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# Is the Daily Price Limit of the Taiwan Stock Exchange Effective? Fundamentals of Listed Stocks and Investors' Perception of Fair Price*

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## Abstract

This study investigates the price limit performance and its difference from previous literature with the analysis of fundamentals of listed stocks. In addition, we examine the influence of price limits on the perception of fair price to investors. The empirical results find that first, price limits lead significantly to less efficient price discovery for listed stocks with worse fundamentals. Second, the inconsistency of fair price perception and the degree of information asymmetry don't decrease for stocks that hit price limits. Finally, we suggest an increase in daily upper limit for Taiwan Stock Exchange.

*Keywords*: Price Limit; Fundamentals; Fair Price Perception; Price Discovery; Information Asymmetry

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# 1. Introduction

The Taiwan Stock Exchange, founded on February 9, 1962, adopted price limit system as a tool to stabilize stock prices as well as to minimize investors' losses caused by dramatic price fluctuations. While price limit system has been implemented by the Taiwan Stock Exchange, it has been flexibly adjusted in response to major domestic and international political and economic events; furthermore, its existence has also been widely questioned. Thus, the authority has decided to suspend the limit for newly listed companies during the first five trading days starting from March 1, 2005 and has been conducting feasibility studies on more liberalized price limit rules. In addition to the Taiwan Stock Exchange, countries such as Korea, Japan, Thailand, Malaysia, Spain, Greece, and Finland impose price limits on daily movement of price, however, and those countries are currently reviewing or have decided to liberalize or even lift price limits. The seven percent single-day price limit (up and down 7%) on the closing price of previous trading day in the Taiwan Stock Exchange is, in fact, one of the lowest price limits compared to that of the foreign stock markets;[1)] moreover, major stock exchanges around the world do not impose price limits on stocks. As a result, there is a need to review and examine the need for the current limit on stocks in the Taiwan Stock Exchange.

The purpose for imposing a price limit is to give more time to investors to rationally evaluate the fair price of stocks and to prevent irrational price fluctuations. Some stock exchanges may also impose price limits on stocks as an important measure to avoid a stock crash driven by panic and to stabilize market trading activities, yet the removal of price limits has been widely discussed and, notably, starting from the 1980s, relevant studies on the influence of price limits on price fluctuation, trading activities, and market efficiency have been actively conducted. The studies on price limits indicate that they are able to decrease price volatility and avoid overreaction to information shocks so as not to influence trading activities (Brennan, 1986; Lee and

1) Take listed stocks on the Tokyo Stock Exchange as the example. At a price higher than 500 Japanese yen but lower than 1000 Japanese yen, the single-day price limit is ￥100 or 10~20% on the closing price of previous trading day.

Kim, 1995; Westerhoff, 2003)[2] while scholars against price limits believe that they create greater price volatility, and reduce market liquidity as well as rule out the formation of equilibrium prices (Lehmann, 1989; Coursey and Dyl, 1990; Lee, Ready, and Seguin, 1994; Huang, Fu, and Ke, 2001; Kuo, Hsu, and Chiang, 2004; Diacogiannis et al., 2005; Habel and Harpaz, 2006). Kim and Rhee (1997) conducted empirical research on price limits by reviewing previous studies and concluded the following three points for evaluating the performance of price limits: first, regarding the issue of volatility, price limits may result in great fluctuation after a price hits either an upper or lower limit (volatility spillover hypothesis); second, on the issue of efficiency, price limits may fail to reach an equilibrium price efficiently (delayed price discovery hypothesis); last, in terms of liquidity, price limits interfere with trading activities (trading interference hypothesis).

Besides the three hypotheses suggested by Kim and Rhee (1997), the valuation of stocks made by investors (the perception of fair price) is another way to gauge price limit performance. In general, if price limits are effective, investors are able to deter irrational trading behavior, and that allows investors to make rational valuations to determine a fair price; that is, price limits are attributed to the consistent perception of fair price for investors. On the contrary, if price limits are ineffective, they will create disputes among investors regarding fair price. General investors would analyze and valuate a fair price via various security analysis methods before developing their investment strategies, but because of the discrepancy of information gathering and investment analysis skills, those investors might hold different views on fair price to some degree. In this regard, earlier studies of behavioral finance recommend that anchoring may influence the fair price perception of investors. Tversky and Kahneman (1974) found that the perception of human beings is easily shaped by irrelevant factors when facing uncertainty. Montier (2002) pointed out that historical stock prices are the anchors of stock prices today due to the lack of relevant information. According to this point of view, when stock prices move towards either upper or lower limits, the judgment of some investors may be influenced by upper limit price (lower

2) In addition to studies on price limits in stock exchanges, some recent studies on the futures markets such as Shanker and Balakrishnan (2005) as well as Chou, Lin, and Yu (2006) proposed that price limits reduce credit risk and margin requirement.

limit price) and change their original perception of fair price and become more optimistic (pessimistic) resulting in the "disturbed stock valuation hypothesis."

According to the fundamental analysis, the fundamentals of a firm are the key factors that determine stock prices. Hence, fundamentals that affect the intrinsic value (fair price) of a firm such as profitability, solvency, size, and growth prospect may have a significant influence on the price limit performance. Wang et al. (2000) suggested that price limits are more likely to dominate the stock prices of small firms than those of large ones. Currently, the Taiwan Stock Exchange imposes the same price limits on all stocks, seven percent of the upper and lower limits of the closing price of previous trading day. Since firms with different fundamentals may have different degree of information asymmetry, the deviation of current stock price from equilibrium price among them may have a quite different picture. Therefore, uniform price limits may not meet the demand of price movements in stocks with different fundamentals. This would result in a loss of investors due to inefficient stock prices. Furthermore, price fluctuation is mainly influenced by information shocks, but firms with different fundamentals are influenced differently. In general, good news is more beneficial to firms with better fundamentals while bad news has a stronger effect on firms with worse fundamentals. If uniform price limits are imposed on all stocks, the price of some stocks may deviate from their equilibrium price for a longer period of time and will affect market efficiency. In short, the discussion of price limit performance on stocks with different fundamentals helps us to understand the function of price limits and serves as a reference for the authorities to adjust or remove price limits.

This study aims to discuss the impact of price limits on trading activities and uses the Taiwan Stock Exchange as the example to examine "volatility spillover hypothesis," "delayed price discovery hypothesis," "trading interference hypothesis," and "disturbed stock valuation hypothesis." This study distinguishes itself from previous literature as follows: first, we examine the influence of price limits on fair price perceived by investors. That is to say besides volatility spillover hypothesis, delayed price discovery hypothesis, and trading interference hypothesis, we test on disturbed stock valuation hypothesis. Second, the fundamentals of a firm is the key influential factor for determining its price and firms with different fundamentals react differ-

ently from both good and bad news; accordingly, this study further analyzes the influence of fundamentals on price limit performance. Finally, the time frame of empirical data in this study spans over a period of ten years, much longer than previous studies.[3] Due to the uniqueness of the Taiwan Stock Exchange, we adjusted limit prices according to the ex-rights/ex-dividends reference price and took the influence of minimum tick size into consideration when designing the control subgroups experiment. The rest of this paper is organized as follows. In the next section, we describe the empirical methodology and data. The third section presents the empirical results of four hypotheses for our study. The forth section discusses the impact of fundamentals on price limit performance. We check the robustness of empirical results by using intraday data and information asymmetry measure in the fifth section and conclude the paper in the last section.

# 2. Data and Methodology

## 2.1 Data Source

In addition to the testing methodology of self-developed disturbed stock valuation hypothesis suggested in this study, testing for volatility spillover hypothesis, delayed price discovery hypothesis, and trading interference hypothesis is based on the methodologies proposed by Kim and Rhee (1997). But due to the difference between the stock trading systems of Taiwan and Japan (Kim and Rhee used the Tokyo Stock Exchange as the empirical subject), this study does not adopt the control subgroups design proposed by Kim and Rhee completely. We adjust limit prices according to the ex-rights/ex-dividends reference price[4] and take the influence of minimum tick size

3) In previous studies, the time frame of Kim and Rhee (1997) and Diacogiannis et al. (2005) are both four years.

4) If Company A distributed 200 shares to each thousand shares and its ex-rights day was on March 2. Besides, the closing price of Company A on March 1 was NT$60. As mentioned above, upper limit and lower limit of Company A on March 2 were NT$53.5 and NT$46.5 according to the ex-rights reference price. If no adjustment was done accordingly, the upper and lower limit would become NT$64 and NT$56 (the upper and lower limit would not become NT$64.2 and NT$55.8 because the minimum tick size of Company A was NT$0.5) resulting in the bias.

into consideration to avoid incorrect results.[5)]

Since February 9, 1962, the size of maximum allowable price movement (price limits) of the Taiwan Stock Exchange has been adjusted several times. It is quite possible that the different price limit performance is responsible for this significant discrepancy. As of June 2007, the newest price limits are ±7% of the closing price on the previous trading day; thus, this study uses the seven percent upper and lower limits during the research period from October 11, 1989 to September 26, 1999 because during the interval, price limits remained seven percent and no adjustment was done to exclude problems caused by different price limits.[6)] After we gathered the data during the research period, we used a total of 18,184 upper limit samples, 18,788 lower limit samples, and 4,730 samples one minimum tick from the upper limit, 3,507 samples one minimum tick from the lower limit, 5,159 samples two minimum ticks from the upper limit, and 3,204 samples two minimum ticks from the lower limit collected from the data bank of the Taiwan Economic Journal.[7)]

Panels A, B, C and D of Table 1 illustrate samples of upper limit, lower limit, one

5) Take upper limit as the example, Kim and Rhee (1997) designed a control subgroup as follows: it assumed the highest price of Company A is greater than the closing price on the previous trading day plus 0.9 time upper limit, but the highest price of Company A did not hit the upper limit (another control subgroup is the highest price of a certain company is less than the closing price on the previous trading day plus 0.9 time upper limit but greater than that plus 0.8 time) and Company A was categorized into the control subgroup to compare with the trading activity change of the upper limit subgroup and control subgroup before and after the trading day hit the upper limit. What is worth noting is that if the closing price of Company A on previous trading day is NT$50 and according to Kim and Rhee (1997), samples of control subgroup which stock price is higher than NT$53.15 and smaller than 53.5, but the minimum tick size of Company A during research period (from October 11, 1989 to September 26, 1999) was NT$0.5. Therefore, it is impossible for Company A to be a sample in this control subgroup. If every company's closing price on previous trading day is all NT$50, then there are not any companies in this control subgroup.

6) Before October 10, 1989, price limits in Taiwan Stock Exchange were 5% or 3% of the closing price on the proceeding trading day and after September 27, 1999, because of major political and economic events, the authorities narrowed down the price limits to 3.5% within a short period of time. These two time intervals were not suitable for this study.

7) During the collection of daily data for this study (from October 11, 1989 to September 26, 1999), the tick size of the Taiwan Stock Exchange held constant. But on March 1, 2005, a new rule for tick size was adopted that was continuously implemented until now and held constant. Here is the introduction to the tick size of Taiwan Stock Exchange: (1) From November 2, 1987 to February 28, 2005: The tick size of stock price less than NT$5 is NT$0.01; The tick size of stock price between NT$5 and NT$15 is NT$0.05; The tick size of stock price between NT$15 and NT$50 is NT$0.1; The tick size of stock price between NT$50 and NT$150 is NT$0.5; The tick size of stock price between NT$150 and NT$1,000 is NT$1; The tick size of stock price more than NT$1,000 is NT$5. (2) Tick size after March 1, 2005 (the most updated): Stock price less than NT$10 has the tick size of NT$0.01; Stock price between NT$10 and NT$50 has the tick size of NT$0.05; Stock price between NT$50 and NT$100 has the tick size NT$0.1; Stock price between NT$100 and NT$500 has the tick size NT$0.5; Stock price between NT$500 and NT$1,000 has the tick size NT$1; Stock price of more than NT$1,000 has the tick size NT$5.

minimum tick from the upper limit, one minimum tick from the lower limit, two minimum ticks from the upper limit, and two minimum ticks from the lower limit in the Taiwanese stock market during research period. The summary statistics were sorted by year, month, day of the week and industry. Panel A of Table 1 shows that the year 1990 had the highest number of upper limit and lower limit samples, and this result tied with the big fluctuation in the Taiwanese stock market of the year (In 1990, the yearly high of the Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) was 12,495.34 and yearly low was 2,560.47). In addition, 1996 had the lowest number of upper limit and lower limit samples because in 1996, Taiwanese stocks did not fluctuate much (In 1996, the opening price of the TAIEX was 5,220.73 and the closing price was 6,826.06 where the high reached 7,002.62 and the low hit 4,675.36). What deserves our attention is that in 1997, the Asian Financial Crisis did not exert much influence on Taiwanese stocks (In 1997, the opening price of the TAIEX was 6,803.75 and the closing price was 8,187.27 where the high reached 9,756.47 and the low hit 6,769.08). Taiwanese stocks in 1997 did not have significant samples of lower limit. Panel B of Table 1 demonstrated that January and November are two months when the highest number of upper limit samples is observed; May has the highest number of lower limit samples. This result indicates that Taiwanese stocks have a January effect that explains why this month has more upper limit samples. The reason for November and December to have the respective highest number of upper limit samples is that the peak season of the electronics industry and some traditional industries (for example, textile, plastic and food) resulted in more positive information for stock prices and investment encouragement. Likely, this contributes to the highest number of lower limit samples in May because, first, the month is the recession seasons of the electronics and textile industries, second, lower prices for the electronics and textile industries are expected, and, finally, more negative information to stock price is in the market. Thus, more samples of lower limit are observed. According to Panel C of Table 1, the evidence of a weak Monday effect has been proven to be true, and the highest number of lower limit samples in the Taiwanese stock market was found on Monday, Tuesday, and Friday, the highest number of upper limit samples was found (Before December 31, 2000, the Taiwan Stock Exchange traded six days a week). Panel D of Table 1 shows that although most publicly listed companies in the Taiwan Stock Exchange are from the electronics industry, the textile industry has the largest number of upper limit and lower limit samples partly because textile companies in Taiwan tend to be smaller firms. Furthermore, the industry with the

lowest number of upper limit and lower limit samples was glass and ceramics because of the low number of companies in this industry (In 1999, there were only seven publically listed glass and ceramics companies).

Table 1. Summary Statistics

| | UP | $UP_{-1}$ | $UP_{-2}$ | DOWN | $DOWN_{+1}$ | $DOWN_{+2}$ |
|---|---|---|---|---|---|---|
| Panel A: By Year | | | | | | |
| 1989 | 697 | 122 | 142 | 895 | 137 | 140 |
| 1990 | 6297 | 1219 | 1102 | 8613 | 1067 | 885 |
| 1991 | 2425 | 627 | 697 | 2581 | 469 | 444 |
| 1992 | 720 | 232 | 309 | 825 | 237 | 223 |
| 1993 | 1395 | 418 | 471 | 532 | 155 | 155 |
| 1994 | 1246 | 383 | 443 | 881 | 192 | 179 |
| 1995 | 599 | 245 | 278 | 798 | 233 | 221 |
| 1996 | 575 | 202 | 258 | 389 | 101 | 75 |
| 1997 | 1570 | 494 | 569 | 1062 | 306 | 297 |
| 1998 | 1224 | 371 | 444 | 1033 | 335 | 284 |
| 1999 | 1436 | 417 | 446 | 1179 | 275 | 301 |
| Panel B: By Month | | | | | | |
| January | 1935 | 415 | 466 | 1835 | 334 | 287 |
| February | 1705 | 444 | 516 | 949 | 198 | 193 |
| March | 1212 | 432 | 473 | 713 | 205 | 228 |
| April | 1300 | 452 | 474 | 944 | 344 | 338 |
| May | 1001 | 291 | 343 | 2033 | 322 | 282 |
| June | 1121 | 306 | 383 | 1794 | 260 | 246 |
| July | 1849 | 478 | 472 | 1452 | 341 | 329 |
| August | 1692 | 387 | 455 | 1664 | 344 | 306 |
| September | 1064 | 299 | 304 | 1562 | 294 | 254 |
| October | 1508 | 384 | 375 | 1725 | 284 | 216 |
| November | 1933 | 374 | 394 | 1312 | 224 | 214 |
| December | 1864 | 468 | 504 | 1805 | 357 | 311 |
| Panel C: By Day of the Week | | | | | | |
| Monday | 3241 | 807 | 853 | 3411 | 758 | 644 |
| Tuesday | 2830 | 714 | 820 | 3523 | 697 | 667 |
| Wednesday | 2814 | 789 | 866 | 3326 | 612 | 584 |
| Thursday | 3037 | 835 | 885 | 3370 | 516 | 424 |
| Friday | 3345 | 797 | 944 | 3062 | 527 | 554 |
| Saturday | 2917 | 788 | 791 | 2096 | 365 | 331 |

Table 1 (Continued). Summary Statistics

| | UP | $UP_{-1}$ | $UP_{-2}$ | DOWN | $DOWN_{+1}$ | $DOWN_{+2}$ |
|---|---|---|---|---|---|---|
| Panel D: By Industry | | | | | | |
| Cement | 342 | 109 | 163 | 399 | 99 | 101 |
| Food | 1178 | 317 | 366 | 1472 | 231 | 133 |
| Plastic | 1466 | 408 | 385 | 1412 | 288 | 149 |
| Textile | 4052 | 982 | 1021 | 4293 | 776 | 659 |
| Electric Machinery | 615 | 152 | 202 | 590 | 112 | 113 |
| Electrical and Cable | 808 | 219 | 253 | 967 | 179 | 155 |
| Chemical, Biotech., and Medical Care | 1275 | 334 | 354 | 1432 | 238 | 210 |
| Glass and Ceramics | 60 | 34 | 33 | 62 | 15 | 17 |
| Paper and Pulp | 864 | 221 | 256 | 887 | 179 | 152 |
| Iron and Steel | 408 | 116 | 120 | 500 | 84 | 81 |
| Rubber | 805 | 229 | 227 | 803 | 117 | 134 |
| Automobile | 103 | 27 | 42 | 92 | 33 | 35 |
| Electronic | 1641 | 429 | 526 | 1721 | 356 | 333 |
| Building Material and Construction | 681 | 210 | 185 | 735 | 152 | 112 |
| Shipping and Transportation | 363 | 134 | 131 | 398 | 80 | 69 |
| Tourism | 887 | 192 | 215 | 856 | 143 | 146 |
| Financial and Insurance | 1653 | 374 | 408 | 1195 | 243 | 262 |
| Trading and Consumers Goods | 711 | 179 | 196 | 725 | 119 | 112 |
| Complex | 77 | 13 | 18 | 99 | 21 | 11 |
| Others | 195 | 51 | 58 | 150 | 42 | 20 |
| Total | 18184 | 4730 | 5159 | 18788 | 3507 | 3204 |

## 2.2 Sample Selection

With regards to testing of volatility spillover hypothesis, delayed price discovery hypothesis, and trading interference hypothesis, this study applied the method of Kim and Rhee (1997) for evaluating the price limit performance of the Taiwan Stock Exchange. Because Kim and Rhee used empirical samples from the Tokyo Stock Exchange, which has a different trading system and price limits than that of Taiwan

Stock Exchange,[8] we modify the method of Kim and Rhee according to the Taiwan Stock Exchange's trading system to reflect the current Taiwanese stock market situation and improve research accuracy. This study used a different method to select control subgroups. For example, we used "one minimum tick from the upper limit" and "two minimum ticks from the upper limit" as the control subgroups of "upper limit," and "one minimum tick from the lower limit" and "two minimum ticks from the lower limit" as the control subgroups of "lower limit." The sample selection method is described as follows.

This study first defines samples that "hit price limits" to categorize them into two samples of "upper limit" and "lower limit." Upper (Lower) limit samples are that the highest (lowest) price of a certain stock on a particular day matches the closing price on the previous trading day plus (minus) upper (lower) limit, $H_{i,t} = C_{i,t-1} + LIMIT_{i,t}$($L_{i,t}$ $= C_{i,t-1} - LIMIT_{i,t}$), where $H_{i,t}$ is the highest price of stock $i$ on day $t$; $C_{i,t-1}$ is the closing price of stock $i$ on day $t$-1; $LIMIT_{i,t}$ is the maximum allowable upward (downward) price movement of stock $i$ on day $t$; and $L_{i,t}$ is the lowest price of stock $i$ on day $t$. Hereinafter samples of "upper limit" and "lower limit" are referred to as "UP" and "DOWN."

8) This study summarized the difference of microstructure between stock markets in Taiwan and Japan as follows:

(1) Price limits: The daily price limits of the Taiwanese stock market are ±7% of the closing price on the previous trading day, while that of the Japanese stock market is set with the maximum daily price variation according to different stock prices. The Japanese stock market also regulates the maximum price variation of the next transaction price.

(2) Tick size: Although the tick size of both stock markets in Taiwan and Japan is defined by stock price range, the ranges of tick size in the Taiwanese stock market are fewer than those of Japan. According to the most updated regulation on tick size between the Taiwanese and Japanese stock markets (2007/12/13), there are six ranges of tick size in Taiwan and nine in Japan.

(3) Different trading times of the day: According to the most updated trading time of the day in both Taiwanese and Japanese stock markets, Taiwan trades from 9 : 00-13 : 30 (9 : 00-12 : 00 during the research period of this study) and Japan trades from 9 : 00-11 : 00 and 12 : 30-15 : 00.

(4) Market participants: The Taiwanese stock market has a majority of retail investors and Japanese stock market has more institutional investors. By October 2006, retail investors accounted for 80% of the trading volume in Taiwanese stock market, and those did only 26.4% of the trading volume in Japanese stock market.

(5) Trading rule: The Taiwanese stock market adopted the trading rule of the call auction and Japan uses both call auction and continuous auction as the trading rules.

(6) Types of order: Both Taiwanese and Japanese stock markets only are traded on market order and limit order, but in Japan, investors can also trade on conditions of ROD (Rest of Day), IOC (Immediately or Cancel), and FOK (Fill-or-Kill).

(7) Trading unit: One standard trading unit in Taiwanese stock market is 1,000 shares, and in Japan, investors trade mostly units of 1,000 shares, secondly 100 shares, and then the diversified trading units of 3,000 shares, 50 shares, and 1 share.

In addition, this study also defines control subgroups samples that are used to compare with samples that "hit the price limits" to examine price limit performance and thus the selection principle of the control subgroups samples is to choose those with similar price movement that hit the price limits.[9] If on a trading day, there is an UP or DOWN stock, this research selects those that nearly hit the upper limit (lower limit); that is, the highest price (lowest price) of the certain stock on a trading day matching with $H_{i,t} = C_{i,t-1} + LIMIT_{i,t} - k \times T_{i,t} (L_{i,t} = C_{i,t-1} - LIMIT_{i,t} + k \times T_{i,t})$ and where $k$=1 or 2 and $T_{i,t}$ refers to the minimum tick size of stock $i$ on day $t$. Above definition tells us that control subgroups are respectively "one minimum tick from the upper limit" and "two minimum ticks from the upper limit" ("one minimum tick from the lower limit" and "two minimum ticks from the lower limit"). This study refers them as $UP_{-1}$ and $UP_{-2}$ ($DOWN_{+1}$ and $DOWN_{+2}$).

In the end, to further address the influence of the fundamentals on price limit performance, this study uses returns on equity (ROE) and earnings per share (EPS) of a certain firm as the proxies of its fundamentals and further sort the firms' ROE/EPS of a particular year in ascending order. Firms will be divided into four subgroups equally and then those with both the highest ROE (highest EPS) and lowest ROE (lowest EPS) will be selected to examine the difference of price limit performance between firms with better fundamentals (the highest ROE or the highest EPS) and those with worse fundamentals (the lowest ROE or the lowest EPS).

## 2.3 Hypothesis Testing

The purpose of this study is to test volatility spillover hypothesis, delayed price discovery hypothesis, trading interference hypothesis, and disturbed stock valuation hypothesis. In testing these hypotheses, the first three are tested through the method proposed by Kim and Rhee (1997) and the last one is through a new method proposed in this study. As mentioned earlier, we take the differences between the trading system in both Taiwan and Japan into consideration and modify the method proposed by Kim and Rhee. The testing of four hypotheses is described as follows:

9) According to Kim and Rhee (1997), if price limits do not influence the efficient price discovery process, then after hitting the price limits, samples of the control subgroup shall closely conform to samples that hit the price limits.

### 2.3.1 Testing of Volatility Spillover Hypothesis

Kim and Rhee (1997) assumed price volatility of stock $i$ on day $t$ as $V_{i,t} = (r_{i,t})^2 \times 10^3$, where $r_{i,t}$ is the returns of stock $i$ on day $t$. They then indicate the day when stock prices "hit the price limits" as day 0 and select day -10 to day 10 as an event window. Different from the method proposed by Kim and Rhee, we use Mann-Whitney U Test to test whether the four pairs of subgroups (UP and $UP_{-1}$, $UP_{-1}$ and $UP_{-2}$, DOWN and $DOWN_{+1}$, $DOWN_{+1}$ and $DOWN_{+2}$) have the same price volatility. If after day 0, UP (DOWN) has significantly higher volatility than $UP_{-1}$ ($DOWN_{+1}$), but that of $UP_{-1}$ ($DOWN_{+1}$) is insignificantly higher than $UP_{-2}$ ($DOWN_{+2}$), then it indicates the support of the empirical result for volatility spillover hypothesis. Furthermore, if a certain stock "hits the price limits" for more than two consecutive trading days, this study has to remove this stock from observation in order for "hitting the price limits" to become a separate event.

### 2.3.2 Testing of Delayed Price Discovery Hypothesis

To test the delayed price discovery hypothesis, Kim and Rhee (1997) examined the two return series, i.e., $\ln(C_0 / O_0)$ and $\ln(O_1 / C_0)$, where $C_0$, $O_0$, $O_1$, and $\ln(\cdot)$ are the closing price on day 0, the opening price on day 0, the opening price on day 1, and the natural logarithm operator, respectively. According to Kim and Rhee, this study uses [X, Y] denoting the symbol of $\ln(C_0 / O_0)$ and $\ln(O_1 / C_0)$ to investigate the price behavior of six subgroups (UP, $UP_{-1}$, $UP_{-2}$, DOWN, $DOWN_{+1}$, and $DOWN_{+2}$) sequent to day 0, and X and Y can be positive (+), negative (-), or zero (0). We classify the price behavior of stocks into three categories described as Table 2 according to [X, Y], i.e., "price continuation," "price reversal," and "no change." Besides, we also look at the price behavior of stocks whose closing price matches the highest (lowest) price in order to avoid contaminated results caused by maximum price variation rules (Lehmann and Modest, 1994; George and Hwang, 1995).

Table 2. Classification of Stock Price Behavior

| Price Limit | Stock Price Behavior | Returns Series |
|---|---|---|
| Upper Limit | Continuation | [+, +] [0, +] |
| | Reversal | [+, -] [0, -] [-, +] [-, 0] [-, -] |
| | No change | [+, 0] [0, 0] |
| Lower Limit | Continuation | [-, -] [0, -] |
| | Reversal | [-, +] [0, +] [+, -] [+, 0] [+, +] |
| | No change | [-, 0] [0, 0] |

This study uses a standard nonparametric binomial test to examine whether there is a different price behavior sequent to day 0 between each subgroup. The testing method of delayed price discovery hypothesis as follows:

$H_0$: $P_rCON_A \leqq P_rCON_B$

$H_1$: $P_rCON_A > P_rCON_B$

where $P_rCON_A$ and $P_rCON_B$ are the proportion of price continuation of subgroup A and B, respectively.

The z-statistics of standard nonparametric binominal test as follows:

$$Z = \frac{CON_A - (P_rCON \times N_A)}{\sqrt{[P_rCON_B \times (1 - P_rCON_B) \times N_A]}}$$

where $CON_A$ and $CON_B$ are the number of price continuation of subgroup A and B, respectively; $N_A$ and $N_B$ are the sample size of subgroup A and B, respectively. The delayed price discovery hypothesis conjectures that the proportion of price continuation of UP (DOWN) subgroup is greater than that of $UP_{-1}$ and $UP_{-2}$ ($DOWN_{+1}$ and $DOWN_{+2}$) subgroups.

### 2.3.3 Testing of Trading Interference Hypothesis

This study applies the method of Kim and Rhee (1997) to test the trading interference hypothesis and makes a use of the percentage change of turnover rate to measure variation of trading activities around limit-hit-day. Specifically, designating the limit-hit-day as day 0, we adopt the 10-day event period from day -4 to day 5 and estimate the turnover rate of stock $i$ on day $t$ ($TA_{i,t}$) as follows:

$$TA_{i,t} = TV_{i,t} / SO_{i,t},$$

where $TV_{i,t}$ is the trading volume of stock $i$ on day $t$ and the number of outstanding shares of stock $i$ on day $t$.

Next, we define the percentage change of turnover rate of stock $i$ on day $t$ as $TR_{i,t} = \ln(TA_{i,t} / TA_{i,t-1}) \times 100$, and Mann-Whitney U Test is again used to test whether

there is a same mean of percentage change of turnover rate among subgroups. As the testing of volatility spillover hypothesis, this study also excludes the observation that hit the price limits more than two consecutive trading days. If empirical evidences indicated that the liquidity of UP (DOWN) subgroup after day 0 is lower than that of $UP_{-1}$ and $UP_{-2}$ ($DOWN_{+1}$ and $DOWN_{+2}$) subgroups, then the price limits would have interfered trading activity.

### 2.3.4 Testing of Disturbed Stock Valuation Hypothesis

In contrast with the traditional financial approach, behavioral finance assumed that investors are irrational. Under the assumptions of lacking relevant information and irrational behavior, Montier (2002) showed that past prices will be the reference point of current prices formation process. Because investors may assess fair price based on past price performance, it possibly affects the investment strategy of investors; in particular, for stocks that hit price limits, some investors may change their perception toward fair price of those and hold a more optimistic or pessimistic projection. In other words, investors may have very different perceptions toward stocks that hit price limits.

The necessity of gauging the inconsistency of fair price perception regarding stocks that hit price limits is significant in order to justify the price limit mechanism. To investigate the investors' perceptions of fair price, the intraday buy/sell order flows may be helpful for measuring the inconsistency of fair price perception. Lease, Masulis, and Page (1991) indicated that the buy-sell order imbalance signals new information about the stock's intrinsic value, while Lauterbach and Ben-Zion (1993) presented that circuit breakers reduce the next-day opening order imbalance. Although it seems difficult to accurately gauge the investors' perception, the information of bid, ask, or transaction prices could be a proxy of investors' perception regarding the intrinsic value of stocks that hit price limits. Because intraday transaction prices could capture the difference between buyer's and seller's recognition of hit-limits stock's fundamentals, this study applies the range of transaction prices to gauge the inconsistency of fair price perception.[10)]

This study uses the ratio, the range of transaction price on a particular trading day

10) Although Parkinson (1980) showed that the extreme value of transaction prices is a good estimate of diffusion of stock price, the range of transaction prices is suitable for measuring the diffusion of investors' perception of fair price.

over the closing price on the previous trading day, in order to gauge the inconsistency of investors' perceptions of fair price. We assume the inconsistency of fair price perception on stock $i$ for day $t$ as $S_{i,t} = [(H_{i,t} - L_{i,t}) / C_{i,t-1}] \times 100$, where $(H_{i,t} - L_{i,t})$ refers to the range of transaction prices of stock $i$ on day $t$. In addition, samples that hit the price limits more than two consecutive trading days are excluded to avoid bias results. In terms of event window and testing method, this study selects day -10 to 10 as the event window and use Mann-Whitney U Test to test whether the four pairs of subgroups (UP and $UP_{-1}$, $UP_{-1}$ and $UP_{-2}$, DOWN and $DOWN_{+1}$, $DOWN_{+1}$ and $DOWN_{+2}$) have same inconsistency of fair price perception. The empirical results will support the disturbed stock valuation hypothesis if the inconsistency of fair price perception of UP (DOWN) is significantly greater than that of $UP_{-1}$ and $UP_{-2}$ ($DOWN_{+1}$ and $DOWN_{+2}$).

# 3. Empirical Results of Price Limit Performance

## 3.1 Empirical Results of Volatility Spillover Hypothesis

### 3.1.1 Upper Limit

The volatility spillover hypothesis states that price limits prevent rational movement of stock prices. When a stock price hits a price limit, this signifies unbalanced supply and demand on the trading day. This imbalance sustains trading activities on to the next trading day and results in greater fluctuation of stock prices for a certain period of time after the stock price hits the price limits on a trading day. Table 3 shows the influence of upper limit on the stock price volatility and indicates that as "whole" samples, a significant difference is found in three subgroups (UP, $UP_{-1}$ and $UP_{-2}$) on day 0 based on the research design. This occurs because during the samples selection process for each subgroup we use the UP subgroups samples that hit their price limits and have greater change of stock price than those of $UP_{-1}$ on day 0. Similarly, the samples of $UP_{-1}$ are likely to have a greater change in stock prices than those of $UP_{-2}$. Consequently, these three subgroups have shown significant difference in volatility on day 0. This is the result of research design rather than the influence of upper limit.

Table 3. The Result of Volatility Spillover Hypothesis: Upper Limit

| Day | UP | | | Significance | | | | | $UP_{-1}$ | | | Significance | | | | | $UP_{-2}$ | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | |
| -10 | 1.3718 | 1.3966 / 1.4491 | 1.3752 / 1.4560 | | | | ⌒ | ⩠ | 1.3473 | 1.2879 / 1.4887 | 1.2333 / 1.4709 | > | | | | ⌒ | 1.2219 | 1.1986 / 1.4198 | 1.1522 / 1.4368 | | ⌒ |
| -9 | 1.3364 | 1.2838 / 1.3977 | 1.2720 / 1.4041 | | | | ⌒ | ⩠ | 1.3354 | 1.3766 / 1.4884 | 1.2456 / 1.4777 | >> | | | | ⌒ | 1.2173 | 1.1851 / 1.3757 | 1.1270 / 1.4349 | ⌒ | ⩠ |
| -8 | 1.3717 | 1.3022 / 1.4573 | 1.3045 / 1.4594 | | | | ⩠ | ⩠ | 1.3697 | 1.2917 / 1.4743 | 1.2758 / 1.4722 | >> | | | ⌒ | ⌒ | 1.2724 | 1.2338 / 1.3515 | 1.1592 / 1.3611 | | ⌒ |
| -7 | 1.6740 | 1.3309 / 2.5522 | 1.3143 / 2.5422 | > | | | ⌒ | ⌒ | 1.3100 | 1.2748 / 1.3887 | 1.2392 / 1.3687 | | | | | | 1.2415 | 1.2097 / 1.4169 | 1.1578 / 1.4012 | | ⩠ |
| -6 | 1.7697 | 1.3577 / 2.7413 | 1.3687 / 2.7402 | | | | | ⌒ | 1.4006 | 1.3834 / 1.5855 | 1.2734 / 1.5790 | >> | | | ⌒ | ⩠ | 1.3026 | 1.2124 / 1.4792 | 1.1329 / 1.4823 | ⌒ | ⩠ |
| -5 | 1.4492 | 1.3901 / 1.5436 | 1.4057 / 1.5568 | >> | | >> | ⌒ | ⩠ | 1.3188 | 1.2312 / 1.4578 | 1.1510 / 1.4245 | >> | | | ⌒ | ⩠ | 1.2110 | 1.2157 / 1.3666 | 1.0457 / 1.3793 | ⌒ | ⩠ |
| -4 | 1.3805 | 1.2762 / 1.5188 | 1.2953 / 1.5226 | | | | ⩠ | ⩠ | 1.3342 | 1.2126 / 1.5814 | 1.1797 / 1.5426 | >> | > | > | ⩠ | ⩠ | 1.2298 | 1.0932 / 1.3253 | 1.0556 / 1.3593 | ⩠ | ⩠ |
| -3 | 1.4426 | 1.4101 / 1.4981 | 1.4042 / 1.4948 | > | | | | ⌒ | 1.3506 | 1.2956 / 1.5270 | 1.2265 / 1.4989 | >> | | >> | | ⩠ | 1.2062 | 1.0716 / 1.3720 | 1.0001 / 1.3564 | ⩠ | ⩠ |
| -2 | 1.6327 | 1.5704 / 1.7079 | 1.5933 / 1.7135 | >> | | > | ⩠ | ⩠ | 1.4291 | 1.3827 / 1.5733 | 1.3356 / 1.5553 | | | | | ⌒ | 1.3646 | 1.3928 / 1.5195 | 1.2987 / 1.5001 | ⌒ | ⩠ |
| -1 | 1.2822 | 1.2862 / 1.2905 | 1.2827 / 1.3018 | << | << | | | | 1.4744 | 1.3259 / 1.6177 | 1.2672 / 1.5846 | >> | | | ⩠ | ⩠ | 1.3799 | 1.1785 / 1.5064 | 1.1226 / 1.4668 | ⩠ | ⩠ |
| 0 | 3.9107 | 3.9439 / 3.8848 | 3.9334 / 3.8786 | >> | >> | >> | | | 2.2185 | 2.3386 / 2.2193 | 2.3707 / 2.2307 | >> | >> | >> | | | 1.6664 | 1.7784 / 1.7067 | 1.7472 / 1.7338 | | |
| 1 | 1.2170 | 1.1442 / 1.3087 | 1.1279 / 1.3142 | << | < | | ⩠ | ⩠ | 1.4517 | 1.5226 / 1.5360 | 1.4452 / 1.4916 | >> | | | | ⩠ | 1.2983 | 1.1731 / 1.4446 | 1.1135 / 1.4270 | ⩠ | ⩠ |
| 2 | 1.4631 | 1.4887 / 1.4795 | 1.4879 / 1.4976 | > | | >> | | | 1.3665 | 1.2850 / 1.3890 | 1.2130 / 1.3806 | >> | | | | | 1.1881 | 1.0907 / 1.3540 | 1.0318 / 1.3773 | ⌒ | ⩠ |
| 3 | 1.3485 | 1.3118 / 1.3853 | 1.3002 / 1.3839 | | | | | | 1.3102 | 1.2687 / 1.4122 | 1.2008 / 1.3665 | >> | | | | | 1.1585 | 1.1870 / 1.3220 | 1.1258 / 1.3271 | | ⌒ |
| 4 | 1.3602 | 1.2882 / 1.4146 | 1.2763 / 1.4169 | >> | | > | | ⌒ | 1.2718 | 1.1822 / 1.3717 | 1.1380 / 1.3669 | > | | | ⌒ | ⌒ | 1.1669 | 1.1737 / 1.2759 | 1.1018 / 1.2837 | | ⩠ |
| 5 | 1.3210 | 1.2629 / 1.3813 | 1.2543 / 1.3845 | | | | | ⌒ | 1.2923 | 1.2187 / 1.3891 | 1.1578 / 1.3761 | > | | | | | 1.2001 | 1.0784 / 1.3573 | 1.0288 / 1.4010 | ⩠ | ⩠ |
| 6 | 1.3292 | 1.2539 / 1.3766 | 1.2421 / 1.3961 | | | | ⩠ | ⩠ | 1.2865 | 1.1227 / 1.3878 | 1.0538 / 1.3467 | >> | | | ⩠ | ⩠ | 1.1688 | 1.1850 / 1.3152 | 1.0569 / 1.2936 | | ⩠ |
| 7 | 1.2614 | 1.1856 / 1.4148 | 1.1736 / 1.4080 | >> | | >> | ⩠ | ⩠ | 1.1854 | 0.9771 / 1.3183 | 0.8959 / 1.2791 | > | | | ⩠ | ⩠ | 1.0920 | 0.9878 / 1.2848 | 0.9684 / 1.2845 | ⩠ | ⩠ |
| 8 | 1.3421 | 1.2316 / 1.4281 | 1.2479 / 1.4311 | >> | | > | ⩠ | ⩠ | 1.2574 | 1.1777 / 1.4334 | 1.0827 / 1.4317 | >> | | | | ⩠ | 1.1771 | 1.0784 / 1.4087 | 1.0063 / 1.3936 | ⩠ | ⩠ |
| 9 | 1.3308 | 1.2834 / 1.4069 | 1.2576 / 1.3981 | >> | | >> | | ⌒ | 1.2445 | 1.0731 / 1.4068 | 1.0424 / 1.3974 | | | | ⩠ | ⩠ | 1.1539 | 0.9682 / 1.3448 | 0.9724 / 1.3485 | ⩠ | ⩠ |
| 10 | 1.2555 | 1.2047 / 1.3772 | 1.1960 / 1.3878 | | | | ⩠ | ⩠ | 1.2578 | 1.1651 / 1.4056 | 1.1430 / 1.4012 | >> | | | ⌒ | ⩠ | 1.1288 | 1.0400 / 1.4041 | 0.9807 / 1.4141 | ⩠ | ⩠ |

Note) >> and > signify that the volatility of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the volatility of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ⩡ and ﹀ signify that the volatility of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ⩠ and ⌒ signify that the volatility of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

Table 3 shows that the volatility of UP subgroup decreases significantly from 3.9107 on day 0 to 1.2170 on day 1. According to above empirical finding, we may de-

velop an initial assumption: the upper limit is able to effectively reduce stock price volatility after price reaches to upper limit. That is to say the upper limit is able to deter irrational volatility in prices and has cool-off effect (Ma, Rao, and Sears, 1989). Kim and Rhee (1997), however, considers the explanation of Ma, Rao, and Sears over simplified and are more inclined to support the proposition of Lehmann (1989) and Miller (1989) that the price of the UP subgroup on day 0 experienced a dramatic change and delayed information that may have either been decreased greatly or disappeared on the second day. Thus, it is inevitable to witness decreased volatility after day 0 and not as a result of being close to the upper limit. This study found that in terms of stock price change $UP_{-1}$ and $UP_{-2}$, subgroups which are similar to the UP subgroup will experience a dramatic decrease on day 1 after highly volatile day 0. Thus, the empirical evidence corresponds to the proposal of Lehmann, Miller, and Kim and Rhee, indicating that the dramatic decrease of volatility on day 1 does not entail that an upper limit is able to deter the irrational volatility of a stock price.

According to the results of "whole" samples of UP, $UP_{-1}$ and $UP_{-2}$ shown in Table 3, this study finds that after day 0, the volatility of the UP subgroup on day 2, 4, 7, 8, and 9 is significantly greater than that of the $UP_{-1}$ subgroup. We cannot support the volatility spillover hypothesis yet because empirical results reveal that the volatility of the UP subgroup on day 1 is lower than that on day -1 and significantly lower than that of the $UP_{-1}$ subgroup. This indicates that the upper limit significantly decreases the stock price volatility. Furthermore, although the volatility of the UP subgroup is significantly higher than that of the $UP_{-1}$ subgroup after hitting the upper limit (day 2, 4, 7, 8, and 9), the same phenomenon also occurs before hitting the upper limit and the volatility of UP subgroup is significantly higher than that of $UP_{-1}$ subgroup on day -2, -3, -5 and -7. A similar situation is also found when comparing the $UP_{-1}$ subgroup and the $UP_{-2}$ subgroup.[11] The UP subgroup has a higher volatility after hitting the upper limit and is not influenced by the upper limit but retains the original volatility trend.

Overall, in relation to the support of volatility spillover hypothesis in the more mature Tokyo Stock Exchange (Kim and Rhee, 1997) and higher volatility caused by trading halt in the New York Stock Exchange (Lee, Ready, and Seguin, 1994), this study found that price limits imposed by the Taiwan Stock Exchange provides an op-

11) Before and after $UP_{-1}$ subgroup reach to upper limit, with the exception of day -7, –2, and 9, its volatility has greater statistical significance than that of $UP_{-2}$ subgroup.

portunity for investors to rationally make valuations and avoid undue volatility. We assume that different empirical results in the above-mentioned three studies are due to the discrepancy in market sophistication; more noise traders exist in the Taiwan Stock Exchange than those in the Tokyo Stock Exchange and New York Stock Exchange, and in Taiwan they are more likely to behave according to a gossip. Price limits, thus, are able to perform a cooling down function and effectively decrease the stock price volatility. This study shows that the empirical aspect of the price volatility reduction caused by price limits correspond to that of the stock market in South Korea, another emerging market (Lee and Kim, 1995).

#### 3.1.2 Lower Limit

This study compares the effect of the prevention of irrational fluctuation caused by upper and lower limits in order to examine further the price limit performance. Table 4 shows the significant difference among DOWN, $DOWN_{+1}$, and $DOWN_{+2}$ subgroups on day 0 as what was found in the above finding of upper limit and is a result of research design. According to Lehmann (1989), Miller (1989), and Kim and Rhee (1997), volatilities of DOWN, $DOWN_{+1}$, and $DOWN_{+2}$ decreased from day 0 to day 1 due to large price fluctuation on day 0 not the effect of the lower limit.

The results of "whole" samples of DOWN, $DOWN_{+1}$ and $DOWN_{+2}$ in Table 4 showed that there is no statistically significant difference of volatility on day 1 among the three subgroups. From Table 4, that price limits can prevent volatility spillover was not evidenced. In addition, Table 4 presented that after day 0, although the volatility of DOWN subgroup on day 2, 3, 5, 7, and 9 is significantly higher than that of $DOWN_{+1}$ subgroup, a further examination of volatility discrepancy between $DOWN_{+1}$ and $DOWN_{+2}$ subgroups and volatility change before and after the day when a lower limit was reached explains the above phenomena for volatility spillover caused by price limits or the maintenance of original volatility trend of the DOWN subgroup. This study observed volatility change in each subgroup before the lower limit was hit and found that the volatility of DOWN subgroup on day -2, -3, -4, -8, and -9 is significantly higher than that of the $DOWN_{+1}$ subgroup indicating a high volatility of DOWN subgroup (that is significantly higher than that of $DOWN_{+1}$ subgroup) after the day when a lower limit was hit. This is due to the original volatility trend not the influence of lower limit. This point was proven to be true by comparing the volatility discrepancy of DOWN, $DOWN_{+1}$ and $DOWN_{+2}$ subgroups.

Table 4. The Result of Volatility Spillover Hypothesis: Lower Limit

| Day | DOWN | | | | Significance | | | | | $DOWN_{+1}$ | | | | Significance | | | | | $DOWN_{+2}$ | | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE | High EPS | Low ROE | Low EPS | | | | | Whole Samples | High ROE | High EPS | Low ROE | Low EPS | | | | | Whole Samples | High ROE | High EPS | Low ROE | Low EPS | | |
| -10 | 1.3776 | 1.3882 | 1.3921 | 1.4254 | 1.4272 | | | | | 1.3499 | 1.3075 | 1.2410 | 1.3124 | 1.3245 | | | | | 1.2345 | 1.0952 | 1.0422 | 1.1720 | 1.2057 | | |
| -9 | 1.5571 | 1.5585 | 1.5716 | 1.5640 | 1.5554 | >> | >> | >> | >> | 1.2875 | 1.2437 | 1.1832 | 1.2373 | 1.2759 | | | | | 1.2495 | 1.2456 | 1.1642 | 1.1713 | 1.1915 | | |
| -8 | 1.4057 | 1.3773 | 1.3767 | 1.4470 | 1.4500 | > | | | | 1.3137 | 1.3372 | 1.2982 | 1.3296 | 1.3280 | | | > | | 1.2799 | 1.3178 | 1.0900 | 1.1314 | 1.1917 | | |
| -7 | 1.4727 | 1.4749 | 1.4543 | 1.5257 | 1.5213 | | | | | 1.3658 | 1.3115 | 1.2824 | 1.3872 | 1.4314 | > | | | | 1.2193 | 1.1877 | 1.2031 | 1.1693 | 1.2236 | | |
| -6 | 1.3523 | 1.2996 | 1.3093 | 1.4052 | 1.4201 | | | | | 1.3505 | 1.2286 | 1.1770 | 1.3221 | 1.3062 | | | | | 1.2558 | 1.1314 | 1.0405 | 1.3312 | 1.3744 | | ⩔ |
| -5 | 1.5279 | 1.5493 | 1.5347 | 1.5918 | 1.5726 | | | | | 1.4114 | 1.2597 | 1.3151 | 1.4930 | 1.4593 | > | > | | | 1.3158 | 1.2075 | 1.2066 | 1.3109 | 1.3638 | | |
| -4 | 1.5533 | 1.6174 | 1.6440 | 1.4987 | 1.5049 | >> | > | >> | > | ⩒ | 1.3896 | 1.3845 | 1.3081 | 1.3205 | 1.3318 | | | | | 1.2404 | 1.1522 | 1.1379 | 1.2063 | 1.2115 | | |
| -3 | 1.5381 | 1.5929 | 1.5652 | 1.5307 | 1.5343 | >> | | >> | | | 1.3977 | 1.3410 | 1.2877 | 1.3486 | 1.3486 | | | | | 1.3444 | 1.2880 | 1.1990 | 1.2942 | 1.3409 | | |
| -2 | 1.5797 | 1.5591 | 1.5947 | 1.6214 | 1.6136 | >> | | >> | | | 1.4316 | 1.3212 | 1.2642 | 1.4400 | 1.4406 | | | | | 1.2864 | 1.2083 | 1.1753 | 1.2903 | 1.3233 | | |
| -1 | 1.2568 | 1.2548 | 1.2295 | 1.3077 | 1.2888 | << | | | | 1.5839 | 1.3506 | 1.2469 | 1.4193 | 1.4366 | >> | | | | 1.4242 | 1.0857 | 1.0239 | 1.4579 | 1.5023 | ⩔ | ⩔ |
| 0 | 3.6539 | 3.6549 | 3.7111 | 3.5640 | 3.5776 | >> | >> | >> | >> | | 2.2803 | 2.3038 | 2.3456 | 2.3123 | 2.3180 | >> | >> | >> | | 1.9014 | 1.8842 | 1.8037 | 2.0198 | 2.0154 | | ⩔ |
| 1 | 1.2102 | 1.2397 | 1.2158 | 1.2008 | 1.1962 | | | | | 1.2697 | 1.1746 | 1.0390 | 1.1783 | 1.1420 | | | | | 1.2097 | 1.0942 | 0.9960 | 1.1533 | 1.1521 | | |
| 2 | 1.6831 | 1.6247 | 1.6047 | 1.7015 | 1.6961 | >> | > | >> | > | | 1.4461 | 1.2672 | 1.2660 | 1.4995 | 1.4879 | > | | | | 1.3554 | 1.1551 | 1.1717 | 1.4444 | 1.4321 | ⩒ | ⩒ |
| 3 | 1.4728 | 1.4690 | 1.4602 | 1.5036 | 1.4980 | >> | >> | > | >> | | 1.3700 | 1.2259 | 1.2082 | 1.2498 | 1.2476 | >> | | | | 1.2564 | 1.2155 | 1.2131 | 1.3097 | 1.3149 | | |
| 4 | 1.4121 | 1.3345 | 1.3389 | 1.4800 | 1.4845 | | | > | | | 1.3477 | 1.1906 | 1.1522 | 1.4080 | 1.4383 | | | | | 1.2799 | 1.2663 | 1.2139 | 1.3058 | 1.2643 | | |
| 5 | 1.4199 | 1.4141 | 1.4207 | 1.4384 | 1.4139 | > | | >> | | | 1.2787 | 1.1275 | 1.0400 | 1.3905 | 1.3885 | | | | ⩔ | ⩔ | 1.2391 | 1.2630 | 1.2101 | 1.2416 | 1.2303 | | |
| 6 | 1.2664 | 1.2216 | 1.2333 | 1.3035 | 1.3109 | | | > | | | 1.2966 | 1.1605 | 1.0755 | 1.3801 | 1.3921 | > | | | | ⩔ | 1.1807 | 1.1362 | 1.1592 | 1.1630 | 1.2007 | | |
| 7 | 1.5170 | 1.4839 | 1.4522 | 1.5356 | 1.5492 | >> | | > | | | 1.3838 | 1.3033 | 1.2495 | 1.3632 | 1.3740 | >> | | > | | | 1.2897 | 1.0629 | 1.0711 | 1.2986 | 1.3246 | ⩒ | ⩒ |
| 8 | 1.2263 | 1.2443 | 1.2264 | 1.2639 | 1.2594 | | | | | | 1.2336 | 1.1287 | 1.1173 | 1.1870 | 1.2347 | > | | > | | | 1.1668 | 1.1646 | 1.1385 | 1.1070 | 1.1590 | | ⩒ |
| 9 | 1.3797 | 1.3958 | 1.3901 | 1.3624 | 1.3608 | >> | | >> | | | 1.2852 | 1.4074 | 1.3495 | 1.3049 | 1.3236 | | | | | 1.1649 | 1.2059 | 1.1107 | 1.1838 | 1.2513 | | |
| 10 | 1.3489 | 1.3291 | 1.3278 | 1.4171 | 1.4018 | | | | | | 1.2699 | 1.2889 | 1.0851 | 1.2845 | 1.2752 | | | | | 1.1604 | 1.1643 | 1.0656 | 1.2421 | 1.2389 | | |

Note) >> and > signify that the volatility of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the volatility of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ⩒ and ⩒ signify that the volatility of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ⩔ and ⩔ signify that the volatility of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

To summarize the empirical results illustrated in Table 4, the evidences before or after the day when the lower price limit was hit indicated that the volatility of the DOWN subgroup was significantly higher than that of the $DOWN_{+1}$ subgroup and as $DOWN_{+1}$ is higher than $DOWN_{+2}$. Therefore, these three subgroups maintained their original volatility trends before and after the day when a lower limit was hit, and no change occurred. Although the lower limit does not provide investors with the opportunity to make rational valuation and decrease price volatility, the empirical result of lower limit in the Taiwan Stock Exchange does not support the volatility spillover hypothesis.

## 3.2. Empirical Results of Delayed Price Discovery Hypothesis

### 3.2.1 Upper Limit

The delayed price discovery hypothesis suggests that price limits stipulate the maximum allowable movement of a daily price and this result in the failure to reflect the influence of information shocks on stocks that hit their price limits on the trading day and moved slowly to a new equilibrium price. Recent study by Habel and Harpaz (2006) pointed out that the price discovery process is impeded when price limit regulations are tightened. Thus, stocks that hit upper and lower limits, in particular, those with closing prices that match price limits, will result in price continuation on the next trading day (or even after a couple of days) due to an movement restraint on day 0.[12] To test the delayed price discovery hypothesis, this study compares the open-to-close returns and the overnight returns of UP, $UP_{-1}$, and $UP_{-2}$ (DOWN, $DOWN_{+1}$ and $DOWN_{+2}$) to discuss the discrepancy of price behavior between those stocks that hit and did not hit price limits. If price limits delay the efficient price discovery process, subgroups that hit their price limits（UP and DOWN） are likely to have higher proportion of price continuation than those that do not hit price limits ($UP_{-1}$, $UP_{-2}$, $DOWN_{+1}$ and $DOWN_{+2}$).

From Table 5, we found that among the "whole" samples, the proportion of "price continuation," "price reversal," and "no change" appears to be 0.59, 0.26 and 0.15, respectively, indicating that the price continuation behavior of UP subgroup was shown

12) According to the delayed price discovery hypothesis, it is more likely that the stocks that fail to reflect information shocks and move slowly to a new equilibrium price are those that their closing price matches upper or lower limits on a trading day.

in higher frequency than that of price reversal and no change. However, this did not appear in the $UP_{-1}$ and $UP_{-2}$ subgroups in which we only observed a slightly higher proportion of price continuation than that of price reversal and no change. Moreover, Table 5 indicates that the comparison of price continuation of the UP subgroups is significantly higher than that of the $UP_{-1}$ subgroup, but there is no significant difference in the proportion of price continuation in both statistics and quantities between the $UP_{-1}$ and $UP_{-2}$ subgroups. Therefore, the above result supports the delayed price discovery hypothesis by showing that the upper limit failures result in the reflection failure of information shocks on price and delay the discovery of a new equilibrium price. Furthermore, the findings also show that the proportion of price reversal in the UP subgroup is significantly lower than that of the $UP_{-1}$ subgroup. Consequently, the lower limit imposed in the Taiwan Stock Exchange impedes prices from continuously moving to a new equilibrium on day 0 while it does not prevent overreaction.

Table 5. The Result of Delayed Price Discovery Hypothesis: Upper Limit

| Price Behavior | UP | | | Significance | | | | | UP-1 | | | Significance | | | | | UP-2 | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | |
| Continuation | 0.59 | 0.57 / 0.67 | 0.57 / 0.67 | ≫ | ≫ / > | ≫ / > | ⩠ | ⩠ | 0.43 | 0.43 / 0.40 | 0.43 / 0.39 | | | | | | 0.42 | 0.42 / 0.45 | 0.44 / 0.48 | | |
| | 0.69 | 0.62 / 0.73 | 0.62 / 0.73 | > | ≫ / > | ≫ / > | ⩝ | ⩝ | 0.44 | 0.41 / 0.47 | 0.41 / 0.44 | | | | ⩝ | | 0.45 | 0.45 / 0.46 | 0.45 / 0.46 | | |
| Reversal | 0.26 | 0.27 / 0.17 | 0.27 / 0.17 | ≪ | ≪ / < | ≪ / < | | ⩡ | 0.37 | 0.37 / 0.35 | 0.37 / 0.35 | | | | | | 0.36 | 0.32 / 0.24 | 0.32 / 0.23 | ⩠ | ⩠ |
| | 0.17 | 0.25 / 0.15 | 0.25 / 0.15 | < | ≪ / < | ≪ / < | ⩡ | ⩡ | 0.28 | 0.39 / 0.24 | 0.38 / 0.26 | | | | ⩡ | ⩡ | 0.26 | 0.37 / 0.30 | 0.37 / 0.31 | ⩝ | ⩝ |
| No change | 0.15 | 0.16 / 0.16 | 0.16 / 0.16 | ≪ | ≪ / < | ≪ / < | ⩡ | ⩡ | 0.20 | 0.21 / 0.25 | 0.21 / 0.25 | | | | | | 0.22 | 0.25 / 0.31 | 0.24 / 0.29 | ⩡ | ⩡ |
| | 0.14 | 0.13 / 0.12 | 0.13 / 0.13 | < | ≪ / < | ≪ / < | ⩡ | ⩡ | 0.28 | 0.20 / 0.29 | 0.21 / 0.30 | | | | | | 0.29 | 0.18 / 0.23 | 0.18 / 0.24 | ⩡ | ⩡ |

Note) >> and > signify that the proportion of price behavior of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the proportion of price behavior of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ⩡ and ⩡ signify that the proportion of price behavior of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ⩝ and ⩝ signify that the proportion of price behavior of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

Previous literature such as Lehmann and Modest (1994) and George and Hwang (1995) proposed that the "maximum price variation rules" may lead to price continuation and studied whether the trading interruption caused by the maximum price variation rules delays price discovery. This study selects stocks whose closing price on day 0 matches the highest price from the UP, $UP_{-1}$, and $UP_{-2}$ subgroups and compared their price behaviors. The results are at the bottom of the double horizontal line in Table 5, showing that all the UP, $UP_{-1,}$ and $UP_{-2}$ subgroups indicate that stocks whose closing prices on day 0 match the highest price have higher proportions of price continuation and lower proportions of price reversal than those whose closing prices on day 0 do not match the highest price. In addition, as in the case of the stocks whose closing prices on day 0 do not match the highest price, the stocks whose closing prices on day 0 match the highest price carry more significant evidences for price continuation of the UP subgroup. Therefore, we are unable to exclude the possibility that maximum price variation rules eventually lead to price continuation despite those empirical results indicating that the upper limit delays the efficient price discovery process.

### 3.2.2 Lower Limit

The effect of lower limit on the price discovery is shown in Table 6 which indicates that in terms of "whole" samples, the proportion of price continuation, price reversal and no change in the DOWN subgroup are 0.53, 0.35 and 0.12, respectively. Although the proportion of price continuation of the DOWN subgroup is slightly lower than that of the UP subgroup, the proportion is still much higher than that of price reversal and no change. However, the findings in the $DOWN_{+1}$ and $DOWN_{+2}$ subgroups are different from those in the DOWN subgroup in that in the former subgroups the proportion of price reversal is even higher than that of price continuation. Further, in the comparison of the proportion of price continuation that occurs in DOWN, $DOWN_{+1}$ and $DOWN_{+2}$ subgroups, we find that the proportion of price continuation in the DOWN subgroup is significantly higher than that of the $DOWN_{+1}$ subgroup, but there is no significant difference in both statistics and quantity of proportion of price continuation between $DOWN_{+1}$ and $DOWN_{+2}$ subgroups. Therefore, empirical results of lower limit support the delayed price discovery hypothesis, confirming that lower limit results in delayed adjustment to new equilibrium price. Furthermore, the empirical results of lower limit also reveal that the proportion of price reversal in the DOWN subgroup is significantly lower than that of the $DOWN_{+1}$ subgroup. Again,

this attests to the fact that the lower limit imposed by the Taiwan Stock Exchange actually slows down the process of efficient price discovery while failing to effectively restrain market overreaction to information shocks.

In addition, the results with all three subgroups of DOWN, $DOWN_{+1}$ and $DOWN_{+2}$ exhibited in Table 6 show that stocks whose closing prices on day 0 match the lowest price have higher proportion of price continuation and lower proportion of price reversal than those of stocks whose closing price on day 0 do not match the lowest price. On the other hand, the result at the bottom of the double horizontal line in Table 6 shows that the proportion of price continuation in the DOWN subgroup samples whose closing prices on day 0 match the lowest price is significantly higher than that in $DOWN_{+1}$ and $DOWN_{+2}$ subgroups samples whose closing prices on day 0 match the lowest price. For this reason, we are unable to exclude the possibility that maximum price variation rules lead to delayed price discovery despite the empirical result that supports the delayed price discovery hypothesis.

Table 6. The Result of Delayed Price Discovery Hypothesis: Lower Limit

| Price Behavior | DOWN | | | Significance | | | | | $DOWN_{+1}$ | | | Significance | | | | | $DOWN_{+2}$ | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | |
| Continuation | 0.53 | 0.52 | 0.52 | ≫ | >> | >> | ⩠ | ⩠ | 0.30 | 0.28 | 0.28 | | | | | | 0.28 | 0.27 | 0.27 | | |
| | | 0.66 | 0.66 | | >> | >> | | | | 0.38 | 0.36 | | | | | | | 0.36 | 0.35 | | |
| | 0.69 | 0.55 | 0.55 | >> | >> | >> | ⩽ | ⩽ | 0.35 | 0.30 | 0.31 | | | | | | 0.34 | 0.29 | 0.28 | | |
| | | 0.72 | 0.72 | | >> | >> | | | | 0.37 | 0.39 | | | | | | | 0.29 | 0.29 | | |
| Reversal | 0.35 | 0.35 | 0.35 | ≪ | ≪ | ≪ | ⩡ | ⩡ | 0.51 | 0.51 | 0.50 | | | | ⩡ | | 0.49 | 0.48 | 0.48 | ⩠ | ⩠ |
| | | 0.21 | 0.22 | | << | << | | | | 0.32 | 0.29 | | | | | | | 0.36 | 0.35 | | |
| | 0.20 | 0.33 | 0.33 | << | ≪ | ≪ | ⩒ | ⩒ | 0.37 | 0.50 | 0.50 | | | | | | 0.36 | 0.52 | 0.53 | ⩽ | ⩽ |
| | | 0.17 | 0.17 | | << | << | | | | 0.34 | 0.34 | | | | | | | 0.42 | 0.43 | | |
| No change | 0.12 | 0.13 | 0.13 | ≪ | ≪ | ≪ | ⩡ | ⩡ | 0.19 | 0.21 | 0.22 | | | | ⩡ | ⩡ | 0.22 | 0.24 | 0.25 | ⩡ | ⩡ |
| | | 0.13 | 0.12 | | << | << | | | | 0.30 | 0.35 | | | | | | | 0.28 | 0.30 | | |
| | 0.12 | 0.12 | 0.12 | << | ≪ | ≪ | ⩒ | ⩒ | 0.27 | 0.20 | 0.20 | | | | ⩒ | ⩒ | 0.29 | 0.19 | 0.19 | ⩒ | |
| | | 0.11 | 0.11 | | << | << | | | | 0.28 | 0.28 | | | | | | | 0.29 | 0.29 | | |

Note) >> and > signify that the proportion of price behavior of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the proportion of price behavior of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ⩡ and ⩒ signify that the proportion of price behavior of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ⩠ and ⩽ signify that the proportion of price behavior of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

In short, those empirical results presented in Table 5 and Table 6 corroborate that both upper and lower limits impede the process of equilibrium price discovery and that those stocks whose prices reaching the upper limit are more likely to continue to rise on the next trading day than those that hit the lower limit to continue to fall on the next trading day. These results show that in the Taiwan Sock Exchange, investors are more likely to purchase stocks that hit the upper limit than to sell out those that hit the lower limit. Such tendency in investors' behaviors is proven in studies of behavioral finance. For instance, after stocks hit upper and lower limits, investors are observed to expect continuous price rising (favorable outcome) and they overlook the possibility of continuous price falling (unfavorable outcome), clearly exhibiting investors' excessive optimism. Generally, stockholders tend to be overconfident about their stock price forecasts, firmly adhering to the forecast of price trend (conservatism bias), and are unwilling to admit their wrong judgment (regret effect). Above all, the situation forces investors to continuously buy in stocks that hit the upper limit and to be unwilling to sell out those that hit the lower limit.

## 3.3 Empirical Results of Trading Interference Hypothesis

### 3.3.1 Upper Limit

Table 7 indicates that for the "whole" samples, trading activity of the UP subgroup on day 0 is significantly higher than that of the $UP_{-1}$ and $UP_{-2}$ subgroups on day 0 and that of the UP subgroup on any other trading day. This result proves that when a certain stock hits its upper limit, more frequent trading is observed; however, what is worth noticing here is the trading activity change after an upper limit day. According to Table 7, the trading activity of the UP subgroup declines from day 1 to day 5. This result seems to indicate that the upper limit has a cooling down effect as the trading activity decreases significantly after hitting the limit. Yet, we are unable to reject the trading interference hypothesis solely based on the finding because in Table 7, the trading activities of the UP, $UP_{-1}$ and $UP_{-2}$ subgroups from day 1 to day 5 also decline, and the trading activities of the UP subgroup on day 1 are only decreased by 9.25%, obviously smaller than those of the $UP_{-1}$ (22.48%) and $UP_{-2}$ (22.83%) subgroups. Moreover, the trading activities of the UP subgroup on day 1 are significantly higher than those of the $UP_{-1}$ and $UP_{-2}$ subgroups. This result only reflects investors regaining their rational investment behaviors, not being forced by the influence of the upper

limit to reduce the trading volume after a dramatic price fluctuation on day 0 even after the UP subgroup is found to be less active on day 1.

Table 7. The Result of Trading Interference Hypothesis: Upper Limit

| Day | UP | | | Significance | | | | | UP-1 | | | Significance | | | | | UP-2 | | | Signi-ficance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE Low ROE | High EPS Low EPS | | | | | | Whole Samples | High ROE Low ROE | High EPS Low EPS | | | | | | Whole Samples | High ROE Low ROE | High EPS Low EPS | | |
| -4 | 1.0332 | 2.3455 | 3.6346 | | | | | ﹀ | -0.3367 | -2.3072 | -1.0909 | | | | | | 0.5258 | -0.6744 | -1.1034 | | |
| | | -0.2759 | -0.1943 | | | | | | | -1.9085 | -1.3557 | | | | | | | -1.2507 | -1.2831 | | |
| -3 | 3.2967 | 4.5952 | 3.7710 | | | | | | 2.9157 | 1.8180 | 1.9135 | | | | | | 2.0991 | 1.9957 | 0.5860 | | |
| | | 3.5555 | 3.5920 | | | | | | | 5.5254 | 4.0642 | | | | | | | 0.6207 | 0.4787 | | |
| -2 | 1.4967 | 2.0911 | 3.1265 | < | < | | | ﹀ | 4.1523 | 2.6375 | 3.5173 | | | | | | 3.6154 | 3.8361 | 5.4575 | | |
| | | -1.1894 | -1.7628 | | | < | | | | 2.5995 | 4.4234 | | | | | | | 5.2525 | 5.3721 | | |
| -1 | 4.6138 | 3.4276 | 3.1768 | | | | | | 6.7838 | 2.9509 | 2.5346 | | | | | | 6.5672 | 4.0185 | 2.5660 | | |
| | | 6.4923 | 6.6219 | | | | | | | 6.3660 | 5.9982 | | | | | | | 8.5309 | 7.4465 | | |
| 0 | 60.2879 | 56.0747 | 55.8277 | >> | >> | >> | ﹽ | ﹽ | 48.6658 | 47.2289 | 47.3910 | >> | >> | | | | 44.7406 | 42.5298 | 45.2752 | | ﹀ |
| | | 60.9970 | 60.6293 | | >> | >> | | | | 46.9727 | 46.6209 | | >> | >> | | | | 38.0797 | 37.6547 | | |
| 1 | -9.2509 | -7.9525 | -8.8649 | >> | >> | >> | | | -22.4814 | -22.6814 | -23.9750 | | | | | | -22.8263 | -20.8691 | -20.8822 | | |
| | | -8.8082 | -8.6470 | | >> | >> | | | | -20.7689 | -20.0661 | | | | | | | -18.9970 | -18.4487 | | |
| 2 | -28.7414 | -27.1537 | -25.8132 | << | << | << | ﹀ | ﹀ | -14.5585 | -11.0056 | -12.2324 | | < | | ﹀ | | -12.2109 | -8.1737 | -9.5837 | | |
| | | -31.0688 | -30.8246 | | << | << | | | | -17.6711 | -17.1801 | | < | < | | | | -11.8247 | -11.6687 | | |
| 3 | -5.1467 | -5.1560 | -4.7973 | | | | | | -3.8231 | 0.5026 | -1.5620 | | | | | | -4.3120 | -4.8147 | -5.1658 | | |
| | | -5.4955 | -5.7631 | | | | | | | -3.7881 | -4.7171 | | | | | | | -2.7729 | -2.6833 | | |
| 4 | -5.0693 | -4.2068 | -4.5514 | | < | | | | -3.9432 | -4.1279 | -3.4743 | | | | | | -3.1500 | 0.0835 | -1.1182 | ﹀ | |
| | | -5.8586 | -5.6848 | | | < | | | | -0.4229 | -0.2302 | | | | | | | -4.0620 | -4.0669 | | |
| 5 | -3.7425 | -3.5799 | -3.4625 | | | | | | -3.8274 | -5.8161 | -5.2092 | | | | | | -3.5056 | -6.7975 | -6.5353 | | |
| | | -4.1336 | -3.6008 | | | | | | | -4.6584 | -4.0344 | | | | | | | -2.2522 | -2.4641 | | |

Note) >> and > signify that the trading activity of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the trading activity of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ﹾ and ﹀ signify that the trading activity of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ﹽ and ﹿ signify that the trading activity of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

### 3.3.2 Lower Limit

The empirical result of trading abnormality influenced by a lower limit is shown in Table 8. It illustrates that for the "whole" samples, the trading activity of the DOWN subgroup on day 0 is significantly higher than that of the $DOWN_{+1}$ and $DOWN_{+2}$ subgroups on day 0 and that of the DOWN subgroup on the other trading days. This increase in trading activity indicates that when a certain stock price hits its lower limit, the stock is traded more frequently. Such trading activities of the DOWN subgroups decrease day 1 to day 5 after hitting the lower limit. Therefore, we reach the same conclusion derived the from the empirical results of the upper limit in that we are

unable to assume that the lower limit in the Taiwanese stock market has a cooling down effect; therefore, we reject the "trading interference hypothesis." As shown in Table 8, trading activities of DOWN, $DOWN_{+1}$ and $DOWN_{+2}$ subgroups from day 1 to day 5 decrease, reflecting investors' regaining rational behavior after a dramatic price drop, and this does not necessarily mean abnormal trading activities pushed by the lower limit.

Table 8. The Result of Trading Interference Hypothesis: Lower Limit

| Day | DOWN | | | Significance | | | | | $DOWN_{+1}$ | | | Significance | | | | | $DOWN_{+2}$ | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE | High EPS | | | | | | Whole Samples | High ROE | High EPS | | | | | | Whole Samples | High ROE | High EPS | | |
| | | Low ROE | Low EPS | | | | | | | Low ROE | Low EPS | | | | | | | Low ROE | Low EPS | | |
| -4 | 0.8070 | -1.1626 | -1.3649 | | | | | | -0.5855 | 2.6103 | 0.8549 | | | | | | 0.9169 | 2.5287 | 4.0633 | ﹀ | ﹀ |
| | | 2.3543 | 2.1864 | | | | | | | -1.7146 | -1.6558 | | | | | | | -3.6982 | -4.9056 | | |
| -3 | 2.5264 | 4.0130 | 4.4173 | | | | ﹀ | ﹀ | 0.5468 | -1.7195 | -0.0238 | | | | | | 0.0086 | -2.7627 | -1.0178 | | |
| | | -0.1022 | -0.0699 | | | | | | | 3.3697 | 3.7658 | | | | | | | -0.1815 | -1.1192 | | |
| -2 | 3.2645 | 3.2040 | 3.2270 | | | | | | 0.5798 | -1.2906 | -0.3037 | | | | | | 0.8495 | -1.6495 | -2.9939 | | |
| | | 4.2629 | 4.3747 | | | | | | | -1.1910 | -1.9462 | | | | | | | 0.4526 | 1.2447 | | |
| -1 | -1.7608 | -3.5162 | -3.5491 | << | | | | | 3.7937 | 2.6942 | 0.9182 | | | | | | 3.4336 | 3.5501 | 2.4940 | | |
| | | -0.0525 | -0.0950 | | | | | | | 3.4027 | 3.8948 | | | | | | | 6.2885 | 6.2993 | | |
| 0 | 15.5511 | 16.9104 | 17.4703 | >> | >> | | | | 6.1916 | 9.1025 | 12.0393 | | | | | | 3.3383 | 10.0906 | 12.9897 | | ﹀ |
| | | 14.9238 | 14.1565 | | >> | >> | | | | 6.9015 | 6.2339 | | | | | | | 2.6676 | 1.6538 | | |
| 1 | -19.6315 | -18.5278 | -19.0461 | | | | | | -19.5642 | -18.9430 | -20.9416 | | | | | | -17.7225 | -20.8270 | -21.4571 | | |
| | | -20.1382 | -19.8716 | | | | | | | -18.3121 | -19.0877 | | | | | | | -17.9319 | -18.4527 | | |
| 2 | -2.2232 | -3.6447 | -4.3590 | << | < | | | | 2.2480 | 0.0389 | -0.3147 | | | | | | 2.9726 | -0.2603 | -0.6012 | ﹀ | ﹀ |
| | | -1.7498 | -1.9843 | | | < | | | | 2.6768 | 3.3895 | | | | | | | 9.1149 | 9.2372 | | |
| 3 | -2.7338 | -4.3961 | -5.1337 | | | | | | -2.1781 | -4.8978 | -5.0246 | | | | | | -1.6986 | 0.5823 | 1.9429 | | |
| | | -3.1389 | -2.9861 | | | | | | | -1.1234 | -1.3503 | | | | | | | -4.1773 | -5.1268 | | |
| 4 | -5.0816 | -5.0595 | -3.9763 | << | | < | | | 1.8269 | 4.7861 | 3.6634 | | | | | | 0.6333 | 1.9192 | 1.3054 | | |
| | | -5.5960 | -4.8288 | | < | | | | | 1.5693 | 1.1576 | | | | | | | 2.3118 | 2.0581 | | |
| 5 | 1.3879 | 1.8799 | 1.6532 | >> | >> | | | | -2.3371 | -2.2853 | -2.0271 | | | | | | -0.1649 | 1.4596 | 0.9045 | | |
| | | 2.0812 | 1.9412 | | > | >> | | | | -4.5618 | -5.0045 | | | | | | | 0.3726 | -0.2217 | | |

Note) >> and > signify that the trading activity of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the trading activity of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ⩾ and ﹀ signify that the trading activity of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ⩽ and ﹀ signify that the trading activity of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

## 3.4 Empirical Results of Disturbed Stock Valuation Hypothesis

### 3.4.1 Upper Limit

The disturbed stock valuation hypothesis claims that the price limits influence in-

vestors' judgment on the fair price of those stocks in their portfolios, implying that when their stock prices hit an upper (lower) limits, the investors are likely to hold a more optimistic (pessimistic) view on stocks that hit the upper limit (lower limit). Table 9 illustrates the influence of the upper limit on stock valuation. It indicates that for the "whole" samples, the inconsistency of investors' perception of fair price for the UP subgroup on day 0 is significantly greater than that of the $UP_{-1}$ subgroup, and the inconsistency of investors' perception of fair price for the $UP_{-1}$ subgroup on day 0 is significantly greater than that of the $UP_{-2}$ subgroup.[13] This evidence ascertains the discrepancy in investors' views on fair prices for stocks that hit their upper limits. Table 9 shows that the inconsistency of fair price perception of the UP subgroup on day 1 (5.1733) is lower than on day 0 (6.0578), yet the same trend is also found in the $UP_{-1}$ and $UP_{-2}$ subgroups (from 6.1036 and 5.5090 to 4.7564 and 4.4795). The inconsistency of fair price perception of the UP subgroup on day 1 is also significantly greater than that of $UP_{-1}$ and $UP_{-2}$ subgroups on day 1 indicating that although the upper limit attributes to a significant reduction of inconsistency in stock valuation of those that hit their upper limit on day 1, investors' expectation does go up when their stocks hit the upper limits.

It is important to note that when comparing the inconsistency of stock valuation before and after a trading day when an upper limit is hit, this study finds that according to the "whole" samples in Table 9, the inconsistency in fair price perception of UP subgroup from day 1 to day 9 is significantly larger than that of the $UP_{-1}$ subgroup. Before day 0, the inconsistency in the UP subgroup is only significantly greater than that of the $UP_{-1}$ subgroup on day -6, -4, -3, -2, and -1, indicating that the inconsistency in the UP subgroup greater than the $UP_{-1}$ subgroup is not caused by the original price behavior. Maximum allowable upward movement motivates investors to change their perception of a fair price of stocks that hit the upper limit, and perception discrepancy is more often observed in stocks that hit an upper limit than those that do not. In addition, the "whole" samples in Table 9 also illustrates that except for day -8, the fair price inconsistency of the $UP_{-1}$ subgroup is significantly greater than that of the $UP_{-2}$ subgroup. This shows that investors do not change their

13) Although the mean of inconsistency of fair price perception for UP subgroup in Table 8 on day 0 (6.0578) is smaller than that of the $UP_{-1}$ subgroup on day 0 (6.1036), the result of Mann-Whitney U Test (i.e., rank test of nonparametric statistics) indicated that the inconsistency of fair price perception for UP subgroup on day 0 is significantly greater than that of $UP_{-1}$ subgroup on day 0.

Table 9. The Result of Disturbed Stock Valuation Hypothesis: Upper Limit

| Day | UP | | | Significance | | | | | UP-1 | | | Significance | | | | | UP-2 | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE | High EPS | | | | | | Whole Samples | High ROE | High EPS | | | | | | Whole Samples | High ROE | High EPS | | |
| | | Low ROE | Low EPS | | | | | | | Low ROE | Low EPS | | | | | | | Low ROE | Low EPS | | |
| -10 | 4.3042 | 4.1584 | 4.1157 | | | | ≪ | ≪ | 4.3144 | 4.2356 | 4.0973 | >> | | | ≪ | ≪ | 4.1501 | 4.1149 | 4.0449 | ≪ | ≪ |
| | | 4.3997 | 4.4144 | | | | | | | 4.5763 | 4.5460 | | | | | | | 4.4150 | 4.4825 | | |
| -9 | 4.2120 | 4.1028 | 4.0571 | | | | ≪ | ≪ | 4.2043 | 4.1890 | 4.0395 | >> | | | < | ≪ | 4.0883 | 3.9909 | 3.9188 | ≪ | ≪ |
| | | 4.3454 | 4.3452 | | | | | | | 4.3891 | 4.3696 | | | | | | | 4.3775 | 4.4222 | | |
| -8 | 4.1293 | 3.9433 | 3.9327 | | | | ≪ | ≪ | 4.1972 | 4.0865 | 3.9910 | | | | ≪ | ≪ | 4.1122 | 4.0907 | 4.0222 | ≪ | ≪ |
| | | 4.2912 | 4.2936 | | | | | | | 4.3898 | 4.3566 | | | | | | | 4.4466 | 4.5049 | | |
| -7 | 4.2063 | 4.0184 | 3.9773 | | | | ≪ | ≪ | 4.2317 | 4.1802 | 4.0646 | >> | | | | < | 4.0710 | 4.0394 | 3.9529 | ≪ | ≪ |
| | | 4.3950 | 4.3998 | | | | | | | 4.3476 | 4.3494 | | | | | | | 4.3012 | 4.3319 | | |
| -6 | 4.3104 | 4.2185 | 4.2319 | > | | | < | ≪ | 4.2139 | 4.1988 | 4.0564 | >> | >> | > | | ≪ | 4.0865 | 3.9785 | 3.8850 | ≪ | ≪ |
| | | 4.3598 | 4.3842 | | | | | | | 4.3833 | 4.3769 | | | | | | | 4.3331 | 4.3969 | | |
| -5 | 4.2800 | 4.1591 | 4.1461 | | | | ≪ | ≪ | 4.2752 | 4.2523 | 4.1654 | >> | >> | >> | < | < | 4.1148 | 3.9681 | 3.8936 | ≪ | ≪ |
| | | 4.4322 | 4.4391 | | | | | | | 4.5461 | 4.4943 | | | | | | | 4.4822 | 4.5142 | | |
| -4 | 4.3231 | 4.2900 | 4.2653 | >> | >> | > | | < | 4.2143 | 4.0570 | 4.0398 | >> | > | >> | ≪ | ≪ | 4.0852 | 3.8989 | 3.8106 | ≪ | ≪ |
| | | 4.4290 | 4.4406 | | | | | | | 4.4026 | 4.4294 | | | | | | | 4.3181 | 4.3206 | | |
| -3 | 4.3935 | 4.3581 | 4.3320 | >> | | > | < | ≪ | 4.2806 | 4.2194 | 4.1245 | >> | >> | >> | < | ≪ | 4.1158 | 3.8255 | 3.7712 | ≪ | ≪ |
| | | 4.4800 | 4.5028 | | | | | | | 4.5388 | 4.4849 | | | | | | | 4.3569 | 4.3960 | | |
| -2 | 4.4574 | 4.3910 | 4.3918 | >> | > | >> | | | 4.3247 | 4.1201 | 4.0901 | > | | > | ≪ | ≪ | 4.2394 | 4.0653 | 3.9617 | ≪ | ≪ |
| | | 4.4979 | 4.5162 | | | | | | | 4.5303 | 4.5477 | | | | | | | 4.5746 | 4.6356 | | |
| -1 | 4.4657 | 4.4261 | 4.4120 | > | | > | | < | 4.3887 | 4.3133 | 4.2412 | >> | >> | >> | < | ≪ | 4.2398 | 4.0594 | 3.8825 | ≪ | ≪ |
| | | 4.5255 | 4.5422 | | | | | | | 4.5221 | 4.5016 | | | | | | | 4.4925 | 4.4876 | | |
| 0 | 6.0578 | 5.9168 | 5.9251 | >> | >> | >> | ≪ | ≪ | 6.1036 | 5.8947 | 5.7528 | >> | >> | >> | ≪ | ≪ | 5.5090 | 5.2188 | 5.1566 | ≪ | ≪ |
| | | 6.2395 | 6.2259 | | | | | | | 6.3445 | 6.3135 | | >> | >> | | | | 5.7278 | 5.7723 | | |
| 1 | 5.1733 | 5.0297 | 4.9830 | >> | >> | >> | ≪ | ≪ | 4.7564 | 4.6252 | 4.4934 | >> | >> | >> | ≪ | ≪ | 4.4795 | 4.3120 | 4.2396 | ≪ | ≪ |
| | | 5.3534 | 5.3729 | | >> | >> | | | | 5.0178 | 5.0019 | | >> | >> | | | | 4.8007 | 4.8131 | | |
| 2 | 4.5635 | 4.5037 | 4.4759 | >> | >> | >> | < | ≪ | 4.4444 | 4.3197 | 4.0935 | >> | > | | | ≪ | 4.2054 | 4.1420 | 4.0259 | ≪ | ≪ |
| | | 4.6296 | 4.6541 | | > | > | | | | 4.4973 | 4.5206 | | | | | | | 4.4415 | 4.4824 | | |
| 3 | 4.6170 | 4.5466 | 4.5409 | >> | > | >> | ≪ | ≪ | 4.3949 | 4.3484 | 4.2083 | >> | | | | < | 4.2286 | 4.2024 | 4.1214 | ≪ | ≪ |
| | | 4.6872 | 4.6989 | | >> | >> | | | | 4.3909 | 4.3918 | | | | | | | 4.4512 | 4.5068 | | |
| 4 | 4.3928 | 4.2811 | 4.3006 | >> | > | >> | ≪ | ≪ | 4.2816 | 4.1399 | 4.0896 | >> | | | < | ≪ | 4.1114 | 4.0479 | 3.9563 | ≪ | ≪ |
| | | 4.4775 | 4.4889 | | > | >> | | | | 4.3218 | 4.3012 | | | | | | | 4.3528 | 4.3763 | | |
| 5 | 4.4250 | 4.3680 | 4.3896 | >> | > | >> | | | 4.3744 | 4.2810 | 4.2048 | >> | >> | >> | | < | 4.1327 | 3.9547 | 3.8950 | ≪ | ≪ |
| | | 4.4651 | 4.4854 | | | | | | | 4.5000 | 4.4723 | | | | | | | 4.4555 | 4.4800 | | |
| 6 | 4.4110 | 4.2450 | 4.2300 | >> | > | >> | ≪ | ≪ | 4.2830 | 4.0800 | 4.0170 | >> | | > | < | ≪ | 4.1020 | 3.9890 | 3.8450 | ≪ | ≪ |
| | | 4.5090 | 4.5450 | | | >> | | | | 4.3830 | 4.3500 | | | | | | | 4.3630 | 4.3310 | | |
| 7 | 4.3062 | 4.1132 | 4.1113 | >> | > | >> | ≪ | ≪ | 4.1854 | 3.9477 | 3.8235 | >> | | | ≪ | ≪ | 4.0331 | 3.8300 | 3.7814 | ≪ | ≪ |
| | | 4.4257 | 4.4208 | | | | | | | 4.4587 | 4.4518 | | | | | | | 4.3657 | 4.3647 | | |
| 8 | 4.2837 | 4.1218 | 4.0900 | >> | > | >> | ≪ | ≪ | 4.1216 | 3.9517 | 3.9092 | >> | > | | ≪ | ≪ | 4.0380 | 3.7883 | 3.7737 | ≪ | ≪ |
| | | 4.4628 | 4.4556 | | | | | | | 4.3838 | 4.3562 | | | | | | | 4.3683 | 4.3231 | | |
| 9 | 4.3733 | 4.2311 | 4.2037 | >> | > | >> | ≪ | ≪ | 4.1968 | 4.0322 | 3.9358 | >> | | | ≪ | ≪ | 4.0428 | 3.9320 | 3.8488 | ≪ | ≪ |
| | | 4.5024 | 4.5367 | | > | > | | | | 4.3569 | 4.3456 | | | | | | | 4.4106 | 4.4013 | | |
| 10 | 4.3338 | 4.2101 | 4.1892 | | | > | ≪ | ≪ | 4.2562 | 4.0838 | 3.9739 | >> | > | > | ≪ | ≪ | 4.0275 | 3.8848 | 3.8330 | ≪ | ≪ |
| | | 4.4293 | 4.4448 | | | | | | | 4.4707 | 4.4627 | | > | | | | | 4.2752 | 4.3316 | | |

Note) >> and > signify that the inconsistency of fair price perception of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the inconsistency of fair price perception of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ≫ and ﹀ signify that the inconsistency of fair price perception of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ≪ and ﹤ signify that the inconsistency of fair price perception of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

outlook on stocks which do not hit thier upper limits before and after day 0. The price behavior of the $UP_{-1}$ and $UP_{-2}$ subgroups stay consistent before and after the upper limit is hit, proving that the upper limit only disturbs the consistency of stock valuations of the UP subgroup.

This study concludes that the upper limit fails to guide investors to rationally valuate fair stock prices; on the contrary, the upper limits stir investors' rational judgment of fair prices, creating more noise traders in the market. This supports the disturbed stock valuation hypothesis. The inconsistency of fair price perception on day 1 declines more dramatically than that on day 0, which seems to be an inevitable outcome after the dramatic change of the stock price that hits its upper limit on day 0; this is not out of the influence of the upper limit.

### 3.4.2 Lower Limit

This study also addresses the influence of lower limit on the fair price perception. Table 10 illustrates the result of lower limits; three subgroups are shown to have significantly decreased inconsistency in fair price perception on day 1 than that on day 0. This is influenced by the dramatic price changes in sample stocks on day 0, not because of the lower limit. It should be noted that the inconsistency in fair price perception of the DOWN subgroup on day 0 is significantly less than that of the $DOWN_{+1}$ subgroup on day 0 because this indicates that the lower limit does not seem to disturb the investors' valuation of stocks which hit their lower limits. However, the above presumption is not accurate because on the day of reaching a lower limit, the price change is completely in control and it is most likely that the range of transaction prices on day 0 would be lower than those that do not arrive at the lower limit. Thus, the findings may be resulted from the trading system, not the influence of the lower limit on the investors' valuation of stocks.

According to Table 10, the inconsistency in fair price perception of the $DOWN_{+1}$ subgroup is significantly greater than that of the $DOWN_{+2}$ subgroup before (on day -9, -5, -3, and -1) and after (on day 0, 1, 2, 3, 5, 6, 7, and 8) reaching the lower limit. The finding indicates that there is no significant change in investors' perception of the $DOWN_{+1}$ and $DOWN_{+2}$ subgroups before and after realizing the lower limit, and investors do not change their valuation of stocks the in $DOWN_{+1}$ and $DOWN_{+2}$ subgroups. Significant differences are found in the observations of inconsistency of fair price perception for DOWN and $DOWN_{+1}$ subgroups before and after hitting the lower

Table 10. The Result of Disturbed Stock Valuation Hypothesis: Lower Limit

| Day | DOWN | | | Significance | | | | | $DOWN_{+1}$ | | | Significance | | | | | $DOWN_{+2}$ | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | | | | | Whole Samples | High ROE / Low ROE | High EPS / Low EPS | | |
| -10 | 4.2837 | 4.2880 | 4.2949 | > | | | | | 4.2049 | 4.2920 | 4.2147 | | > | >> | ﹀ | | 4.1226 | 3.9187 | 3.7278 | | ⌃⌃ |
| | | 4.3309 | 4.3426 | | >> | >> | | | | 4.0178 | 4.0726 | | | | | | | 4.1164 | 4.2288 | | |
| -9 | 4.1564 | 4.1495 | 4.1441 | | | > | | | 4.2022 | 4.0889 | 3.9020 | > | > | > | | | 4.0851 | 3.8468 | 3.6577 | | ⌃⌃ |
| | | 4.1249 | 4.1500 | | | | | | | 4.1300 | 4.1475 | | | | | | | 3.9806 | 4.1087 | | |
| -8 | 4.3103 | 4.3492 | 4.3919 | | >> | >> | ﹀ | ﹀ | 4.2716 | 4.0575 | 4.0155 | | | | | | 4.2310 | 4.0234 | 3.9010 | | ⌃⌃ |
| | | 4.2256 | 4.2333 | | | | | | | 4.2252 | 4.2235 | | | | | | | 4.0194 | 4.0895 | | |
| -7 | 4.2603 | 4.2612 | 4.2524 | | | > | | | 4.2569 | 4.1687 | 4.1050 | | | | | | 4.1318 | 4.0381 | 3.8748 | | |
| | | 4.2173 | 4.2300 | | | | | | | 4.0746 | 4.0887 | | | | | | | 3.9462 | 4.0798 | | |
| -6 | 4.2132 | 4.2847 | 4.2618 | | >> | >> | ﹀ | | 4.2494 | 3.8963 | 3.8277 | | | | | | 4.2476 | 4.0030 | 3.7910 | ⌃ | ⌃⌃ |
| | | 4.2155 | 4.2226 | | | > | | | | 4.0335 | 4.0312 | | < | < | | | | 4.2696 | 4.3506 | | |
| -5 | 4.4369 | 4.4221 | 4.4385 | | | >> | | | 4.3647 | 4.2273 | 4.1233 | > | | > | | ⌃ | 4.2119 | 4.0722 | 3.8823 | | ⌃⌃ |
| | | 4.4499 | 4.4570 | | | | | | | 4.3325 | 4.3700 | | > | | | | | 4.0074 | 4.1171 | | |
| -4 | 4.1465 | 4.1282 | 4.1447 | << | | | | | 4.3206 | 4.1536 | 4.0260 | | | | | ⌃ | 4.2192 | 4.1263 | 3.9494 | | ⌃ |
| | | 4.2131 | 4.2167 | | | | | | | 4.2924 | 4.3105 | | | | | | | 4.2144 | 4.2347 | | |
| -3 | 4.3996 | 4.4153 | 4.4216 | > | | >> | | | 4.3660 | 4.3158 | 4.1648 | > | > | > | | | 4.2402 | 3.9744 | 3.8571 | | ⌃⌃ |
| | | 4.4558 | 4.4535 | | | | | | | 4.3419 | 4.3623 | | | | | | | 4.2545 | 4.2543 | | |
| -2 | 4.3881 | 4.4299 | 4.4380 | | > | >> | | | 4.4181 | 4.2405 | 4.1371 | | | > | | ⌃ | 4.3011 | 4.0657 | 3.9260 | ⌃ | ⌃⌃ |
| | | 4.3842 | 4.3946 | | | | | | | 4.4708 | 4.4003 | | | | | | | 4.2931 | 4.3360 | | |
| -1 | 4.5207 | 4.4739 | 4.4522 | << | | | | | 4.7217 | 4.5875 | 4.3734 | >> | >> | >> | | ⌃⌃ | 4.4931 | 4.1552 | 3.9767 | ⌃⌃ | ⌃⌃ |
| | | 4.5522 | 4.5679 | | | | | | | 4.7150 | 4.6885 | | | | | | | 4.5004 | 4.5326 | | |
| 0 | 6.2994 | 6.2384 | 6.1730 | << | | | ⌃⌃ | ⌃⌃ | 6.6380 | 6.2835 | 6.2172 | >> | >> | >> | ⌃⌃ | ⌃⌃ | 6.1845 | 5.8953 | 5.7675 | ⌃⌃ | ⌃⌃ |
| | | 6.4847 | 6.4736 | | | | | | | 6.7502 | 6.7782 | | >> | >> | | | | 6.3048 | 6.3378 | | |
| 1 | 5.2082 | 5.2672 | 5.2819 | >> | >> | >> | | | 4.6489 | 4.4560 | 4.2700 | >> | | | | ⌃ | 4.4722 | 4.3541 | 4.1942 | | ⌃⌃ |
| | | 5.2441 | 5.2373 | | >> | >> | | | | 4.6974 | 4.6783 | | | | | | | 4.4800 | 4.5266 | | |
| 2 | 4.6615 | 4.6705 | 4.6391 | >> | >> | >> | | | 4.4471 | 4.1684 | 4.0499 | >> | | | | ⌃ | 4.3532 | 4.1679 | 4.0462 | ⌃ | ⌃⌃ |
| | | 4.6979 | 4.7105 | | >> | >> | | | | 4.3530 | 4.3303 | | | | | | | 4.3233 | 4.3419 | | |
| 3 | 4.4275 | 4.3750 | 4.3689 | > | >> | >> | ⌃ | ⌃ | 4.3714 | 4.0477 | 4.0257 | > | | | ⌃ | ⌃ | 4.2556 | 4.0578 | 4.0133 | | ⌃ |
| | | 4.5353 | 4.5291 | | >> | >> | | | | 4.2886 | 4.2966 | | | | | | | 4.1727 | 4.2261 | | |
| 4 | 4.3170 | 4.3002 | 4.2611 | < | | | | | 4.4251 | 4.1991 | 4.1703 | | | | ⌃ | ⌃ | 4.3391 | 4.1520 | 4.1086 | | ⌃ |
| | | 4.3713 | 4.3824 | | | | | | | 4.4369 | 4.4337 | | | | | | | 4.3696 | 4.3583 | | |
| 5 | 4.3184 | 4.2976 | 4.2955 | > | >> | >> | | | 4.2109 | 4.0069 | 3.9210 | > | | | ⌃ | ⌃⌃ | 4.0978 | 3.9501 | 3.8986 | | ⌃ |
| | | 4.3508 | 4.3377 | | | | | | | 4.2344 | 4.2135 | | | | | | | 4.1273 | 4.1316 | | |
| 6 | 4.4180 | 4.3600 | 4.3300 | >> | >> | >> | | ⌃ | 4.2670 | 4.0020 | 3.7570 | > | | < | ⌃⌃ | ⌃⌃ | 4.1550 | 4.1180 | 4.0110 | | ⌃ |
| | | 4.4790 | 4.4790 | | | | | | | 4.3110 | 4.3230 | | | | | | | 4.1650 | 4.2580 | | |
| 7 | 4.2400 | 4.1788 | 4.1440 | | | > | | | 4.3166 | 4.1083 | 3.9633 | > | | | | ⌃⌃ | 4.2466 | 3.9949 | 3.9203 | ⌃⌃ | ⌃⌃ |
| | | 4.2446 | 4.2548 | | | | | | | 4.2520 | 4.3207 | | | | | | | 4.3139 | 4.3195 | | |
| 8 | 4.3111 | 4.2759 | 4.2685 | | >> | >> | | | 4.3553 | 4.1527 | 4.0817 | >> | | | ⌃ | ⌃⌃ | 4.1967 | 3.9980 | 3.9055 | ⌃⌃ | ⌃⌃ |
| | | 4.3602 | 4.3675 | | | | | | | 4.3749 | 4.3846 | | | | | | | 4.2958 | 4.3016 | | |
| 9 | 4.3395 | 4.3506 | 4.3215 | >> | >> | >> | | | 4.1694 | 3.9103 | 3.6905 | | | < | ⌃ | ⌃⌃ | 4.1027 | 4.0637 | 3.9379 | | |
| | | 4.3202 | 4.3321 | | | > | | | | 4.1473 | 4.1343 | | | | | | | 4.1010 | 4.1183 | | |
| 10 | 4.2969 | 4.2132 | 4.1763 | >> | >> | >> | ⌃ | ⌃⌃ | 4.1833 | 3.9291 | 3.8053 | | | | ⌃ | ⌃⌃ | 4.1024 | 3.9887 | 3.8616 | | ⌃⌃ |
| | | 4.4040 | 4.4036 | | > | > | | | | 4.1704 | 4.1807 | | | | | | | 4.1600 | 4.2380 | | |

Note) >> and > signify that the inconsistency of fair price perception of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the inconsistency of fair price perception of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; ﹀﹀ and ﹀ signify that the inconsistency of fair price perception of subgroup on the top is greater than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively; ⌃⌃ and ⌃ signify that the inconsistency of fair price perception of subgroup on the top is less than that of subgroup on the bottom at the 0.01 and 0.05 levels of significance, respectively.

limit. After the lower limit is hit, the inconsistency of fair price perception of DOWN subgroup is significantly greater than that of the $DOWN_{+1}$ subgroup on day 1, 2, 3, 5, 6, 9, and 10. But before the lower limit is hit, the DOWN subgroup only has significantly greater inconsistency than the $DOWN_{+1}$ subgroup does on day -10 and day -3, and the DOWN subgroup has significantly less inconsistency in fair price perception than the $DOWN_{+1}$ subgroup does on day -4 and day -1. These results lead to the conclusion that the extensive inconsistency of stock valuation among investors is, in fact, caused by the lower limit.

In short, the empirical result of "whole" samples indicates that the lower limit interferes with the stock valuation of investors. For those stocks that hit their lower limits, the inconsistency of fair price perception is significantly greater than that of stocks that do not. This is more likely to be influenced by the anchoring effect. After a stock price hits its lower limit, some investors anchor on a price at a lower limit and hold more pessimistic outlooks on the future price performance; this changes the investors' initial perception, causing a wider range of transaction prices.

# 4. The Influence of Fundamentals on Price Limit Performance

According to the fundamental analysis, the stock price of a certain firm that deviates from its equilibrium price in the short run will eventually return to the equilibrium price in the long run. But for firms with different fundamentals, there may be different speed of adjustment to the equilibrium prices, and they may respond differently to positive and negative information shocks. At present, in the Taiwan Stock Exchange, the limit of ±7% of previous trading day's closing price is imposed on the maximum allowable price movement of today's transaction price. It is likely to cause different performance of price limit for stocks with different fundamentals. To examine the validity of this assumption, this study conducts the analysis of the impacts of fundamentals on price limit performance.

## 4.1 The Impact of Fundamentals on the Stock Price Volatility

In terms of the influence of fundamentals on the volatility spillover of stocks which hit the upper limit, we find that in Table 3 except for day 0, the three subgroups of samples clearly show lower volatility of firms with better fundamentals (high ROE

firms and high EPS firms) than that of firms with worse fundamentals (low ROE firms and low EPS firms), indicating the existence of higher volatility of firms with worse fundamentals resulting from the existence of more non-rational investors. On the other hand, the volatility of firms with different fundamentals on day 1 demonstrates that except for those with high EPS, the volatility of high ROE firms, low ROE firms, and low EPS firms of the UP subgroup on day 1 is significantly lower than that of high ROE firms, low ROE firms, and low EPS firms of $UP_{-1}$ subgroups, but this is not observed between the $UP_{-1}$ and $UP_{-2}$ subgroups. Thus, although previous studies suggest that a decreased volatility is an inevitable result on day 1, the upper limit results in significantly lower volatility of UP subgroups than that of $UP_{-1}$ and $UP_{-2}$ subgroups on day 1, and this has been proved more obvious on firms with worse fundamentals.

It is interesting that although the empirical result of the "whole" samples does not support the volatility spillover hypothesis, we find that the volatility of high EPS firms of the UP subgroup does generate the volatility spillover phenomena after the upper limit is hit. According to Table 3, high EPS firms of the UP subgroup has significantly higher volatility than that of high EPS firms of the $UP_{-1}$ subgroup on day 2, 4, 7, 8, and 9, but after the upper limit is hit, there is no significant difference found between the $UP_{-1}$ and $UP_{-2}$ subgroups samples with high EPS and before the upper limit is hit. High EPS firms of UP subgroup has only significantly higher volatility than that of high EPS firms of $UP_{-1}$ subgroup on day -2 and day -5. This result suggests that an upper limit enables firms with high EPS to generate a significant increase of volatility after the day when an upper limit is hit, and the Taiwan Stock Exchange does not impose uniform price limits on all firms. Because firms with better fundamentals need to have more freedom to respond to positive information shocks, when an existing seven percent upper limit is imposed, the volatility spillover effect will be generated.

With regards to the influence of fundamentals on the volatility spillover of stocks which hit their lower limits, we find that in Table 4, DOWN subgroup samples with better and worse fundamentals have higher volatility than $DOWN_{+1}$ with better and worse fundamentals before and after the day when the lower price limit is hit, so this higher volatility results from the original trend of volatility not from the lower limit. It also indicates that the lower limit does not decrease the volatility of firms with different fundamentals, nor does it cause the volatility spillover in firms with different fundamentals.

In addition, empirical results on the lower price limit also show that the volatility of firms with better fundamentals is lower than that of those firms with worse fundamentals. Relative to the empirical results of the upper limit, the lower limit does not show a significant result (most trading days in Table 4 do not show statistically significant difference of volatility between firms with better and worse fundamentals), yet in Table 4, DOWN, $DOWN_{+1}$ and $DOWN_{+2}$ subgroups demonstrate the existence of higher stock price volatility for firms with worse fundamentals than those with better fundamentals (although it is statistically insignificant) before and after the lower limit is hit. This attests to the influence of an original volatility trend, not the influence of the lower limit. In sum, upper and lower limit results prove that the volatility of firms with worse fundamentals is higher than those with better fundamentals and that the difference in the volatility of firms with different fundamentals caused by the lower limit is less significant than that caused by the upper limit.

## 4.2 The Influence of Fundamentals on the Price Discovery Process

From the empirical results of Table 5 and 6, both research projects on stocks with better and worse fundamentals, no matter if there is an upper or lower limit, both support the delayed price discovery hypothesis (In both stocks with better or worse fundamentals, a significantly higher proportion of price continuation behavior was observed in UP (DOWN) subgroup than that of $UP_{-1}$ ($DOWN_{+1}$) and $UP_{-2}$ ($DOWN_{+2}$) subgroups and the proportion of price continuation behavior is found to have no statistically significant difference between $UP_{-1}$ ($DOWN_{+1}$) and $UP_{-2}$ ($DOWN_{+2}$) subgroups. That also indicates that both the upper and lower limits delay the efficient price discovery process. In addition, the empirical results on the upper and lower limits cannot exclude the domination of a maximum price variation rule in delayed price discovery. This result is also found in stocks with better and worse fundamentals.

In comparing stocks with different fundamentals that hit their upper limit, we find that in Table 5, among the UP subgroup samples, stocks with worse fundamentals have a significantly higher proportion of price continuation and significantly lower proportion of price reversal, but the situation is not prevalent among the $UP_{-1}$ subgroup samples and is not observed among the $UP_{-2}$ subgroup samples. This indicates that an upper limit obviously delays the efficient price discovery of stocks with worse fundamentals than it does for those with better fundamentals.

In the comparison of stocks with different fundamentals that hit their lower limits, we find that in Table 6, among the DOWN subgroup samples, stocks with worse fundamentals have a significantly higher proportion of price continuation than those with better fundamentals, but the proportion of price reversal is significantly lower, and this situation is not observed among the $DOWN_{+1}$ and $DOWN_{+2}$ subgroups samples. Thus, the empirical result of the influence of the lower limit on stocks with different fundamentals also proves that compared with stocks of better fundamental values, lower limit obviously supports the delayed price discovery hypothesis and triggers overreaction toward stocks with worse fundamentals.

In brief, the price limits exert more influence on stocks with worse fundamentals than they do on those stocks with better fundamentals, and this generates a higher price continuation proportion and lower price reversal proportion. Thus, for stocks that hit an upper or lower limit (especially for those with worse fundamentals), higher investment performance will be achieved through the adoption of momentum strategy than contrarian strategy.

## 4.3 The Influence of Fundamentals on the Trading Activity

In terms of the influence of upper limit on the trading activities of stocks with different fundamentals, the empirical result of Table 7 indicates that stocks with better and worse fundamentals do not support the trading interference hypothesis and only proves that after the dramatic change in the UP, $UP_{-1}$ and $UP_{-2}$ subgroup samples on day 0, investor behavior returns to be rational and following trading activities, thus, decrease. Furthermore, the empirical result of the UP subgroup on day 0 also shows that stocks with worse fundamentals have a significantly higher trading activity than that of stocks with better fundamentals, but from day 1 to day 5, a decrease of turnover ratio in stocks with worse fundamentals is more significant than that of stocks with better fundamentals (where UP subgroup samples on day 3 shows that the change of turnover ratio of stocks with worse fundamentals is significantly smaller than that of stocks with better fundamentals). This implies that trading activities of stocks with worse fundamentals tend to be more active than those of stocks with better fundamentals when hitting an upper limit, but after that, fewer trading activities of stocks with worse fundamentals will occur.

In terms of the influence of the lower limit on the trading activities of stocks with

different fundamentals, the empirical result of Table 8 indicates that stocks with better or worse fundamentals do not support the trading interference hypothesis. On the other hand, the empirical result of the DOWN subgroup indicates that stocks with better fundamentals show increased trading activities on day 0 than those with worse fundamental values (although statistically insignificant). This empirical result demonstrates that when stocks with better fundamentals hit lower limit, their change of turnover ratio is greater than those with worse fundamentals. To conclude, the empirical results of stocks with different fundamentals on days when upper and lower limits are hit, we find stocks with worse fundamentals and those with better fundamentals have respective increased trading activities on the days when the upper and lower limits are hit, indicating that investors in the Taiwan Stock Exchange often make wrong decisions when a stock price hits its price limit: "they tend to purchase stocks with worse fundamentals and sell those with better fundamentals."

## 4.4 The Influence of Fundamentals on the Stock Valuation

In terms of the influence of fundamentals on the disturbed stock valuation hypothesis, we can observe in Table 9 that the inconsistency in fair perception of stocks with better fundamentals is smaller than that of stocks with worse fundamentals; firms with high ROE and high EPS among the $UP_{-2}$ subgroup have a significantly smaller inconsistency in fair price perception than firms with low ROE and EPS. This illustrates that a greater disturbance of stock valuation exists in firms with worse fundamentals in the Taiwan Stock Exchange. This may result from the trading behavior of noise traders that are commonly found in the trade of stocks with worse fundamentals. These investors do not rationally evaluate the intrinsic values of the stocks they trade, and such investors, thus, are more likely to hold an irrational perception on certain stocks' fair prices, easily influenced by the market trend.

The empirical result in Table 9 also illustrates that the firms with high ROEs in the UP subgroup have significantly greater inconsistency in fair price perception than the firms with high ROEs in the $UP_{-1}$ subgroup from day 0 to day 9; moreover, those firms with high EPS in the UP subgroup also have a significantly greater inconsistency in fair price perception than those in the $UP_{-1}$ subgroup from day 0 to day 10. However, this does not occur before the upper limit is hit. The high ROE firms in the UP subgroup have significantly greater inconsistency in fair price perception

than those in $UP_{-1}$ samples only on day -4 and day -2, and the high EPS firms in the UP subgroup had a significantly greater inconsistency in fair price perception than those in the $UP_{-1}$ subgroup only from day -4 to day -1. In addition, Table 9 indicates that before the upper limit is hit, the inconsistency in fair price perception of low EPS firms and low ROE firms in the UP subgroup is not significantly greater than that of low EPS firms and low ROE firms in the $UP_{-1}$ subgroup, but after the upper limit was hit, firms with worse fundamentals in the UP subgroup have a significantly greater inconsistency than that of firms with worse fundamentals in the $UP_{-1}$ subgroup. The results assert a greater disturbance in the stock valuation of firms with better or worse fundamentals after their stock prices hit their upper limits.

According to Table 10, before a lower limit is hit, the inconsistency in fair price perception of high ROE firms in the DOWN subgroup is significantly greater than that of low ROE firms in the DOWN subgroup on day -8 and day -6, and high EPS firms in the DOWN subgroup have a significantly greater inconsistency in fair price perception than that of low EPS firms in the DOWN subgroup on day -6. But after a lower limit is hit, high ROE firms in the DOWN subgroup show significantly less inconsistency in fair price perception than that of low ROE firms in the DOWN subgroup on day 0, 3, and 10, and the inconsistency of high EPS firms in the DOWN subgroup is significantly less than that of low EPS firms in the $DOWN_{+1}$ subgroups on day 0, 3, and 10. In addition, empirical results of the $DOWN_{+1}$ and $DOWN_{+2}$ subgroups in Table 10 indicate a significantly smaller inconsistency for stocks with better fundamentals than that for stocks with worse fundamentals (except for the result of the $DOWN_{+1}$ subgroup samples on day -10). The above results confirm that the lower limit disturbs the investors' evaluation of intrinsic values of firms with worse fundamentals more than it does for with the firms with better fundamentals. Although the lower limit brings about more deviated perception of investors on fair valuation of stock prices, the limit does have less influence on firms with better fundamentals than those with worse fundamentals.

The result in Table 10 also illustrates that firms with better or worse fundamentals in the DOWN subgroup mostly have a significantly greater inconsistency in fair price perception than those of the $DOWN_{+1}$ subgroup (where it is more obvious in those with better fundamentals). However, except for day 0, we do not find firms with better or worse fundamentals in the DOWN subgroup which have significantly greater inconsistency than those in the $DOWN_{+2}$ subgroup. This seems to indicate that the

evidences on the lower limit of both stocks with better and worse fundamentals in the DOWN subgroup support the disturbed stock valuation hypothesis.

# 5. Robust Analysis

## 5.1 The Result of Intraday data

This study adopts daily data to examine four hypotheses. However, in recent years, studies on circuit breakers have used intraday data in empirical analysis (for example: Christie, Corwin, and Harris, 2002; Chen, Chen, and Valerio, 2003; Abad and Pascual, 2007). Although Hou (2007) believed that the adoption of intraday data results in more serious microstructural problems and bid-ask bonuses, due to the direct influence of the circuit breaker mechanism on serial information of daily stock price, the adoption of intraday data increases the accuracy of the conclusions. In order to test the accuracy of the result of daily data, this study uses intraday data to examine four hypotheses and compare the differences in the results of daily data and intraday data.

For choosing the daily price limits of the same scale and the research period longer than that in previous literature, the daily price data of October 11, 1989 to September 26, 1999 (for a ten-year period of time, the price limits maintained at $\pm 7\%$ of the closing price on the previous day) is used for our empirical analysis. However, having difficulty in acquiring intraday price data from October 11, 1989 to September 26, 1999, this study uses intraday price data from the Taiwan Economic Journal Database from January 1, 1999 to September 30, 1999. We use methods proposed by Darrat, Rahman, and Zhong (2003) and Abad and Pascual (2007) to select trading price data at the interval of five minutes for empirical analysis. During the research period, the Taiwan Stock Exchange traded from 9:00 to 12:00 (currently, the trading time stars from 9:00 to 13:30), each day; therefore, we have 36 5-minute intraday data. In order to test four hypotheses, this study uses a research model similar to that of daily data. For the volatility spillover hypothesis, we assume price volatility of stock $i$ on a 5-minute interval $k$ as $V_{i,k}^{5m} = (r_{i,k}^{5m})^2 \times 10^3$, where $r_{i,t}^{5m}$ is 5-minute returns of stock $i$ on interval $k$. In addition, we also define the 5-minute interval when stock prices hit the price limits as interval 0. In the delayed price discovery hypothesis, we examine the symbol of $\ln(C_0^{5m} / O_o^{5m})$ and $\ln(O_1^{5m} / C_0^{5m})$, where $C_0^{5m}, O_0^{5m}$, and $O_1^{5m}$ are the

closing prices on interval 0, the opening price on interval 0, and the opening price on interval 1, respectively. For the trading interference hypothesis, we assume the percentage change of turnover rate of stock $i$ on interval $k$ as $TR_{i,k}^{5m} = \ln(TA_{i,k}^{5m} / TA_{i,k-1}^{5m}) \times 100$, where $TA_{i,k}^{5m}$ and $TA_{i,k-1}^{5m}$ are referred to as the turnover rate of stock $i$ on interval $k$ and $k$-1, respectively. In regards to the distributed stock valuation hypothesis, we assume the estimated value of inconsistency of fair price perception of stock $i$ on interval $k$ as $S_{i,k}^{5m} = [(H_{i,k}^{5m} - L_{i,k}^{5m}) / C_{i,k-1}^{5m}] \times 100$, where $(H_{i,k}^{5m} - L_{i,k}^{5m})$ is the range of transaction prices of stock $i$ on interval $k$.

Panel A of Table 11 shows the empirical result of the intraday data on the examination of the volatility spillover hypothesis where Panel A of Table 11 indicates that before the stock price hits its upper limit, the volatility of the UP subgroup on interval -5 and interval -1 is significantly higher than that of the $UP_{-1}$ subgroup, but 25 minutes after the stock price hit upper limit (interval 1 to 5), the UP subgroup has significantly lower volatility than $UP_{-1}$ subgroup does. Whether before or after the stock price hits its upper limit, the difference in volatility between the $UP_{-1}$ and $UP_{-2}$ subgroups is lower than that between the UP and $UP_{-1}$ subgroups. Furthermore, Panel A of Table 11 also shows a similar empirical result with the lower limit (although the volatility of the DOWN subgroup before the stock price hit lower limit is insignificantly different from that of the $DOWN_{+1}$ subgroup). What deserves our attention is the result of the intraday data possibly being contaminated by daily price limits and research design because of the daily maximum price variation. Stocks that hit upper (lower) limits cannot continuously increase (decrease) their prices on the same trading day. Therefore, we need to discuss the volatility a few days after a certain stock hitting its price limit. Panel A of Table 11 indicates that the volatility of the UP (DOWN) subgroup on interval 36, 72, and 108 is insignificantly different from that of the $UP_{-1}$ ($DOWN_{+1}$) subgroup. According to the result of intraday data, as above mentioned, upper and lower limits both effectively control the volatility of stock price and maintain the function of avoiding irrational behaviors. Compared with intraday data and daily data, we find the results of these two research projects not in support of the volatility spillover hypothesis, and the result of the intraday data is believed to demonstrate a better cool-off function of the price limit than that of the daily data.

Panel B of Table 11 also exhibits the empirical result of intraday data on the delayed price discovery hypothesis where the UP subgroup has a price continuity pro-

portion significantly smaller than that of the $UP_{-1}$ subgroup. The above result seems to lead to the conclusion that "the upper price limit does not support the delayed price discovery hypothesis." However, this conclusion sounds too hasty because the result may be contaminated by daily price limits and research design. Due to the influence of the daily maximum price variation, a stock that hits its upper (lower) limit at a certain 5-minute interval cannot increase (decrease) its price at the next interval on the same trading day. Thus, under the research design of intraday data on the delayed price discovery hypothesis, the price continuity proportion of UP (DOWN) subgroup is more likely to be lower than that of the $UP_{-1}$ ($DOWN_{+1}$) subgroup. In order to acquire more accurate conclusions regarding the delayed price discovery hypothesis, we find from the empirical results of the closing price of stocks hitting their upper (lower) limits on the 5-minute interval that the UP and DOWN subgroups hold a consistent price (that is, the stock price on the next 5-minute interval remains at upper and lower limits) at the respective proportions of 0.80 and 0.73, significantly larger than that of the $UP_{-1}$ (0.55) and $DOWN_{+1}$ (0.68) subgroups. The price reversal proportions of the UP and DOWN subgroups (0.14 and 0.21) are significantly smaller than those of the $UP_{-1}$ and $DOWN_{+1}$ subgroups (0.23 and 0.28). Therefore, the empirical result of intraday data is found to correspond to that of daily data; that is, stocks that hit their price limits on a certain interval are more likely to remain at the price of upper or lower limits and less likely to see a stock price reversal on the next interval. In short, the empirical result of intraday data supports the delayed price discovery hypothesis and proves that price limits have less control in making overreaction.

Panel C of Table 11 demonstrates the empirical result of intraday data in which before the stock price hits its upper (lower) limit, there is no significant statistical difference in trading volume between the UP (DOWN) subgroup and $UP_{-1}$ ($DOWN_{+1}$) subgroup, but after the stock price hits its upper (lower) limit, the UP subgroup on interval 2-5 has significantly smaller trading volume than that of the $UP_{-1}$ subgroup (the DOWN subgroup has significantly smaller trading volume than the $DOWN_{+1}$ subgroup has on interval 2). Furthermore, there is no significant statistical difference between the trading volume of the $UP_{-1}$ and $UP_{-2}$ ($DOWN_{+1}$ and $DOWN_{+1}$) subgroups after the stock price hits its upper (lower) limit. According to the intraday data, we find that after a stock price hits its price limit, its trading volume is smaller than the stock "that does not hit its price limit"; therefore, the price limits do not hinder normal trading activities. Comparing the empirical results of Table 7, Table 8, and Panel

C of Table 11, we conclude that the intraday data is less likely to support the trading interference hypothesis than the daily data.

Panel D of Table 11 indicates that the empirical result of intraday data on the disturbed stock valuation hypothesis in which before the stock price hits its upper (lower) limit, the inconsistency in fair price perception of the UP (DOWN) subgroup is insignificantly different from that of the $UP_{-1}$ ($DOWN_{+1}$) subgroup, but 25 minutes after the stock prices hit their upper (lower) limits, the UP subgroup on interval 1-5 has significantly lower levels of inconsistency than of the $UP_{-1}$ subgroup (the DOWN subgroup on interval 4 is at significantly lower levels of inconsistency than of the $DOWN_{+1}$ subgroup). This result seems prove that "price limits mitigate the inconsistency in fair price perception between buyers and sellers"; however, like the conclusion based on the intraday data on the volatility spillover hypothesis, this is a rushed conclusion because the above result may be contaminated by daily price limits and research design. According to the estimated value of inconsistency in fair price perception on different trading dates, the inconsistency in fair price perception of the UP (DOWN) subgroup on interval 36, 72, and 108 is insignificantly different from that of the $UP_{-1}$ ($DOWN_{+1}$) subgroup. Therefore, contrast to daily data, based on the intraday data we do not find a significant evidence that price limits enhance the inconsistency in fair price perception, but this conclusion does not contradict the disturbed stock valuation hypothesis.

## 5.2 Information Asymmetry Measure

This study aims to evaluate the performance of price limits in the Taiwan Stock Exchange through volatility, price behavior, trading activity, and perception on fair price, but in addition to these four hypotheses, price limits would affect the degree of information asymmetry between buyers and sellers. Earlier studies such as those of Glosten and Milgrom (1985) and Easley, Hvidkjaer and O'Hara (2002) find the existence of information asymmetry. From the perspective of information asymmetry between sellers and buyers, if the majority of market participants are informed traders, price limits may hinder the spreading of information related to quick response to stock prices, thereby intensifying information asymmetry. On the contrary, if major market participants are noise traders, then price limits help investors to determine fair prices. In order to further evaluate the performance of price limits, this study

adopts the method of Glosten and Milgrom to make use of a bid-ask spread to measure the degree of information asymmetry in the market. More importantly, the Taiwan Stock Exchange is an order-driven market, so this study uses a definition different from what Glosten and Milgrom propose for an information asymmetry measure. Glosten and Milgrom uses a bid-ask spread that belongs to a quote spread, and this study uses a bid-ask spread that belongs to an order spread.

Undoubtedly, gauging the perception of buyers and sellers on the fair pricing of a certain stock is one of the best ways to evaluate the performance of price limits. Both information asymmetry measure and disturbed stock valuation hypothesis aim to investigate the information asymmetry between buyers' and sellers' perception to the fundamentals of a certain stock. However, we will have a more complete picture of the fair price perception of buyers and sellers if the two analyses are presented separately. In contrast with the disturbed stock valuation hypothesis, applying the range of transaction prices to estimate the inconsistency of fair price perception, the information asymmetry measure, using the information of bid and ask prices is a more direct and comprehensive way to gauge the differences between buyers' and sellers' recognition. There is a notable psychological difference between the disturbed stock valuation hypothesis and the information asymmetry measure based on behavioral finance. From the view of self-interest, buyers tend to quote a lower bid price and sellers tend to quote a higher ask price for a certain stock than their real perception of fair price. In other words, buyers (sellers) may quote a tentative bid (ask) price for a certain stock before quoting a real price that they are willing to trade in. Therefore, although the disturbed stock valuation hypothesis, using the price which both buyers and sellers agree to trade in is more cautious than the information asymmetry measure for the difference in investors' perception, the range of transaction prices can avoid the adverse impact of tentative quotes on the bid-ask spread measure, especially for the stocks with lower liquidity. Because the relationship between the disturbed stock valuation hypothesis and the information asymmetry measure is complementary, this study applies the two analyses to get more accurate results to bettern understand buyers' and sellers' perception on fair pricing of hit-limit stocks.[14)]

14) In previous literature, studies employing respectively bid-ask spread and transaction prices were found. Park and Krishnamurti (1995) compared the difference between the variance of closing-transaction-price returns and the variance of average-of-bid-ask-price returns. Battalio (1997) utilized the difference between the transaction price and midpoint of bid-ask spread as the trading cost. Bae, Chan, and Cheung (1998) used respectively real-time transaction prices and bid-ask quotes to examine the profitability of index futures arbitrage.

Table 11. The Result of Intraday Data and Information Asymmetry Measure

| Interval (Price Behavior) | UP / DOWN | Significance | UP-1 / DOWN+1 | Significance | UP-2 / DOWN+2 |
|---|---|---|---|---|---|
| Panel A: The Result of Intraday Data of Volatility Spillover Hypothesis | | | | | |
| -5 | 0.0911 | > | 0.0314 | | 0.0483 |
| | 0.0340 | | 0.0353 | | 0.0362 |
| -4 | 0.0574 | | 0.0402 | | 0.0365 |
| | 0.0308 | | 0.0347 | | 0.0332 |
| -3 | 0.0529 | | 0.0387 | | 0.0429 |
| | 0.0364 | | 0.0411 | | 0.0510 |
| -2 | 0.0487 | | 0.0462 | | 0.0336 |
| | 0.0379 | | 0.0506 | | 0.0462 |
| -1 | 0.1134 | >> | 0.0768 | | 0.0818 |
| | 0.0978 | | 0.0965 | | 0.0706 |
| 0 | 0.4971 | >> | 0.3521 | | 0.3073 |
| | 0.6420 | | 0.5649 | | 0.4709 |
| 1 | 0.0732 | < | 0.1524 | | 0.0611 |
| | 0.2102 | | 0.1256 | | 0.1902 |
| 2 | 0.0561 | << | 0.0715 | | 0.0550 |
| | 0.1330 | << | 0.1704 | | 0.1307 |
| 3 | 0.0524 | << | 0.0603 | | 0.0577 |
| | 0.0945 | << | 0.1408 | | 0.2258 |
| 4 | 0.0460 | << | 0.0726 | | 0.0322 |
| | 0.1200 | | 0.0792 | | 0.0485 |
| 5 | 0.0346 | << | 0.0380 | | 0.0362 |
| | 0.0755 | << | 0.0665 | | 0.0534 |
| 36 | 0.0669 | | 0.0376 | > | 0.0463 |
| | 0.0741 | | 0.1031 | | 0.0543 |
| 72 | 0.0366 | | 0.0272 | | 0.0386 |
| | 0.0403 | | 0.0616 | | 0.0670 |
| 108 | 0.0328 | | 0.0391 | | 0.0288 |
| | 0.0351 | | 0.0352 | | 0.0378 |
| Panel B: The Result of Intraday Data of Delayed Price Discovery Hypothesis | | | | | |
| Continuation | *0.06* | << | *0.11* | | *0.09* |
| | 0.06 | << | 0.22 | | 0.22 |
| | 0.05 | >> | 0.03 | | 0.05 |
| | 0.05 | | 0.05 | | 0.08 |
| Reversal | *0.20* | << | *0.41* | | *0.45* |
| | 0.14 | << | 0.23 | | 0.26 |
| | 0.32 | << | 0.47 | | 0.51 |
| | 0.21 | << | 0.28 | | 0.35 |

| | | | | | |
|---|---|---|---|---|---|
| No change | *0.75* | >> | *0.47* | | *0.46* |
| | 0.80 | >> | 0.55 | | 0.52 |
| | 0.62 | >> | 0.50 | | 0.44 |
| | 0.73 | >> | 0.68 | | 0.56 |

Panel C: The Result of Intraday Data of Trading Interference Hypothesis

| | | | | | |
|---|---|---|---|---|---|
| -5 | 10.8373 | | 12.2043 | | 2.3364 |
| | 5.3118 | | 1.3137 | | 7.2702 |
| -4 | 5.6871 | | 8.4666 | | -0.2162 |
| | -5.3203 | | 7.2040 | | 2.3809 |
| -3 | 14.5671 | | 1.2427 | | 9.5439 |
| | 14.5737 | | 7.6602 | | 17.0004 |
| -2 | 18.7910 | | 18.9229 | | 22.7481 |
| | 15.4117 | | 18.9803 | | 17.3483 |
| -1 | 43.0285 | | 42.3165 | | 47.1552 |
| | 36.4729 | | 27.8177 | | 21.0963 |
| 0 | 103.8931 | >> | 62.4655 | | 46.8713 |
| | 84.2838 | >> | 56.4879 | | 54.3912 |
| 1 | -100.9666 | | -78.0603 | | -79.3405 |
| | -84.0271 | | -90.1842 | | -85.7764 |
| 2 | -65.9647 | << | -25.1131 | | -17.7035 |
| | -62.7528 | << | -26.4659 | | -26.4603 |
| 3 | -45.6277 | << | -13.8997 | | -20.9752 |
| | -19.7715 | | -0.1142 | | 0.6715 |
| 4 | -28.2221 | << | -6.1762 | | -9.8986 |
| | -10.6767 | | -1.4544 | | -5.2557 |
| 5 | -30.4370 | << | -6.3176 | | -5.8225 |
| | -8.3083 | | -5.3558 | | -7.1553 |

Table 11 (Continued). The Result of Intraday Data and Information Asymmetry Measure

| Interval | UP | Significance | UP-1 | Significance | UP-2 |
|---|---|---|---|---|---|
| | DOWN | | DOWN+1 | | DOWN+2 |

Panel D: The Result of Intraday Data of Disturbed Stock Valuation Hypothesis

| | | | | | |
|---|---|---|---|---|---|
| -5 | 0.6664 | | 0.5957 | | 0.6320 |
| | 0.6319 | | 0.5489 | | 0.6362 |
| -4 | 0.6881 | | 0.6435 | | 0.6382 |
| | 0.6428 | | 0.6132 | | 0.6751 |
| -3 | 0.7081 | | 0.6639 | | 0.6955 |
| | 0.6328 | | 0.6819 | | 0.6683 |
| -2 | 0.7633 | | 0.7337 | | 0.7488 |
| | 0.7636 | | 0.7951 | | 0.7389 |

| | | | | | |
|---|---|---|---|---|---|
| -1 | 1.0754 | | 0.9561 | | 1.0538 |
| | 0.9439 | | 0.9076 | | 0.8705 |
| 0 | 1.3900 | << | 1.5734 | | 1.5858 |
| | 1.7044 | | 1.7346 | | 1.6861 |
| 1 | 0.4987 | << | 0.9065 | | 0.8936 |
| | 1.0488 | | 1.1302 | | 1.1586 |
| 2 | 0.5286 | << | 0.7981 | | 0.7810 |
| | 0.8491 | | 0.9722 | | 0.9814 |
| 3 | 0.5676 | << | 0.7612 | | 0.7977 |
| | 0.8135 | | 0.8904 | | 0.8379 |
| 4 | 0.5350 | << | 0.7890 | | 0.7313 |
| | 0.8196 | << | 0.9853 | > | 0.7874 |
| 5 | 0.5414 | << | 0.7293 | | 0.6916 |
| | 0.7336 | | 0.8047 | | 0.8066 |
| 36 | 0.6775 | | 0.6616 | | 0.6097 |
| | 0.6274 | | 0.5623 | | 0.5809 |
| 72 | 0.6376 | | 0.7026 | | 0.6566 |
| | 0.6053 | | 0.5901 | | 0.5968 |
| 108 | 0.6085 | | 0.6277 | | 0.5739 |
| | 0.5628 | | 0.5789 | | 0.4937 |

Panel E: The Result of Intraday Data of Information Asymmetry Measure

| | | | | | |
|---|---|---|---|---|---|
| -5 | 0.3331 | | 0.3759 | | 0.4394 |
| | 0.7255 | | 0.3937 | | 0.3942 |
| -4 | 0.3284 | | 0.4629 | | 0.5074 |
| | 0.5116 | | 0.2952 | | 0.5113 |
| -3 | 0.3608 | | 0.5181 | | 0.4137 |
| | 0.5389 | | 0.4910 | | 0.4213 |
| -2 | 0.3245 | | 0.4144 | | 0.3983 |
| | 0.3966 | | 0.1265 | | 0.6551 |
| -1 | 0.3222 | | 0.3949 | | 0.2515 |
| | 0.0939 | | -0.0623 | | 0.0624 |
| 0 | -0.0072 | << | 0.6628 | | 0.5008 |
| | -0.2529 | << | 0.3292 | | 0.5272 |
| 1 | 0.0791 | < | 0.6991 | | 0.2639 |
| | 0.4280 | | 0.3413 | | 0.6390 |
| 2 | 1.0237 | | 0.5990 | | 0.5615 |
| | 0.7058 | | 0.4093 | | 0.7996 |
| 3 | 0.8099 | | 0.5829 | | 0.7884 |
| | 0.8132 | | 0.5052 | | 0.7812 |
| 4 | 1.0049 | | 0.5974 | | 0.4828 |
| | 0.5297 | | 0.3699 | | 0.6036 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | 1.0086 | | 0.5785 | | 0.5099 |
| | 0.4691 | | 0.4430 | | 0.5325 |
| 36 | 1.1317 | | 0.9156 | | 0.7335 |
| | 0.3079 | | 0.3770 | | 0.3840 |
| 72 | 0.5475 | | 0.3195 | | 0.7036 |
| | 0.3177 | | 0.3346 | | 0.3211 |
| 108 | 0.2985 | | 0.3667 | | 0.3363 |
| | 0.3716 | | 0.3509 | | 0.3536 |

Note) >> and > signify that the inconsistency of fair price perception of subgroup on the left is greater than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively; << and < signify that the inconsistency of fair price perception of subgroup on the left is less than that of subgroup on the right at the 0.01 and 0.05 levels of significance, respectively.

Because intraday data helps to improve the accuracy of the empirical results, this study adopts 5-minute intraday data collected from January 1, 1999 to September 30, 1999 to calculate the bid-ask spread of each interval and to measure the information asymmetry between buyers and sellers. This research assumes an information asymmetry measure of stock $i$ on interval $k$ as $ASY_{i,k}^{5m} = \{(ASK_{i,k}^{5m} - BID_{i,k}^{5m}) / [(BID_{i,k-1}^{5m} + ASK_{i,k-1}^{5m}) / 2]\} \times 100$, where $BID_{i,k}^{5m}$ and $ASK_{i,k}^{5m}$ refers to the best bid and ask price of stock $i$ on interval $k$, respectively. We also assume the interval of hitting price limits as interval 0 and selected interval -5 to interval 108 as the event window. This study uses nonparametric Mann-Whitney U Test to test whether the four pairs of subgroups (UP and $UP_{-1}$, $UP_{-1}$ and $UP_{-2}$, DOWN and $DOWN_{+1}$, $DOWN_{+1}$ and $DOWN_{+2}$) have same degree of information asymmetry. After interval 0, the UP (DOWN) subgroup is shown to have higher degree of information asymmetry than that of $UP_{-1}$ ($DOWN_{+1}$) subgroup, but the degree of information asymmetry of the $UP_{-1}$ ($DOWN_{+1}$) subgroup is insignificantly different from that of the $UP_{-2}$ ($DOWN_{+2}$) subgroup, indicating the support of "price limits intensifying the degree of information asymmetry between buyers and sellers." Moreover, this study deletes two continuous 5-minute intervals that "hit price limits" to avoid their influence on the accuracy of empirical result.

Panel E of Table 11 demonstrates the empirical result of the information asymmetry measure in which the bid-ask spread of the UP subgroup on interval -5 to -1 is insignificantly different from that of the $UP_{-1}$ subgroup, and the same result exists in the difference between the $UP_{-1}$ and $UP_{-2}$ subgroup. But 25 minutes after the stock

price hits its upper limit, the bid-ask spread of the UP subgroup on interval 1 is significantly lower than that of the $UP_{-1}$ subgroup and shows no significant statistical difference between the $UP_{-1}$ and $UP_{-2}$ subgroups. In terms of the lower limit, the empirical result from Panel E of Table 11 also indicates that 25 minutes before and after the stock price hits its lower limit, the bid-ask spread of the DOWN subgroup on interval -5 to 5 is insignificantly different from that of the $DOWN_{+1}$ subgroup, and the same result exists in the difference between the $DOWN_{+1}$ and $DOWN_{+2}$ subgroup.

Based on the above result, we find that the upper limit does not interfere with the quick flow of information and fails to effectively decrease the bid-ask spread and information asymmetry. Like the empirical result for the upper limit, the lower limit does not support the conclusion either that "price limits intensify information asymmetry" because weak evidence of information asymmetry change is found in three subgroups of samples after hitting the lower limits. Although the information asymmetry measure of 5-minute intraday is less likely to be influenced by daily price limits and research design than by the volatility spillover measure, we still cannot rule out the possible influence of daily price limits and research design; therefore, we are not able to conclude that "price limits reduce the degree of information asymmetry." The result of Panel E of Table 11 shows that the bid-ask spread of the UP (DOWN) subgroup on interval 36, 72, and 108 is insignificantly different from that of the $UP_{-1}$ ($DOWN_{+1}$) subgroup; hence, the price limits do not stabilize the market and after the stock hits the price limit, the degree of information asymmetry between buyers and sellers remains high. Furthermore, the degree of information asymmetry is determined by fair price perception of buyers and sellers, so we are able to use the conclusion of the information asymmetry measure to test the accuracy of the disturbed stock valuation hypothesis. After comparing Table 9, Table 10, and Panel D and Panel E of Table11, we find a corresponding conclusion: price limits don't mitigate the inconsistency in fair price perception and the degree of information asymmetry. As a result, the results of daily and intraday data on the disturbed stock valuation hypothesis are proven to be robust.

# 6. Conclusion

This study examines the Taiwan Stock Exchange to study the effect of price limits

on the price volatility, efficient price discovery, trading activity, and fair price perception. To that end, we collect ten-year trading data, a longer period than that adopted by previous studies, for our empirical analysis in order to improve the research accuracy. Furthermore, we adopt a more careful data processing method and research samples designed to comply with ex-rights/ex-dividends price adjustments as well as the requirement of the minimum tick size. There are two aspects that distinguish this study from previous literature. First, in addition to addressing price limit performance on price volatility, price discovery, and trading activity, this study applies the proposition of behavioral finance to analyze whether investors' perception on fair stock price is more heavily influenced by the price limits. Second, we examine the influence of fundamentals on price limit performance.

While testing for the volatility spillover hypothesis, this study finds that the upper limit in the Taiwan Stock Exchange does not support the volatility spillover hypothesis, and the stock price volatility decreases after an upper limit is reached. The empirical result of the lower limit, on the other hand, finds no support for the volatility spillover hypothesis. In other words, from these two results, we conclude that in the Taiwan Stock Exchange there are many noise traders who are more likely to purchase at a high price following good news and sell at a lower price following bad news, a trait of a less mature stock market. The upper limit measure helps to provide noise traders with an opportunity to rationally evaluate the intrinsic value of stocks and then effectively decrease stock price volatility. In terms of the delayed price discovery hypothesis testing, empirical results indicate that both upper and lower delay adjustments of stock prices to equilibrium prices, investors are more likely to purchase stocks that hit upper limits "at high prices" than sell stocks that hit lower limits at " low prices." In terms of the trading interference hypothesis, we find that both upper and lower limits fail to support the trading interference hypothesis. As to the disturbed stock valuation hypothesis, empirical results prove that price limits actually increase the inconsistency in fair price perception held by investors.

In regards to the influence of fundamentals on price limit performance, empirical results indicate that stocks with different fundamentals are found to have significantly different evidences in the volatility spillover hypothesis, delayed price discovery hypothesis, trading interference hypothesis, and disturbed stock valuation hypothesis. This confirms that stocks with better fundamentals need to have greater upper limits in order to sufficiently respond to positive information shocks, and if the

existing seven percent upper limit is imposed, those stocks demonstrate volatility spillover. Second, the price limits result in a higher proportion of price continuation and lower proportion of price reversal of stocks with worse fundamentals; therefore, when those stocks hit upper/lower limits (especially for those with worse fundamentals), a momentum strategy will produce a higher returns than a contrarian strategy will. Furthermore, we also find that stocks with worse fundamentals have more frequent trading activities on the day when the upper limit is hit and stocks with better fundamentals have more frequent trading activities on the day when the lower limit is hit. The results indicate that investors in the Taiwan Stock Exchange often make incorrect decisions when price limits are realized. That is, they are more likely to purchase stocks with worse fundamentals at a high price and sell stocks with better fundamentals at a low price. Finally, in stocks with worse fundamentals, due to more noise traders, investors are likely to show a greater inconsistency in their fair price perception when price limits are reached.

In order to verify the accuracy of the result of daily data, this study adopts 5-minute intraday data to examine the four hypotheses and the degree of information asymmetry between buyers and sellers. The empirical result between 5-minute intraday data and daily data turns out to be similar, but the result of 5-minute intraday data provides a stronger evidence against the volatility spillover hypothesis and a weaker evidence for the disturbed stock valuation hypothesis than that of daily data. That is, the application of daily data leads to a more accurate result. Furthermore, information asymmetry measures show that price limits do not diminish the degree of information asymmetry between buyers and sellers. Because investors' perception on fair price is determined by the degree of information asymmetry, the empirical result for information asymmetry is able to explain why price limits increase the inconsistency in the fair price perception of the investors.

In short, the empirical results support our conclusion that there is less significant evidence of inefficiency of price limits in the Taiwan Stock Exchange than in other more mature markets.[15] In addition, our results only support the delayed price discovery hypothesis and the disturbed stock valuation hypothesis. Although the upper limit in the Taiwan Stock Exchange effectively prevents volatility spillover, yet as a

15) Kim and Rhee (1997) used Tokyo Stock Exchange as the empirical subject and found the support of volatility spillover hypothesis, delayed price discovery hypothesis, and trading interference hypothesis (Kim and Rhee did not test the disturbed stock valuation hypothesis).

whole, price limits have more cons than pros. In addition, empirical results also show that upper and lower limits have different influences on trading activities of stocks with different fundamentals, so a different size of maximum allowable price movement should be imposed on stocks with different fundamentals. Although the existing upper limit outperforms lower limit with regards to volatility spillover, the upper limit delays the discovery of an equilibrium price more than the lower limit does, and trading activities of stocks on the next trading day after hitting upper limits tend to be more frequent than those after hitting lower limits. In conlcusion, we suggest that the Taiwan Stock Exchange adopt an "asymmetry price limit" measure, i.e., asymmetric size of maximum allowable price movement between upper and lower limits, imposing more relaxed upper limits than lower limits.

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