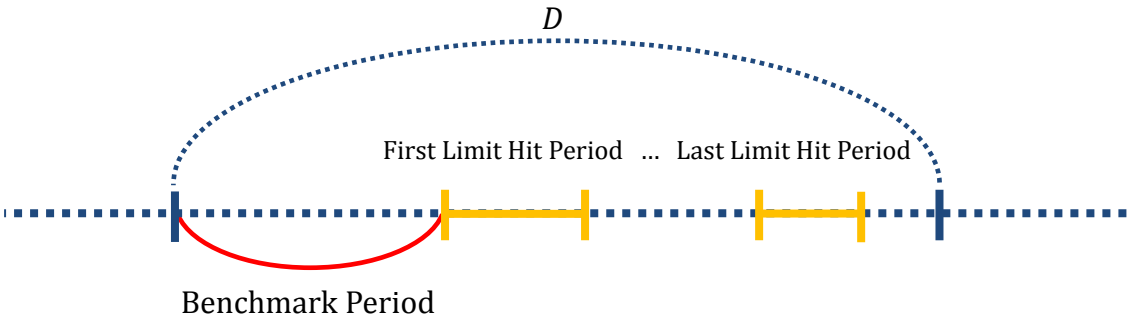
In the last half of 2008, the number of lower limit hits is particularly large because of the deteriorating financial crisis. Distributions of lower and upper limit hits are respectively shown in the top and bottom panels.

Figure 2. Benchmark Period for Liquidity Impacts



If a limit hit takes place on day D, the interval from day D-5 to day D-1 will be treated as the benchmark period.

Figure 3. Benchmark Period for Price Impacts



If the limit hit takes place on day D, the time interval before the limit hit is treated as the benchmark period and all trades after the limit hit are excluded from the benchmark.