Does the Change of Price Limit Affect the Volatility in Stock Price? – Evidence from Korea

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Abstract

This paper verifies the effects of the changes in the price limit in the KOSPI market by conducting a comparative analysis on stock price's volatility under the 15% and 30% price limit. We employ time series data for all individual stocks from January 2, 2001 to December 31, 2020. In particular, the focus of our research is to verify the Volatility Spillover Hypothesis, Delayed Price Discovery Hypothesis and Trading Interference Hypothesis. First, analysis for Volatility Spillover Hypothesis indicates that volatility spillover takes place as stocks trade at their limit price. However, after the price limit expands, the volatility spillover for stocks that previously failed to reach the limit decreases. Second, the result for the Delayed Price Discovery Hypothesis suggests that although the price spillover takes place during the trading its price limit, the price spillover for groups that have failed to reach the limit price significantly decreases after the expansion of the price limit. Lastly, the result for the Trading Interference Hypothesis indicates that after the price limit expands, the trading interference decreases as stock price reaches its price limit. In all hypotheses tested, it seems apparent that the volatility in the KOSPI market gradually decreased as a result of the expansion of the price limit.

Keywords: Price Limit, Volatility Spillover Hypothesis, Delayed Price Discovery Hypothesis, and Trading Interference Hypothesis

JEL Classification: G, G1

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1 Introduction

Price limit refers to the range in which individual stock price are allowed to fluctuate in a single day. Usually, investors place orders more aggressively as the price limit expands, since they would lose opportunity to trade if the price meets its limit. This behavior, in turn, could even affect the stock price the next trading day. In this regard, the debate over the effectiveness of the price limit system has emerged as an object of discussion. Historically, the price limit in the KOSPI market changed from flat rate to 6% fixed rate on April 1, 1995. Then, it increased to 8% on November 25, 1996 and then to 12% on March 2, 1998 subsequently. Around 9 months later, the rate even further increased to 15%. Finally, the rate of 30%, which was adjusted during June 15, 2015 and May 2021, has been implemented since then. As mentioned above, the price limit has continuously increased due to deregulation and the Asian financial crisis in 1997. And in particular, when it increased to 30% on June 15, 2015, the Volatility Relief System (VI) was also introduced as a supplementary measure. In fact, countries including Taiwan, China, Vietnam and Japan, have implemented price limits in their stock markets. On the other hand, countries such as the United States, Germany, Hong Kong, and New Zealand have not yet introduced any form of price limit.

One of the well-known side effects of the changes in price limit is the magnet effect. The magnet effect means the tendency of investors concerned with a likely impediment to trade in time, which actually pushes prices further towards the price limit, increasing volatility. However, the price limit on the trading day would prevent the stock price from rising, resulting in delayed price discovery on the following day. Previous research (Seon, 2016; Eom et al. 2008, 2010) suggests that price limits could cause a very small effect on stock price volatility, while the volatility of the stock price can still be observed next day. They further argue that due to the price limit, price discovery could be delayed and the trading activity could be carried forward. Moreover, Kim et al. (2018) and Park et al. (2014) note that the implementation of the price limit eases the volatility of stock price in various sectors including manufacturing industry.

The following Figure 1 and 2 below present volatility and market return trend of the KOSPI market from January 1, 2001 to December 31, 2020

respectively. In this context, although the rate of return in the KOSPI market from the Figure 2 does not seem to be affected by the changes in the price limit, it seems quite clear that the volatility of the KOSPI market in Figure 1 has gradually decreased. Moreover, this downward trend has continued, even after the occasional expansion of the price limit. Even if we exclude the financial crisis in 2008, European financial crisis in 2012 and the COVID-19 crisis in 2020, the volatility in the KOSPI market overall has decreased over time.

Figure 1. The stock price volatility trend in the KOSPI market

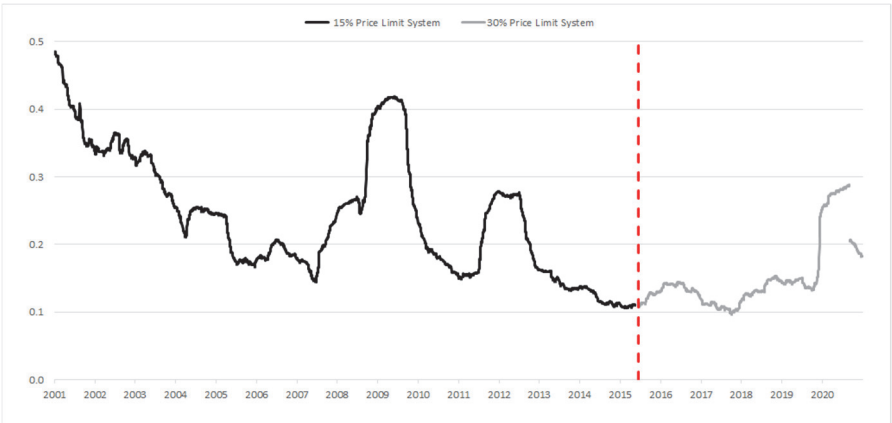
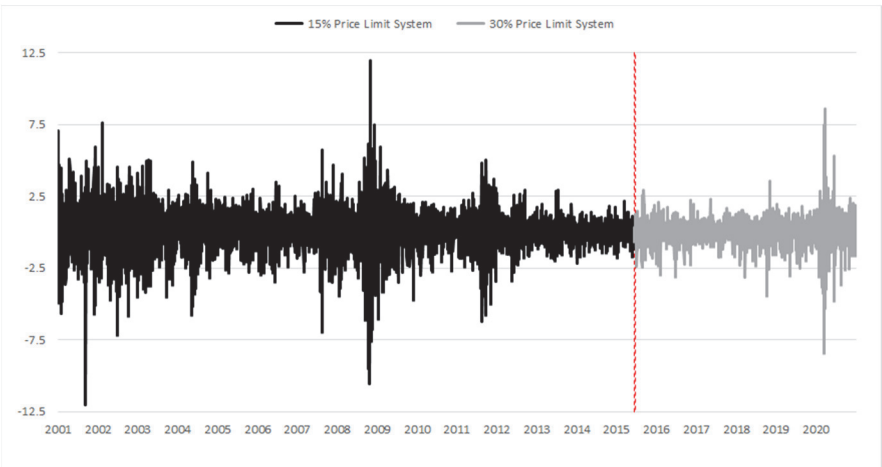


Figure 2. The return trend in KOSPI market



Interestingly, previous research point out price limit as the cause of the volatility change. For example, Park et al. (1995) indicate that price limit has limited effect on stock price volatility, while, at the same time, causes a substantial negative impact on the volatility, causing the magnet effect, as a result. On the other hand, previous studies indicate that financial factors such as the adoption of stock futures and short sale, are attributable to the decrease of the volatility in recent decades (Cho et al., 2012; Yoo, 2015).

In this context, the key interest of our research is whether the volatility due to the magnet effect would exist even after the change of the price limit from 15% to 30% fixed rate. We believe the verification of impact of the price limit change to the new 30% in 2015 could bear important policy implication to the investors and regulators. In line with the previous studies on the impact of price limits on stock price volatility (Lee, 2017; Kim et al., 2018; Park et al., 2014), we further verify this pattern even under the change of the price limit by testing the following hypotheses: Volatility Spillover hypothesis, Delayed Price Discovery hypothesis, and Trading Interference hypothesis. To summarize, the major argument of these hypotheses is that price limits cause higher volatility on subsequent days (Volatility Spillover hypothesis), prevent price from efficiently reaching equilibrium level (Delayed Price Discovery hypothesis) and interfere with trading due to limitations imposed by price limits (Trading Interference hypothesis).

The major findings of our study are of the following. First, for the Volatility Spillover Hypothesis, we find that after price limit changes, the volatility of stock groups that once failed to reach the price limit, decreased. Second, for the Delayed Price Discovery Hypothesis, the price transfer effect for the stock groups that once failed to reach the price limit decreased. Finally, for the Trading Interference Hypothesis test, the pattern of trading interference diminished when the stock groups reached the price limit. To summarize, this overall trend suggests that while the volatility of stock price decreases as the price limit changes, the trading interference also diminishes, leading to the decrease of the volatility spillover effect. Simply speaking, it is reasonable to argue that the Korean stock market has become stabilized under the new 30% price limit.

The major contribution of our study is that we successfully analyzed and compared the stock market volatility behavior under the new 30% price limit by verifying the three hypotheses: the Volatility Spillover hypothesis, the Delayed Price Discovery hypothesis and the Trading Interference

hypothesis. Specifically, our study suggests that after the price limit changes, the frequency of stock price which has reached price limit decreases, leading to the decrease of the volatility spillover effect, as a result. In other words, it seems reasonable to conclude that the Korean stock market has stabilized under the 30% price limit.

Our paper is composed as follows. In Section II, previous studies on the effectiveness of the price limit system are introduced. In Section III, we establish an analysis model. Section IV, using the analysis model in Section II, we empirically analyze the Volatility Spillover hypothesis, Delayed Price Discovery hypothesis, and Trading Interference hypothesis in the KOSPI market. In Section V, we present a conclusion.

2 Literature Review

A number of scholars have attempted to verify the impact of the price limit change. For example, Lee (2017) verifies the Volatility Spillover hypothesis, Delayed Price Discovery hypothesis, and Trading Interference hypothesis by using stock price data of listed-firms in the KOSPI market from January 2, 2001 to June 14, 2015. He argues that stocks that reached the previously 15% price limit experienced high volatility, a price spillover, and less trading interference. Shin (2015) verifies the effect of price limit changes on the return and volatility by employing stock indices and trading volumes of KOSPI, KOSPI 200 spot, and KOSPI 200 futures from May 3, 1996 to October 20, 2015, along with KOSDAQ index data from July 1, 1996 to October 20, 2015. His study reveals that the expansion of the price limit leads to a decrease in stock price volatility, solving uncertainty in the stock market.

Kim et al. (2018) find that in each two months period before and after June 15, 2015, when the price limit changed to 30%, the intra-day volatility in KOSPI market reduced. Park et al. (2014) note that the expansion of price limit reduced the stock price volatility of manufacturing firms listed in the KOSDAQ from May 22, 2000 to March 24, 2010. Further, employing stock price data on the KOSDAQ market from July 1, 1996 to February 29, 2012, Kim (2013) argues that the stock price spillover occurs because price limit restricts the reflection of information in stock price. Further, using

stock data at the time when price limit changed from an average 4.6% to 6% from April 1, 1995, Seonwoo et al. (1997) confirms that the volatility in the stock market has not increased excessively, despite the expansion of the price limit from a flat-rate to a fixed-rate. According to their research, short-term return volatility within 1, 5, 10 minutes and 1 hour, rather than daily return volatility, has decreased at a statistically significant level. Further, no significant change has been observed in volatility in nighttime return and weekly return.

Employing daily stock price data in the Tokyo Exchange from 1989 to 1992, Kim et al. (1997) demonstrate that the price limit interferes with stock-trading behavior and lowers stock price volatility. Further, using data from October 13th to October 16th, 1989, Kuhn et al. (1991) finds that price limit only delays price discovery, and its correlation with the volatility of stock price return has not been observed. Yu (2003) verifies the effect of the price limit expansion on stock volatility by using data for each 60 days before and after May 25, 1998 when the price limit changed from 8% to 12% in the KOSDAQ market. By using the state-space model and Kalman filtering, he notes that the limit to which traders' information is reflected in stock price, has increased due to the price limit changes, leading to the increase of its volatility. As well, using data from January 4, 1992 to July 31, 1994, Nam et al. (1996) argue that the price limit in KOSPI market is not attributable to the stability of stock price. On the assumption of the absence of price limit, they prove that the difference between the estimates for stock price volatility were not statistically significant, when in comparison with actual data.

Park et al. (1995) analyze the effect of the price limit in the KOSPI market, using data from January 1985 to December 1992. After analyzing the daily open price, high price, low price, and closing price of listed-firms' stocks, they conclude that the price limit system has not reduced volatility as it limits the formation of new prices. Also, French et al. (1986), Ma et al. (1989), and Kodres et al. (1994) find that when unusual price fluctuation alleviates, investors' overreaction would decrease and excessive volatility would also be suppressed, as a result. Thus, the combination of the effects could lead to the buildup of the trust between market participants while maintaining stock market stability. In addition, Blume et al. (1987) analyze that price limit would promote the inflow of the capital of value-investors since the limit notifies the market of 'the existence of a temporary

order-imbalance', which would also reduce the cost of monitoring the market due to sudden price fluctuations.

3 Methodology

Our research verifies the Volatility Spillover Hypothesis, Delayed Price Discovery Hypothesis, and Trading Interference Hypothesis by employing the methodologies introduced by Kim et al. (1997) and Lee (2017).

3.1 Volatility Spillover Hypothesis

Volatility spillover is an effect that volatility from the previous day would still be observed in the next day, as traders postpone orders due to price restrictions. Consequently, the investors' opinions would not be reflected in stock price until the next trading day. To verify, we analyze the stock price change for each 10 days before and after a trading day (day 0), when price records the highest or lowest. The daily return on the trading day t for the individual stock j is denoted by r(t,j). As well, the volatility, $v(t,j)$, is calculated as the square of the daily return of the stock. By conducting a nonparametric Wilcoxon signed-rank test with three different groups under two categories, which are Price Limit (Upper/Lower), the 90% change (Upper/Lower) group, the 80% change(Upper/Lower) group, during observation period, we compare the center difference in their daily variability.

$$v(t,j) = r(t,j)^2$$

3.2 Delayed Price Discovery Hypothesis

The Delayed Price Discovery Hypothesis expects that price limit would delay the price discovery of stocks, so that the price would continue to rise (or fall) in the same manner even after it has reached the price limit in the previous day. We analyze the pattern of stock price in order to test the delayed price discovery for following groups: Price-Limit (Upper/Lower Limit) group, 90% change (Rise/Fall) group, and 80% change (Rise/Fall)

group. Closing price, opening price and opening price on next day are defined as C_t, O_t, O_{t+1} respectively. The intraday rate of return, $\mathrm{r}(O_t, C_t)$, and the night rate of return, $\mathrm{r}(C_t, O_{t+1})$, are calculated as follows.

$$\mathrm{r}(O_t, C_t) = \log \frac{C_t}{O_t}$$

$$r(C_t, O_{t+1}) = \log \frac{O_{t+1}}{C_t}$$

The signs of the intraday and night-returns have nine values as follows.

[+,+] [+,0] [+,–]
[0,+] [0,0] [0,–]
[–,+] [–,0] [–,–]

In the case of the Upper-Limit group, [+,+], [0,+] means Continuation(+). [+,0], [0,0] are defined as No Change, and [+,–], [0,–], [–,+], [–,0], [–,–] mean Price Reversal respectively. On the other hand, in the case of the Lower Limit group, [0,–], [–,–] imply Continuation(-), and [–,0], [0,0] mean No Change respectively. [+,+], [+,0], [+,–], [0,+], [–,+] are defined as Price Reversal.

3.3 Trading Interference Hypothesis

To test the Trading Interference Hypothesis, we set a sample period as 10 days, which are 4 days before and 5 days after the trading day 0. Then, in order to eliminate bias, stock prices that have reached price limit for two consecutive days are removed in line with the test for Volatility Spillover hypothesis. Then, we use turnover ratio, instead of absolute trading volume, to verify the change in trading volume based on trading day 0. We denote each stock's volume on the trading day as *Trading Volume(t,j)*, the total number of stocks as *Shares Outstanding(t,j)*. Then we calculate turnover ratio, which is denoted as *Turnover(t,j)*.

$$Turnover(t,j) = \frac{Trading\ Volume(t,j)}{Share\ Outstanding(t,j)}$$

Using *Turnover(t,j)* on trading day t for individual stock j, we take natural logarithm of percentage change in daily trading volume for all stocks in Price-Limit (Upper/Lower) group, 90% change (Rise/Fall) group, and 80% change (Rise/Fall) group. We calculate t changes in previous day and the trading day(t0) and compare the magnitude of the change in turnover between groups, using the nonparametric Wilcoxon signed-rank test. If there exists a statistically significant difference within the 1% error range, we indicate it as ">>",and within the 5% error range, we denote it as ">."

$$\Delta Turnover(t,j) = \log\left(\frac{Trading\ Volume(t,j)}{Share\ Outstanding(t,j)}\right) \times 100(\%)$$

4 Results

4.1 Data Summary

The observation period for our sample is from January 2, 2001 to December 31, 2020. To eliminate survival bias, we include previously delisted stocks with a trading record. We use the data from the DataGuide. In total, we conduct research on 779 stocks in KOSPI market. The data includes daily base price, opening price, closing price, highest price, lowest price, upper limit price, lower limit price, yield, trading volume, number of listed stocks and so on.

In this research, the sample is classified into three sample groups under two categories: an Upper Limit (Lower Limit) group, a 90% Rise (Fall) group and an 80% Rise (Fall) group. Among the 779 KOSPI stock samples, the group of stocks that have reached the upper price limit on a certain trading day is defined as Upper Limit group. Specifically, stocks with (Upper Limit - base price) × 0.9 ≤ high - base price < (upper price - base price) ×1.0 are defined as 90% Rise group. Stocks with (Upper Limit - base price) × 0.8 ≤ high price – base price < (Upper Limit - base price) × 0.9 are defined as 80% Rise group. Similarly, the group of stocks that have fallen to lower price limit on a trading day is defined as Lower Limit group. The stocks with (base price – lower limit price)×0.9 ≤ base price - low < (base

price - lower limit)×1.0 are defined as 90% Fall group. The stocks with (base price - lower limit)×0.8 ≤ base price - low price < (base price – lower limit) × 0.9 are defined as a 80% Fall group.

The yearly samples of each group show similar pattern under both the 15% and 30% fixed rate systems except in 2020. In contrast to the number of group samples between 2001 and 2019, the number of stocks at the Upper Limit in 2020 is less than the sum of the number of group samples for 90% Rise group and 80% Rise group, and also less than the sum of the group samples for 90% Fall group and 80% Fall group. This could be caused by an increase in stock market volatility due to the COVID-19 outbreak in 2020.

Table 1. Observation Number of Each Group Sample

Year	Upper Limit	90% Rise	80% Rise	Lower Limit	90% Fall	80% Fall	Fixed rate system
2001	3,483	1,164	1,342	1,515	582	581	15%
2002	3,060	1,011	1,100	1,044	447	498	
2003	2,045	702	792	603	216	300	
2004	2,718	793	810	813	362	435	
2005	2,701	896	909	526	225	251	
2006	1,350	543	591	548	231	249	
2007	2,046	806	862	682	333	325	
2008	2,952	1,163	1,404	2,630	1,336	1,449	
2009	2,381	929	1,045	638	347	388	
2010	1,636	586	671	527	273	220	
2011	1,810	766	845	938	628	650	
2012	2,085	723	761	586	273	250	
2013	1,106	392	494	345	188	146	
2014	1,079	426	543	297	133	99	
2015.01.01. ~ 2015.06.14.	1,027	385	451	147	69	81	
2015.06.15 ~ 2015.12.31.	265	103	142	19	5	5	30%
2016	283	82	119	18	5	2	
2017	174	56	73	20	8	7	
2018	369	144	191	12	2	4	
2019	314	99	134	20	1	3	
2020	647	349	474	42	36	63	

4.2 Test for Volatility Spillover Hypothesis

4.2.1 Upper Limit group

Table 2 below presents the daily volatility for the Upper Limit, 90% Rise group, and 80% Rise group for 21 days, including 10 days before the trading day (base date), the trading day and 10 days after the trading day. Panel A and B in the table show the daily volatility for the groups under the 15% and 30% price limits respectively. Lee (2017) argues that all the dates for the stocks that have reached the price limit for two or more days consecutively, can be a base date (trading day 0). In this case, the stock price of our interest could be biased, since the stocks have already reached the price limit on previous day. In order to eliminate this bias, stocks that have reached the price limit for two or more consecutive days are excluded from our sample.

In Panel A and B, all three groups show their largest volatility on their base date (trading day 0). To be specific, in Panel A, the Upper Limit group, the 90% Rise group, and 80% Rise group show the highest volatility of 157.28, 77.55, and 56.36 respectively. In Panel B, the Upper Limit group, the 90% Rise group, and 80% Rise group show 687.19, 294.65, and 186.75 on trading day 0 respectively. By conducting a nonparametric Wilcoxon signed-rank test on three different groups under two categories, we compare the central difference in their daily variability. Again, a significant difference within the 1% and 5% error range are denoted ">>" and ">" respectively.

In Panel A, there exists a difference in absolute values of daily volatility after the base date (trading day 0) between the Upper Limit group, the 90% Rise group, and the 80% Rise group. In Panel A, the volatility of the Upper Limit group on trading day 1 is 1.5 times, and 1.7 times the volatility of the 90% Rising group and the 80% Rising group on trading day 1 respectively. Thereafter, the volatility of the Upper Limit group seems to be significantly higher until trading day 10. During the sample period, while Upper Limit group consistently shows significantly large volatility, the group's difference in volatility with other groups becomes larger after trading day 0. As well, there exists a significant difference in volatility from -2 trading day to the 1st trading day between the 90% Rise group and 80% Rise group, but this difference is smaller than the volatility between the Upper Limit and the 90% Rise group. In particular, stocks that have reached their upper price

limit show a different price trend, when compared to stocks that have risen to more than 90% or 80% of the maximum price. This trend becomes even more apparent after trading day 3.

Similarly, in Panel B, the volatility of stock price for the Upper Limit group on trading day 1 is 1.1 and 1.4 times the volatility of the 90% and 80% Rising group on trading day 1, respectively. During the observation period, the volatility for the Upper Limit group increases after the base date. Although smaller than the Upper Limit group, the volatility of stock price for the 90% and 80% Rise groups becomes larger after the trading day 0. After conducting nonparametric Wilcoxon signed-rank test, the difference in volatility between the Upper Limit group and the 90% Rise group seems significant, while the difference in volatility between the 90% Rise group and 80% Rise group appears from -2 trading day to 5 trading day, as evident in Panel A. On the other hand, a significant difference in volatility between all three groups can be found on trading day 0, as shown in Panel B. Since trading day 0 is the base date all three groups' stocks that have reached the highest price, it seems certain that there exists significant difference in volatility. This difference decreases before and after the trading day, as the rate of price limit changes from 15% to 30%.

Table 2. Test for the Effect of Volatility Spillover for Stocks at Upper Limit

Panel A. The Upper Limit group under the 15% Price Limit System

Trading day	Upper Limit		90% Rise		80% Rise
-10	30.87	>>	26.10		25.80
-9	29.97	>>	27.17		27.14
-8	30.74	>>	27.25		27.48
-7	31.57	>>	28.30		27.49
-6	33.59	>>	28.32		28.27
-5	35.18	>>	30.84		29.69
-4	38.29	>>	32.64		31.56
-3	41.59	>>	35.54		33.57
-2	47.53	>>	39.96	>	36.65
-1	65.43	>>	53.11	>>	46.61
0	157.28	>>	77.55	>>	56.36
1	49.05	>>	33.81	>>	29.37

2	48.27	>>	33.81	>	29.80
3	54.90	>>	28.43	>	26.26
4	40.46	>>	33.01	>	25.29
5	37.72	>>	26.79	>>	24.56
6	33.02	>>	29.23		28.79
7	34.76	>>	25.64		24.39
8	31.50	<	34.11		28.62
9	32.33	<<	32.99		23.21
10	32.10	>>	24.04	>	21.94

Panel B. The Upper Limit Group Under the 30% Price Limit System

Trading day	Upper Limit		90% Rise		80% Rise
-10	28.65		33.67		27.90
-9	32.00		29.76		35.53
-8	31.01		33.09		36.38
-7	35.65		43.42	>	34.57
-6	37.61		42.62		38.49
-5	39.91		32.74		38.08
-4	45.43		42.98		47.71
-3	56.31		58.43		51.33
-2	70.55		77.01		64.64
-1	128.66		135.19		131.51
0	687.19	>	294.65	>	186.75
1	80.46		74.26		57.39
2	72.09		60.15		52.87
3	55.89		42.70		40.65
4	46.13	>	33.35		40.53
5	48.02		33.40		33.42
6	48.53		36.33		36.73
7	44.23		33.84		32.93
8	43.12		34.67		26.95
9	40.39		31.96		30.19
10	33.76		28.43		28.27

4.2.2 Lower Price group

The volatility of stock price for the Lower Limit group, the 90% Fall group and the 80% Fall group, is presented in Table 3 below. The samples in Panel A, and B refer to the Lower Limit group under the 15%, 30% price limit, respectively. Similar to the Upper Limit group in Table 2, the observation period is 21 days, which are composed of 10 days before and after the trading day 0, which is a base date. Again, stocks that have reached the lower limit for two or more consecutive days are excluded from our sample.

In Panel A, although there exists a statistically significant difference between the Lower Limit group and the 90% Fall group, less significant difference is found between the 90% and the 80% Fall group. On trading day 0, a statistically significant difference is found between all three groups, which all experience the largest volatility. On trading day 1, the volatility of stock price for the Lower Limit group, 90% Fall group and 80% Fall group decrease from 151.34 to 43.88, from 92.14 to 38.18, and from 76.67 to 38.23, respectively. In Panel B, the statistically significant difference between all three groups only exists on trading day 0. Similar to Panel A in Table 2 and Table 3, stock price shows great volatility on trading day 0, and on trading day 1, the volatility of stock price for the Lower Limit group, 90% Fall group, and 80% Fall group decrease from 797.09 to 151.73, from 544.51 to 138.64, from 404.17 to 146.80, respectively. Like the Upper Limit group in Table 2, it seems clear that the volatility for the 90% Rise group and the 80% Rise group, is greater after the trading day 0. In addition, for the Upper Limit group, the statistically significant difference in volatility following the change in trading day decrease as the price limit changes from 15% to 30%.

Overall, the volatility spillover effect for the Lower Limit group seems to be greater than that of the Upper Limit group. This may be due to the volatility asymmetry phenomenon, in which volatility increases for stocks with negative returns (Glosten et al., 1993; Bekaert et al., 2000). In other words, price limit transfers price volatility, rather than eliminates it, and as the price limit expands from 15% to 30%, the difference could decrease. As well, even after the price limit expands, volatility transfer still occurs when a stock closes at the upper or lower price limit. However, the spillover of volatility for stocks that have not reached their price limit decreases as the price limit expands.

Table 3. Test for the Effect of Volatility Spillover for Stocks at Under Limit

Panel A. The Lower Limit Group Under the 15% price limit system

Trading day	Upper Limit		90% Rise		80% Rise
-10	38.13	>>	32.54		33.43
-9	38.52	>>	31.21		34.39
-8	40.59	>>	34.47		33.44
-7	41.84	>>	34.53		36.47
-6	45.37	>>	37.96		38.31
-5	49.75	>>	39.35		39.47
-4	53.09	>>	41.59		41.05
-3	59.07	>>	44.99		45.49
-2	63.81	>>	49.49		50.68
-1	72.36	>>	53.98		55.75
0	151.34	>>	92.14	>>	76.67
1	43.88	>>	38.18		38.23
2	47.16	>>	36.37		33.68
3	41.13	>	35.26	>	30.87
4	39.77	>>	30.42		29.06
5	35.74	>	30.08		28.59
6	33.79	>	30.43		27.96
7	32.94	>	29.26		27.41
8	33.06	>>	27.21		26.28
9	31.57	>>	25.61		26.65
10	32.62	>>	26.70		25.95

Panel B. The Under Limit Group Under the 30% Price Limit System

Trading day	Upper Limit		90% Rise		80% Rise
-10	40.55		28.33		58.87
-9	40.56		23.30		50.47
-8	93.72		60.23		89.59
-7	56.11		41.99		90.85
-6	63.27		86.68		127.53
-5	83.62	>	33.51		96.98
-4	79.91		62.30		58.87
-3	85.41		40.45		103.29
-2	125.31		82.87		94.99
-1	176.77		131.77		137.35
0	797.09	>	544.51	>	404.17

1	151.73		138.64		146.80
2	67.70		60.47		45.63
3	90.13		63.07		65.01
4	45.44		59.91		82.40
5	106.25		42.71		75.98
6	49.79		27.37		40.29
7	43.90		26.93		36.23
8	28.54		33.14		50.85
9	33.18		30.77		36.52
10	25.82		61.22		25.39

4.2.3 Test for Delayed Price Discovery Hypothesis

Table 4 below presents the test results for the Delayed Price Discovery hypothesis. Panel A and B show the analysis for the Upper and Lower Limit price groups under the 15% price limit. Panel C and D provide the analysis for the Upper and Lower price groups under the 30% price limit. In Panel A, the stock price for 63.30% of the Upper Limit group rise until the next day, while only 29.46% of them experience a price reversal. On the other hand, the percentage of the 90% Rise group was 45.79%, which is more than 43.68% of the group which continue to rise. Similar to the 90% Rise group, stock price for 42.38% of the 80% Rise group continue to rise, while 45.84% of the same group suffer a price decline. In Panel C, similar to Panel A, the stock price for 58.90% of the Upper Limit group continually rose, which is higher than the 37.12% for the group that experienced price reversal. As well, 39.99% for the 80% Rise group experienced a continuous stock rise, which is higher than 53.51% of the group that suffered price reversal. On the other hand, same percentage for the 90% Rise group experienced continuous rise and price reversal, which is 57.37%.

Similarly, in Panel B, the percentage of the Lower Limit group that experienced continuous decline (49.34%) is higher than that of the price reversal (42.57%). On the other hand, the percentage of the 90% Fall group and the 80% Fall group that experienced the price reversal is 53.82%, and 54.02%, which is higher than their percentage of continuing decline, which are 36.40%, and 35.28% respectively. In Panel D, similar to Panel B, the percentage of the Lower Limit group that experienced continuous decline (56.16%) is higher than that of the price reversal (39.17%) In contrast, the percentage of the 90% Fall group that experienced price reversal (45.19%)

is higher than that of the continuous decline (39.35%). However, contrary to the 80% Fall group in Panel B, where the percentage of the price reversal is higher than that of continuous rise, the percentage of the 80% Fall group in Panel D, which experienced the continuous decline and price reversal are 49.96%, and 49.77% respectively, with a slight difference of 0.19%p.

Table 4. Test for Delayed Price Discovery Hypothesis (entire sample)

Panel A. Changes in Stock Price for the Upper Limit Group Under the 15% Price Limit

Year	Stock Price Change	Upper Limit	90% Rise	80% Rise	T value (Upper limit - 90%Rise)
2001~2015	Continually Rise	63.30%	43.68%	42.38%	20.36
	No Change	7.24%	11.33%	11.78%	-6.48
	Price Reversal	29.46%	45.79%	45.84%	-19.78

Panel B. Changes in Stock Price for the Lower Limit Group Under the 15% Price Limit

Year	Stock Price Change	Lower Limit	90% Fall	80% Fall	T value (Lower limit - 90%Fall)
2001~2015	Continually Rise	49.34%	36.40%	35.28%	10.95
	No Change	8.09%	9.77%	10.70%	-2.48
	Price Reversal	42.57%	53.82%	54.02%	-9.36

Panel C. Changes in Stock Price for the Upper Limit Group Under the 30% Price Limit

Year	Stock Price Change	Upper Limit	90% Rise	80% Rise	T value (Upper limit - 90%Rise)
2015~2020	Continually Rise	58.90%	57.37%	39.99%	0.64
	No Change	3.98%	5.49%	6.50%	-1.54
	Price Reversal	37.12%	57.37%	53.51%	-5.67

Panel D. Changes in Stock Price of the Lower Limit Group Under the 30% Price Limit

Year	Stock Price Change	Lower Limit	90% Fall	80% Fall	T value (Lower limit - 90%Fall)
2015~2020	Continually Rise	56.16%	39.35%	49.96%	1.38
	No Change	4.67%	15.46%	0.27%	-1.21
	Price Reversal	39.17%	45.19%	49.77%	-0.39

As evident in Table 4, the price continuation for the price limit group is at a higher rate than the price reversal, and in contrast, the price reversal is at a higher rate in the 90% Rise (Fall) and 80% Rise (Fall) groups. Thus, it is reasonable to argue that this difference supports the idea of Delayed Price Discovery hypothesis. In Panel A and C, it is commonly found that as the price limit changes from 15% to 30%, the percentage of price continuation is higher than that of the price reversal for the Upper Limit group, while the percentage of the price reversal is higher than the percentage price continuation for other groups. On the other hand, for all three groups, the percentage of price reversal rise, while the percentage of stock prices unchanged decrease. Similarly, in Panel B and D, the percentage of price continuation is higher than the price reversal for the Lower Limit group, while the percentage of price reversal is higher than that of price continuation for the 90% Fall group. Only for the 80% group, contrary to other groups, the percentage of price reversal seems to be higher than that of price continuation.

Table 5 presents the effect of delayed price discovery for the samples, in which closing price on the trading day t and price changed at maximum are the same. In Panel A, 79.84% of the Upper Limit group experience continuing price rise until the next day, while only 14.83% experience a price reversal. On the other hand, for the 90% Rise group, price reversal is experienced in 47.96%, which is more than the 36.58% where price continually rise. For the 80% rise group, price continue to rise in 31.78%, while 54.92% suffer price decline. In Panel C, similar to Panel A, stock price continually rises for 71.31% of the Upper Limit group, which is higher than the price reversal (25.67%), and for the 90% Rise group, price reversal (36.18) is higher than price increase (26.33%). Contrary to Panel A, the percentage of the 80% Rise group in Panel C which experience continuing to rise is 43.33%, which is higher than the percentage of price reversal (30.00%).

Similarly, in Panel B, the percentage of the Lower Limit group that experienced stock price's continuous decline (65.37%) is higher than that of price reversal (28.11%). Also, the percentage of the 90% Fall group and the 80% Fall group that experienced price reversal is 47.73% and 34.92%, which is higher than their percentage of continuing decline which are 44.43% and 22.13% respectively. In Panel D, similar to Panel B, the percentage of the Lower Limit price group that experienced continuous

decline (70.35%) is higher than that of the price reversal (25.47%). However, the percentage for the 90% Fall group experiencing continuous decline and price reversal are the same at 0.00%. As well, the percentage of experiencing continuous decline (25.00%) of the 80% Fall group is higher than their percentage of price reversal (8.33%).

Table 5. Test for Delayed Price Discovery hypothesis
(matching sample of closing price and maximal change price)

Panel A. Changes in Stock Price for the Upper Limit Group Under the 15% Price Limit

Year	Stock Price Change	Upper Limit	90% Rise	80% Rise	T value (Upper limit - 90%Rise)
2001~2015	Continually Rise	79.84%	36.85%	31.78%	13.50
	No Change	5.33%	15.19%	13.31%	-6.87
	Price Reversal	14.83%	47.96%	54.92%	-9.97

Panel B. Changes in Stock Price for the Lower Limit Group Under the 15% Price Limit

Year	Stock Price Change	Lower Limit	90% Fall	80% Fall	T value (Lower limit - 90%Fall)
2001~2015	Continually Rise	65.37%	44.43%	22.13%	5.20
	No Change	6.52%	7.83%	9.61%	-0.76
	Price Reversal	28.11%	47.73%	34.92%	-4.97

Panel C. Changes in Stock Price for the Upper Limit Group Under the 30% Price Limit

Year	Stock Price Change	Upper Limit	90% Rise	80% Rise	T value (Upper limit - 90%Rise)
2015~2020	Continually Rise	71.31%	26.33%	43.33%	6.24
	No Change	3.03%	4.17%	10.00%	-0.27
	Price Reversal	25.67%	36.18%	30.00%	-0.7

Panel D. Changes in Stock Price of the Lower Limit Group Under the 30% Price Limit

Year	Stock Price Change	Lower Limit	90% Fall	80% Fall	T value (Lower limit - 90%Fall)
2015~2020	Continually Rise	70.35%	0.00%	25.00%	10.32
	No Change	4.18%	0.00%	0.00%	1.82
	Price Reversal	25.47%	0.00%	8.33%	4.77

In Table 5, where the matching samples of closing price and maximum price change are presented, the price spillover effect is more evident. In particular, for the limited price group, the percentage of experiencing price continuation increase significantly, while their percentage of price reversal significantly decrease, when compared to the entire sample in Table 5. Conversely, for the 90% Rise (Fall) group and the 80% Rise (Fall) group, the percentage of experiencing price continuation decrease in general.

To summarize the results in Table 4 and 5, a most significant difference exists between the limit price (Upper/Lower) group, the 90% change (Rise/Fall) group, and the 80% change (Rise/Fall) group. For the limited price group in all eight panels, the price continuation seems more significant than the price reversal. On the other hand, for the 90% change (Rise/Fall) group, and the 80% change (Rise/Fall) group, price reversal, rather than price continuation, seems more significant in Panel A and B in both Table 4 and 5. Also, for Panel C and D in both Table 4 and 5, the price reversal seems more significant than the price continuation, in general. Also, the matching samples' price continuity strengthens when closing price is set at the limit price, and for the 90% and 80% change (Rise/Fall) group, this continuity weakens. In other words, if the stock closes at upper or lower limit, the price spillover effect takes place. However, after the expansion of the price limit, the price spillover effect of stocks that have failed to reach the limit significantly decrease.

Table 6 below presents the stock price changes due to the financial crisis in 2008 and COVID-19 in 2020. In Panel A, when the average changes from 2001 to 2007, and 2008 for the entire sample are compared, it seems apparent that the percentage of experiencing continuous rise decrease, while the percentage of experiencing price reversal increases, for all three groups. In Panel A, when the average changes of stock price from June 15, 2015 to 2019, and 2020 are compared, it seems evident that the percentage of experiencing continuous increase in the Upper Limit group and the 80% Rise group increase, while the percentage of experiencing price reversal in the Upper Limit group and the 90% Rise group decrease. In Panel B, when the average changes from 2001 to 2007, and 2008 are compared for the entire sample, it seems evident that the percentage of experiencing continuous decline increases for Lower Limit group, while their percentage of price reversal decrease. In contrast, the percentage of the 90% Fall group and 80% Fall group experiencing the continuous declining decrease,

while their percentage of experiencing price reversal increase. When the averages of stock price changes from June 15, 2015 to 2019, and 2020 are compared, it appears that the percentage of experiencing continuous declining decrease and the percentage of price reversal increase for the Lower Limit group and the 90% Fall group, while the percentage of experiencing continuous declining increase and the price reversal rate decrease for the 80% Fall group.

In Panel C, when the average changes of stock price from 2001 to 2007, and 2008 are compared, the percentage of the Upper Limit group experiencing continuous rise increase, while their percentage of price reversal increase. Also, when the average changes of stock price from June 15, 2015 to 2019, and 2020 are compared, the percentage of experiencing continuous increase for the Upper Limit group and the 90% Rise group increase. On the other hand, the percentage of price reversal for the Upper Limit group decrease, while that of the 90% Rise group and 80% Rise group increase. In Panel D, when the average changes of stock price from 2001 to 2007, and 2008 are compared, the percentage of experiencing continuous decline increase for all three groups, while the percentage of price reversal decrease. Lastly, when the average changes of stock price from June 15, 2015 to 2019, and 2020 are compared, the percentage of continuous declining in the Lower Limit group decrease, while their percentage of price reversal increases.

Table 6. Delayed Price Discovery Effect Hypothesis Test for 2008 and 2020 Samples

Panel A. Stock Price Change Trend (for the entire sample) in the Upper Limit group in 2008 and 2020

Year	Stock Price Change	Upper Limit	90% Rise	80% Rise
2001~2007	Continually Rise	63.70%	42.22%	42.12%
	No Change	7.27%	10.60%	11.39%
	Price Reversal	29.04%	47.19%	46.49%
2008	Continually Rise	61.24%	40.40%	36.07%
	No Change	7.98%	11.37%	10.26%
	Price Reversal	30.77%	48.23%	53.67%

2015~2019	Continually Rise	58.13%	57.40%	39.93%
	No Change	3.54%	5.24%	6.36%
	Price Reversal	37.12%	57.37%	53.51%
2020	Continually Rise	62.75%	57.19%	40.30%
	No Change	6.18%	6.73%	7.17%
	Price Reversal	31.07%	57.19%	52.53%

Panel B. Stock Price Change Trend (for the entire sample) in the Lower Limit group in 2008 and 2020

Year	Stock Price Change	Lower Limit	90% Fall	80% Fall
2001~2007	Continually Decline	49.49%	38.58%	37.58%
	No Change	8.94%	10.89%	10.56%
	Price Reversal	41.57%	50.54%	51.86%
2008	Continually Decline	51.58%	34.66%	32.60%
	No Change	7.22%	6.74%	6.96%
	Price Reversal	41.20%	58.61%	60.44%
2015~2019	Continually Decline	58.34%	40.00%	49.95%
	No Change	3.22%	18.00%	0.00%
	Price Reversal	39.17%	45.19%	49.77%
2020	Continually Decline	45.24%	36.11%	50.00%
	No Change	11.90%	2.78%	1.61%
	Price Reversal	42.86%	61.11%	48.39%

Panel C. Stock Price Change Trend in 2008 and 2020, using matching sample of closing price and maximum change price within Upper Limit group

Year	Stock Price Change	Upper Limit	90% Rise	80% Rise
2001~2007	Continually Rise	81.02%	35.74%	32.76%
	No Change	5.15%	13.25%	13.60%
	Price Reversal	13.83%	51.02%	53.64%
2008	Continually Rise	78.06%	49.18%	48.54%
	No Change	6.50%	10.66%	14.56%
	Price Reversal	15.44%	40.16%	36.89%

2015~2019	Continually Rise	70.13%	22.50%	48.00%
	No Change	2.87%	5.00%	4.00%
	Price Reversal	25.67%	36.18%	30.00%
2020	Continually Rise	77.20%	45.45%	20.00%
	No Change	3.80%	0.00%	40.00%
	Price Reversal	19.00%	54.55%	40.00%

Panel D. Stock Price Change Trend in 2008 and 2020, using matching sample of closing price and maximum change price within the Lower Limit group

Year	Stock Price Change	Lower Limit	90% Fall	80% Fall
2001~2007	Continually Decline	65.05%	35.30%	33.30%
	No Change	6.71%	10.43%	12.73%
	Price Reversal	28.23%	54.27%	53.97%
2008	Continually Decline	69.10%	48.28%	48.08%
	No Change	6.73%	6.90%	7.05%
	Price Reversal	24.17%	44.83%	44.87%
2015~2019	Continually Decline	73.51%	0.00%	20.00%
	No Change	4.11%	0.00%	0.00%
	Price Reversal	25.47%	0.00%	8.33%
2020	Continually Decline	54.55%	0.00%	50.00%
	No Change	4.55%	0.00%	0.00%
	Price Reversal	40.91%	0.00%	50.00%

In Table 6, similar to results in Table 4 and 5, there exists a significant difference between the Limited Price group, the 90% change (Rise/Fall) group, and the 80% change (Rise/Fall) group. From the results in Table 6, it seems clear that the price limit delays stock price discovery. In particular, the stock price in 2008 and 2020 are in reversing trend. In Panel A and C, the percentage of continuous declining and price reversal increase in 2008, and in 2020, the percentage of continuous rising increase, while the percentage of price reversal decreases. In Panel B and D, the percentage of continuous declining increase while the percentage of the price reversal

decreases in 2008. In contrast, the percentage of continuous rising decreases and the percentage of the price reversal increases in 2020. Simply speaking, the falling trend of stock prices after reaching price limit seems quite clear in 2008, while the rising trend of stock price after reaching its limit becomes more apparent in 2020.

4.2.4 Test for Trading Interference Hypothesis

Panel A in Table 7 presents the percentage change in daily turnover for the Upper Limit group, the 90% Rise group, and the 80% Rise group under the 15% price limit. The most striking feature is found on trading day 1. On that day, the turnover of the Upper Limit group, the 90% Rise group, and the 80% Rise group, decrease by about 24%, 68%, and 66%, compared to trading day 0. Panel B shows the percentage change in daily turnover of the Upper Limit group under the 30% price limit. Similar to Panel A, the most statistically significant difference is found on trading day 1. On trading day 1, the percentage of turnover of the Upper Limit group, the 90% Rise group, and the 80% Rise group decrease by about 19%, 106%, and 111% respectively, compared to trading day 0. In both Panel A and B in Table 7, not only the percentage of turnover of the Upper Limit group decreases slightly on trading day 1, but also the difference in turnover between the Upper Limit group and the other two groups becomes statistically significant.

Panel A in Table 8 shows the percentage change in daily turnover for the Lower Limit group, the 90% Fall group, and the 80% Fall group under the 15% price limit. As in Table 7, the trading volume changes significantly a day after the base date. The percentage of turnover of the Lower Limit group, the 90% Fall group, and the 80% Fall group decreases significantly by 37%, 51%, and 46% respectively, when compared to the 0th trading day. Panel B presents the percent change in daily turnover for the lower limit price group under the 30% price limit, which shows the most remarkable feature on trading day 1, similar to Panel A. On that day, the percentage of turnover for the Lower Limit group, the 90% Fall group, and the 80% Fall group decrease by about 1%, 75%, and 70% respectively, when compared to the trading day 0.

In Panel A and B in both Table 7 and 8, there also exists differences between the limit price (Upper/ Lower) group, the 90% Fall group, and 80% Fall group. In Panel B in Table 7, compared with Panel A, the declining

trend in turnover for the Upper Limit group diminishes when compared to Panel A, but the declining trend in turnover for the 90% Rise group and the 80% Rise group becomes apparent. Panel B in Table 8 presents a decrease in the percentage of turnover of the Lower Limit group compared to Panel A, but the declining trend in the 90% Fall group and 80% Fall group becomes apparent. This overall trend is in line with previous research. For instance, Lee (2017) argues that price limit prevents further trading when stock price reaches its limit. In this case, since investors' opinions are not reflected in stock price, stocks would be only traded within the range of new price limit the next day. Further, Park et al. (1995) note that the frequency of fluctuations for stock price next day is high within their positive/negative range of price limit. Particularly, the trend of fluctuation under price limit for the upper limit is clearer than that of the Lower Limit. The fact that price fluctuation becomes substantial in the absence of the price limit suggests that stock price would reach its 'expected price' late when such restriction is removed. In other words, it seems reasonable to argue that price limit delays stock price from reaching the equilibrium price. The price limit has a delaying effect on the price discovery by limiting price fluctuations, suppressing the formation of new prices. To put it differently, as a result of the expansion of the price limit, the trading interference decreases after the stock price reaches the new limit.

Table 7. Trading Interference Hypothesis test for Upper Limit Group

Panel A. Upper Limit group under 15% Price Limit system

Trading Date	Upper Limit		90% Rise		80% Rise
-4	5.41%		5.15%		4.55%
-3	6.94%	>	4.68%		3.58%
-2	10.56%	>	7.32%		7.01%
-1	14.05%	>	9.72%		8.28%
0	123.33%	>>	100.47%	>>	90.45%
1	-23.57%	>>	-67.56%		-66.06%
2	-37.65%	<<	-15.64%	<	-13.65%
3	-11.01%	<<	-6.26%		-5.18%
4	-10.19%	<<	-5.89%		-5.76%
5	-9.20%	<<	-5.76%	<<	-3.59%

Panel B. Upper Limit group under 30% Price Limit System

Trading Date	Upper Limit		90% Rise		80% Rise
-4	8.43%		9.95%		5.74%
-3	15.33%		18.80%		18.45%
-2	18.03%		19.11%		13.88%
-1	31.75%		28.43%		34.75%
0	243.80%	>	233.22%		225.24%
1	-19.30%	>	-105.52%		-111.25%
2	-68.97%	>	-47.35%		-45.49%
3	-38.14%	>	-35.74%		-31.22%
4	-26.32%		-24.95%	>	-19.81%
5	-25.73%		-23.71%		-24.92%

Table 8. Trading Interference Hypothesis test for Lower Limit Group

Panel A. Lower Limit group under 15% Price Limit System

Trading Date	Lower Limit		90% Fall		80% Fall
-4	5.94%		4.59%		3.94%
-3	4.16%		3.29%		3.18%
-2	6.00%		3.78%		5.62%
-1	8.39%	>	4.03%		2.50%
0	58.57%	>>	46.84%	>>	37.38%
1	-36.99%	>>	-51.24%	<<	-46.05%
2	-18.07%	<<	-10.61%		-10.14%
3	-8.64%		-6.21%		-6.60%
4	-6.18%		-5.13%		-4.90%
5	-3.74%		-3.33%		-4.14%

Panel B. Lower Limit group under 30% Price Limit System

Trading Date	Lower Limit		90% Fall		80% Fall
-4	8.18%		9.79%		10.41%
-3	25.76%		21.68%		18.95%
-2	10.87%		12.78%		10.94%
-1	15.28%		14.16%		12.76%
0	153.36%		151.90%	>	116.65%
1	-1.23%	>	-75.23%		-69.67%
2	-63.46%		-57.34%		-54.50%
3	-44.98%		-44.18%		-41.57%
4	-31.51%		-29.89%		-27.43%
5	-29.83%		-30.01%		-29.85%

5 Conclusion

This paper comprehensively examines the volatility of individual stocks in the KOSPI market under the new 30% price limit. In particular, our research differs from previous research in the way that we observed the changes in stock price volatility before and after the changes of price limit in three different groups of samples under two categories – namely, the Limited Price (Upper/Lower) group, the 90% change (Rise/Fall) group and the 80% change (Rise/Fall). In comparison with previous research (Lee, 2017; Shin, 2015; Kim, 2013; Seonwoo et al., 1997), our approach focuses on how price limit affects market volatility, and thus facilitating market stability by testing the Volatility Spillover hypothesis, the Delayed Price Discovery hypothesis, and the Trading Interference Hypothesis.

To summarize, the result for the Volatility Spillover hypothesis suggests that if a stock is traded at the limit price, upper or lower, the volatility spillover takes place. However, after the expansion of price limit, the volatility spillover of stocks that failed to reach price limit, significantly decreased. Subsequently, the result for the Delayed Price Discovery hypothesis indicates that although price spillover effect takes place when stocks are traded at price limit, the price spillover of groups that failed to reach the limit price, significantly decrease, as a result of the expansion of price limit. Lastly, the result for the Trading Interference hypothesis demonstrates trading interference diminishes after the stock price reaches its expanded price limit.

This overall trend suggests that the frequency of stock price's reaching its price limit after the expansion of the price limit decrease, so that the interference in the investors' opinions on stock price decreases, leading to less volatility spillover effect. Additionally, it seems reasonable that the delayed price discovery diminishes as investors' opinions are reflected in the stock price without any interference. In other words, the Korean stock market has become stabilized under the 30% price limit, in contrast with when under the 15% price limit.

The main contributions of our study are summarized as follows. We successfully analyzed the volatility of stock price under the new 30% price limit in the KOSPI market for last 20 years, by verifying the Volatility Spillover hypothesis, the Delayed Price Discovery hypothesis and the

Trading Interference hypothesis. However, since the new supplementary measures including the Volatility Alleviation system (VI), have been implemented along with the price limit, which is the core subject of our discussion, the subsequent research for the effect of the VI, is left to future research.

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