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Price Limits Performance: Evidence from the Kuala Lumpur Stock Exchange*

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Abstract. In this paper we examine the performance of price limits enforced by the KLSE to curb excessive short-term price volatility. Three hypotheses were used: first to test the effectiveness of price limits on price volatility; second, the effectiveness of price limits on the price discovery process and finally the effectiveness of price limits on the interference of trading activity. Our evidence appears to suggest that price limits cause a higher volatility level, delay efficient price discovery process and interfere with trading activity.

Keywords: Price limits, price discovery, price continuation, trading interference and volatility

1. Introduction

Prior to the severe worldwide market crash in October 1987, price limits and circuit breakers were hardly known. Only a few stock exchanges chose to enforce price limits or circuit breakers to stabilize volatility in their respective markets. Two such exchanges were the Tokyo Stock Exchange (TSE) and the Tel Aviv Stock Exchange (TASE).

The course of history was changed on October 1987, when stock markets across the world crumbled. The cause of the crash has become a hot topic. Allan Greenspan, then the chairman of the Reserve Board, said the crash was an accident waiting to happen.[1] While others attribute the accident to price bubbles, economic fundamentals, futures-related trading and even program trading.

Several reports were compiled immediately following the crash. The first to be released was the interim report by Commodity Future Trading Commission (CFTC). This report was released on 9 November 1987. The second report was released on 21 December 1987 by Chicago Mercantile Exchange (CME). The third report, released on 8 January 1988, was the most prominent among the four. Called the Brady Commission Report, it was named after Nicholas Brady who chaired the task force of the study.

The Brady Report discusses the causes of Black Monday and prescribed solutions to prevent similar incidents from recurring. The report concluded that market crashes were attributed to futures-related trading (including portfolio insurance and index arbitrage). The report recommended the use of coordinated circuit breakers (including price limits) and coordinated margin requirements as mechanisms to prevent future market crashes.

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[1] *Source* : Dr David Blake, 1989, Crash of '87:Why markets fail? *Professional Investor*. October 1989:20.

Brady's recommendations generated a lot of controversies. Regulators and academicians view the recommendations with skepticism. Alan Greenspan, reportedly said that the price limits and other circuit breakers are inherently destabilizing, but they may be the least bad of all the solutions.[2] Economists generally scorn at price limits implementation to curb excessive market volatility.[3] Prior to its implementation, the Securities and Exchange Commission (SEC), CME and New York Stock Exchange (NYSE) were reported to have urged for a careful examination of the effect of price limits.

The first argument against price limits is the 'magnet effect'. It is argued that when the share prices move up or down in the range of the trigger point of the price limits, the traders will rush in to buy or sell the shares to avoid being locked into their current position. In other words, price limits attract traders to rush in to buy or sell the shares. The price limits is alleged to act as an magnet instead of an arrester. The study by McMillan (1990) of SEC's office of Economic Analysis supports the existence of a magnet effect. He studied the effect of circuit breakers in a mini crash on 13 October, 1989 and found that price dispersion as measured by distribution of the absolute value of successive price changes, increased after circuit breakers were lifted on 13 October. He concluded that the imposition of price limits seems to have a 'magnet effect' and may have impaired efficient price discovery on the 13 Friday 1989 mini crash.

The second argument against the price limits is as put forth by Fama (1989). He argued that the price limits cause 'over-reaction effect' and 'delay effect'. Both these effects can alter some characteristics of the stock prices. In 'over-reaction effect', it is argued that price limits could increase price volatility by inciting trading in anticipation of trading halts. This effect is consistent with the 'magnet effect' discussed earlier. In 'delay effect', it is argued that the price limits delay the adjustment of price to the changes in fundamental values, thus affecting the price adjustment speed but do not have any effect on the price adjustment size. Fama's argument on the delay effect is consistent with the study by Roll (1988) which shows that the range of the price crash in the 1987 market crash of each country is similar without regard to price limits

The third argument against price limits is as pointed out by Yea-Mow Chen (1993). He argued that the price limits serve no purpose to control price volatility. He further argued that price limits are only useful to slow down or delay price change. Even though price limits can stop the price of a stock from falling on the trading day when a stock hits its limit, the price will continue to move in a direction towards equilibrium on subsequent trading periods as new trading limits are established. Yea-Mow Chen (1993) concluded that price limits only prolong the number of trading days it will take for the market to adapt to a disturbance toward equilibrium.

The negative effect of the price limits was further highlighted in empirical research by Roll (1989) and Ma *et al.*(1989). Their studies reveal that price limits interfere with market liquidity.

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[2] William J. Brodsky. 1988. After the Crash. American Enterprise Institute for Public Policy Research : 59.

[3] M.H Miller. 1991. Volatility, episodic volatility and co-ordinated circuit-breaker. *Pacific-Basin Capital Market Research*. Vol. II:26

On the positive side, the Brady Commission (1988)[4] argued that price limits could provide a cooling-off period, allowing investors to re-evaluate market information and reformulate a new investment strategy. Price limits are also claimed to allow order imbalance to be publicized in order to attract value traders who will bring back the equilibrium.

The effectiveness of price limits is still being debated. Many questions remain unanswered. The questions raised are not just on the effectiveness of price limits, but also the implication of price limits enforcement on the market. Does it incite volatility to increase or cause the volatility to decrease? Does it affect market liquidity? Does it affect efficient market discovery process?

Amidst the skepticism on the effectiveness of price limits and the alleged negative impact on market liquidity, price limits are still been widely implemented among the exchanges across the world.[5] The regulators view the drawback of the price limits as a small price to pay in favor of its benefits. Meanwhile, economists view price limits as an unnecessary beast that interferes with the market process, especially efficient price discovery process and market liquidity.

Previous empirical research on effectiveness of price limits to curb excessive market volatility has produced mixed results. Yea-Mow Chen (1993) and Jung-Rock Chung (1991) who studied the Taiwan and Korea Stock markets respectively discovered that price limits are not effective in containing excessive fluctuations in the stock market. A study by Beni Lauterbach and Uri Ben-Zion (1993) on the Tel Aviv Stock Exchange (TASE) gave similar results. The result of these studies, however, could not be generalised to other markets because each of the studies focused on a single stock market where the trading environments are homogeneous.

Roll (1988) performed a comparative study of the October 1987 declines of 23 major stock markets in the world where trading environments are heterogeneous. The study revealed that price limits have no significant impact on the decline in price. Two years later, Bertero and Mayer (1993) performed a similar study on the same 23 markets. The study gave completely contrasting results. The study concluded that the markets that had circuit breakers in operation, on average declined by 7 per cent and 9 per cent (depending on the period) less than those which did not. This indicates the effectiveness of price limits to curb market declines.

KLSE enforced price limit rules on 4 May 1989. The limits were set at 15 per cent per trading session[6] for 'old' listing and 500 per cent for new listing.[7] Under this system, the stocks were prevented from rising above or falling below a predetermined price level for a trading session. The limits were doubled to 30 per cent for old listings on 15 December 1989. The limits remain unchanged till today. It would be interesting to see whether the price limits enforced about a decade ago remain effective amidst numerous changes on factors influencing market volatility.

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[4] Presidential Task Force on market Mechanism (Brady Commission). 1988. Government Printing Office, Washington, DC

[5] Federation Internationale des Bourses de Valeur. 1991. Report 1991 on Hypervolatility, 1-32.

[6] The KLSE has two trading sessions per trading day. The first trading session runs from 9:00 am to 12:30 pm, while the second trading session runs from 2:30pm to 5:00 pm

[7] Refers to Members' Circular No 1511 of 1989.

The objective of this study is to examine the performance of price limits enforced by the KLSE which is to curb excessive short-term price fluctuation on share prices traded on the KLSE.

2. Data and Methodology

The study is based on a total of 635 counters traded daily on KLSE from 20 April 1994 to 30 May 1997, a period of over 600 trading days. The data after 30 May 1997 are excluded from the study to avoid bias. Stock price behavior after this date was considered to be abnormal as a result of the currency turmoil that plagued the South Asian nations. The bearish sentiment worsened from July following the devaluation of Thai Baht and Philippine Peso.

Initially, a total of 782,630 data sets were identified as records that hit the price limits in the period of study. Then stock selection was refined further by excluding non-ordinary stocks (preferential shares, warrants, debentures, loan stocks and bonds), stocks with incomplete data and stocks which made their 'maiden appearance' on KLSE (new listing).

Non-ordinary stocks were excluded because most of their prices were extremely low, ranging from RM1.00 to 10 Sen. For these stocks, a marginal increase in price results in a limit hit. For example, for a stock with a reference price of 10 Sen, an increase of 3 Sen will result in the share price hitting a limit up. These stocks dominated our sample (more than 60 per cent) before they were excluded. Inclusion of these stocks in our sample would definitely cause a bias in our study because they do not represent the actual behaviour of ordinary stocks. For these reasons, non-ordinary stocks were excluded from the sample.

New listings were excluded because their price limits were set at a much higher level, at 500 per cent of its offered price. Stocks with incomplete data were excluded because they would cause unexpected results in the study. Stocks with zero trading volume, zero closing, opening, highest or lowest prices and zero share capital were considered as incomplete data. Calculation of turnover ratio to measure the trading activity, for example, is impossible if the share outstanding for a stock is recorded as zero in the database. For this reason, these data were excluded from our stock selection.

The data were adjusted to reflect capital distribution that includes stock splits, capital reductions, right offering and stock dividends.

The methodology used for this study was modeled after a similar study by Kim and Rhee (1977) who studied the performance of price limits on the Tokyo Stock Exchange (TSE). The study utilized data of TSE from 1989 to 1992 – a period of 4 years.

The method used by Kim and Rhee (1977) was chosen because there is a similarity between price limits system implemented in KLSE and TSE. The price limits system in the TSE was not changed or revised during the duration of the study by Kim and Rhee (1977). Similarly, the price limits system on KLSE was not revised for the period selected for this study. If the limits had been changed at any time during the period of study, the method would not be suitable for use.

However, there are a few differences between price limits implementation between these two markets. One difference is in the price limits re-establishment. On TSE, the price limits for individual securities is re-established for each trading day, based on the previous day's closing price, whereas, on KLSE price limits for individual securities is re-established every trading session, based on previous trading session's closing price (on KLSE, there are

two trading sessions per day, morning and afternoon). The second difference is in the rate of price limits. The limit for KLSE is fixed at 30 per cent for all 'old' stocks, regardless of the price of the stocks while on TSE, price limits vary between 30 Yen to 5,000 Yen depending on the price of the stocks. The higher the price of the stocks, the higher the price limits.

The first step in data analysis for this study was to select stocks that reached their price limits (referred to as $Stock_{hit}$). The stock is considered to reach its upper limit for a trading session if its highest price for the session is equal to its upper price limit for the session. The stock is considered to reach its lower limit for a trading session if its lowest price for the session is equal to its lower price limit for the session. The highest and lowest price limits for a session are pre-calculated and readily available for retrieval from data obtained from SCANS[8] database for each stock.

Special computer programs were developed to extract relevant information from data obtained from SCANS. The programs scan through all trading data from January 1994 to May 1997 and extract relevant information for $Stock_{hit}$. This information is written to a special file for further processing. This information is then massaged or formatted to produce a file in a special format required for this study.

Once the $stock_{hit}$ has been extracted and the date of the price limits hit had been determined, the trading database was scanned a further two times, first to extract stocks that reached at least 90 per cent of their daily limits (refer to $Stock_{0.9}$ henceforth), and second to extract stocks that reached at least 80 per cent but below 90 per cent of their daily limit (refer to $Stock_{0.8}$). As in the case of the $Stock_{hit}$ group, the data extracted for $Stock_{0.9}$ and $Stock_{0.8}$ were written to special files and massaged to produce a file in special format as required by this study.

Now we had three groups of stocks for analysis, namely $Stock_{hit}$, $Stock_{0.9}$ and $Stock_{0.8}$. These three groups of stocks were used to test the performance of the price limits system on KLSE via three hypotheses namely, Volatility Spillover, Delayed Price Discovery and Trading Interference.

3. The Results

3.1 The Volatility Spillover Hypothesis

From a micro-economic perspective, share prices are determined by market forces. If the demand exceeds supply, competition between buyers and sellers will cause prices to rise; if supply exceeds demand, competition between sellers will cause the prices to fall; and if the demand equals supply, the price will be at equilibrium. If this equilibrium were perturbed by an exogenous shock which changes the magnitude of demand or supply, the system will seek a new equilibrium. However, if there were interference on this efficient price discovery process, such as imposition of price limits that impede price movement, the prices would be pent-up and prevented from discovering their equilibrium. Consequently, there would be some unrealised demand or supply. This interference would prolong the process of reaching a new equilibrium. If the prices were excessively volatile then the excessive volatility would

[8] Acronym for Securities Clearing Automated Network Services, a subsidiary company of KLSE.

be spread over to the next trading days before the new equilibrium is reached. This is the basis for the volatility spillover hypothesis. It postulates that interference with normal price discovery process would cause the volatile share prices to spread over to the next trading days.

To test the hypothesis, we compared the behaviour of stocks that had experienced disturbance in price movement against the stocks that had not experienced disturbance. We choose the $Stock_{hit}$ group which had experienced price disturbance, and examined its behaviour in relation to volatility spillover characteristics and compard against the behaviour of normal stocks proxied by $Stock_{0.8}$ and $Stock_{0.9}$. We considered $Stock_{0.8}$ and $Stock_{0.9}$ as normal stocks because these stocks had not experienced disturbance in their price movement.

To study the behaviour of the three stock groups, we used a 21-day event window, Day-10 to Day+10, where Day 0 represents the day the price limits were hit, Day –1 represents a day before Day 0 and Day+1 represents a day after Day 0. For $Stock_{0.8}$ and $Stock_{0.9}$, Day 0 represents the day the stock experienced reaching 80 per cent and 90 per cent of its limits respectively.

Stock price volatility for each of these stocks group was calculated for each day, beginning from Day-10, ten days prior to limit hit day, to Day 0, the limit hit day, to Day+10, ten days after the limit hit day. To measure daily price volatility, the following formula was used:

EQUATION 1 - Volatility measurement

$V_{t,j} = (r_{t,j})^2$ where $\mathbf{r_{t,j}}$ represent close-to-close return using Day_{t-1} and Day_t closing price for each stock *j*

After calculating the daily volatility for each stock group, we calculated the average volatility for each stock category ($Stock_{hit}$, $Stock_{0.8}$ and $Stock_{0.9}$) for each day *t*. We then used non-parametric Wilcoxon signed-rank test to compare the volatility for each stock subgroup for each day *t*.

Formally, the null hypothesis to test the effect of price limits on volatility spillover between all three stock groups can be stated as follows:

HYPOTHESIS 1- Volatility Spillover Hypothesis

H_0: *Ceteris paribus*, $Stock_{hit}$ group experiences the same price volatility during post-limit days as the $Stock_{0.8}$ and $Stock_{0.9}$ groups.

To simplify our study, only stocks that hit upper limits were analysed. Stocks that hit lower limits were excluded from analysis. This is consistent with the method used by Kim and Rhee (1977) in their study. They argued that the findings on the lower limit-hit were expected to be similar to the findings on the upper limit-hit. Based on this argument, we could safely discard the need to analyse stocks that hit the lower limit without impairing the results of our study.

Table 1. Volatility for day -10 to day +10

Day	$Stock_{hit}$	*vs*	$Stocks_{0.90}$	$Stock_{hit}$	*vs*	$Stock_{0.80}$	$Stock_{0.90}$	*vs*	$Stock_{0.80}$
-10	92.986		202.846	92.986		121.844	202.846		121.844
-9	81.326		140.876	81.326		91.764	140.876		91.764
-8	95.837		193.327	95.837		129.320	193.327	>	129.320
-7	105.412	>	153.354	105.412		103.339	153.354	>	103.339
-6	124.535		152.916	124.535		104.385	152.916	>	104.385
-5	131.500		151.439	131.500		87.045	151.439		87.045
-4	143.251		200.438	143.251		432.907	200.438	>	432.907
-3	150.924		350.204	150.924		138.194	350.204		138.194
-2	306.764		849.445	306.764	>>	228.149	849.445	>>	228.149
-1	644.292	>>	351.211	644.292	>>	346.539	351.211	>>	346.539
0	9388.889	>>	2216.952	9388.889	>>	1078.306	2216.952	>>	1078.306
+1	3001.237	>>	444.963	3001.237	>>	210.093	444.963	>>	210.093
+2	732.008	>>	282.954	732.008	>>	179.722	282.954	>>	179.722
+3	342.241	>	186.609	342.241	>	118.554	186.609	>>	118.554
+4	366.811	>>	195.859	366.811	>>	77.984	195.859	>>	77.984
+5	207.945		162.781	207.945	>>	83.150	162.781	>>	83.150
+6	283.183	>>	158.855	283.183	>>	106.590	158.855	>>	106.590
+7	121.621		140.570	121.621		99.570	140.570	>>	99.570
+8	170.383		158.959	170.383		64.088	158.959	>	64.088
+9	202.066		133.161	202.066		62.046	133.161	>>	62.046
+10	171.150		140.133	171.150	>>	91.862	140.133	>>	91.862

Where: >> and > signify that left hand volatility measure is greater than the right hand measure at the 0.01 and 0.05 levels of significance respectively.

For stocks that hit price limits on consecutive days, the first hit day was considered as Day 0. The subsequent hit days were not considered as a separate event (or Day 0) to avoid volatility bias in our study. This method is also consistent with the method used by Kim and Rhee(1977).

3.1.1 Empirical Results for Volatility Spillover Hypothesis

Table 1 summarises the volatility (multiplied by 10^3) for $Stock_{hit}$, $Stock_{0.90}$ and $Stock_{0.80}$.

We observed a large drop in volatiliy for $Stock_{hit}$, a day after limit hit day as also indicated in Figure 1. This observation is consistent with previous studies by Kim and Rhee (1977) and Ma (1989). Based on this observation, Ma (1989) concluded that price limits have effectively reduced volatility. Kim and Rhee (1977) however disputed this claim, arguing that volatility will naturally decline after an extremely large volatility day. They pointed out that the volatility for the other two stock groups demonstrates similar behaviour despite the absence of price limits. In this regard, we agree with the insight of Kenneth and Rhee. That is, this observation alone is not sufficient to conclude that the price limits effectively curb price volatility. The large volatility drop on Day+1 is a natural phenomena as demonstrated by the other two stock groups, $Stock_{0.90}$ and $Stock_{0.80}$.

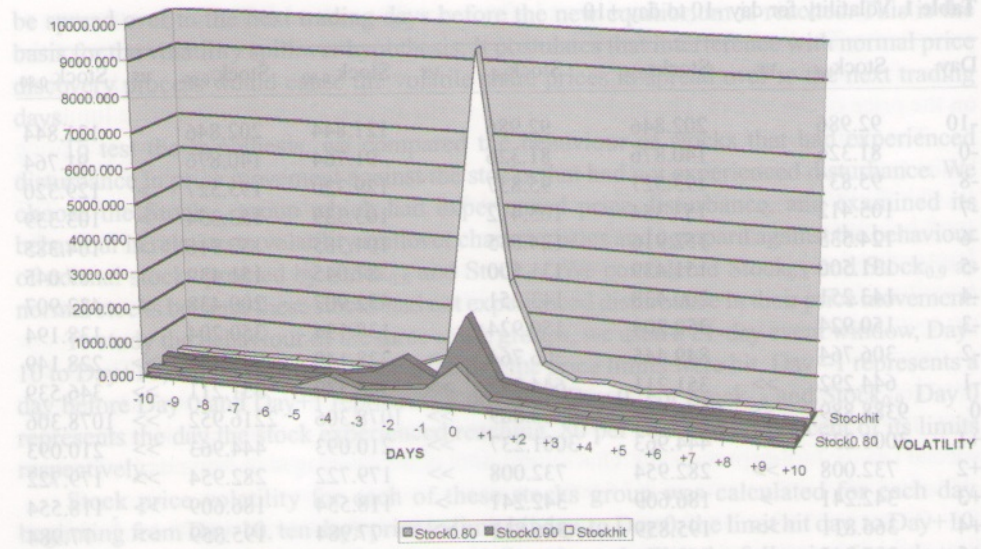

Figure 1. Volatility for Day -10 to Day + 10

Second, the comparative volatility pattern between $Stock_{hit}$ and $Stock_{0.9}$ showed statistically significant differences in volatility magnitude from Day-1 to Day+6. The volatility of $Stock_{hit}$ was statistically larger at 0.05 or 0.01 level from Day-1 to Day+6, except for Day+5. This observation seems to indicate that there is evidence of volatility spillover effect induced by price limits hit. The volatility was observed to remain high, six days subsequent to Day-0, the limit-hit day.

Third, comparative volatility between $Stock_{hit}$ and $Stock_{0.8}$ showed statistically significant differences in volatility from Day-2 to Day+6 and Day+10. The volatility for $Stock_{hit}$ was statistically larger over these periods at 0.05 or 0.01 significant level reinforcing our earlier finding that there is evidence of price limits inducing volatility to be spilled over to the next trading days. In both cases the volatility appeared to persist until the next six trading days after Day 0. These observations are consistent with the study by Kim and Rhee (1977) on TSE. They argued that these observations occur due to price limits preventing stocks that reach their daily price limits from correcting their order imbalance thereby hampering the price adjustment process. The effects of a trading halt (price limits) hampering the price adjustment process was also recorded by Lee *et al.* (1994).

Comparative volatility between $Stock_{0.9}$ and $Stock_{0.8}$ showed that volatility for $Stock_{0.9}$ is statistically larger at 0.05 or 0.01 levels than the volatility for $Stock_{0.8}$ from Day-2 to Day+10. This observation seems to indicate that absence of price limits to curb price volatility caused the price volatility to remain high on Day 0 and persist until Day+10. This observation is inconsistent with the observation made by Kim and Rhee(1977). This observation also seems to indicate the existence of the 'magnet effect' whereby investors are drawn to trade their share in anticipation of a trading halt, causing volatility to be persistently high for the next ten trading days after Day 0. On a closer look, however this interpretation can be dismissed because the volatility on trading days prior to Day 0 for $Stock_{hit}$ were not persistently statistically significant. Should the 'magnet effect' exist, then the volatility on trading days

prior to Day 0 would be persistently high, indicating increased interest from investors to trade their shares in anticipation of a trading halt on Day 0.

The above result seems to show that there is evidence of volatility spillover for $stock_{hit}$ which has experienced price limits hit. The volatility remains high six days after the limit hit day and stabilises onwards. This seems to imply that price limits enforced on the KLSE has induced the volatility to spillover to the next trading days.

3.2 *The Delayed Price Discovery Hypothesis*

The Delayed Price Discovery Hypothesis postulates that stocks which experience reaching upper price limits would have positive overnight returns while stocks which experience reaching lower price limits would have negative overnight returns.

To examine the effect of price limits on delayed price discovery, we compared the behaviour of return series unique to $Stock_{hit}$ group against the return series of normal stocks, proxied by $Stock_{0.8}$ and $Stock_{0.9}$. The comparison was based on an examination of stock price movement subsequent to price-limit-hit on limit-hit day. Stocks that had not reached their price limits ($Stock_{0.8}$ and $Stock_{0.9}$) would go through the normal price discovery process, while stocks that had reached their price limits ($Stock_{hit}$) would not. The price limits would delay the efficient price discovery process for these stocks.

To test the hypothesis, we first examined two return series on the limit day, namely open-to-close return series and close-to-open return series. The open-to-close return series is measured by $LN(C_0/O_0)$ and close-to-open return series is measured by $LN(O_1/C_0)$, where LN is natural log, O_0 denotes open price on the limit-hit-day, O_1 denotes open price on a day after the limit day, C_0 denotes the close price on the limit-hit day, and C_1 denotes the closing price a day after the limit-hit day. Stock returns can be positive (+), negative (-) or zero (0). By arranging return series in a pair of open-to-close and close-to-open series, nine return series are possible, namely, [+,+], [+,-], [+,0],[-,+],[-,-], [-,0], [0,+], [0,-] and [0,0].These return series can be categorised into three price trends. First, Price Reversal in which a price change is reversed in a direction from one transaction to the next (price goes up after a decrease or decline after an increase). Second, Price Continuation in which a price change is followed by another price change of the same sign (a decrease is followed by a decrease, or an increase is followed by an increase). Third, price unchanged in which a price remains at the same level.

We classified the return series into six subgroups, three for stocks that hit upper limit and the remaining three for stocks that hit lower limit. The subgroups are tabulated in Table 2.

Table 2. Return series for stocks that hit upper and lower limits

Trends	Stocks hit upper limits	Stocks hit lower limits
Price Reversal	[+,-] or [0,-] or [-,+] or [-,0] or [-,-]	[-,+] or [0,+] or[+,-] or [+,0] or [+,+]
Price Continuation	[+,+] or [0,+]	[-,-] or [0,-]
Price Unchanged	[+,0] or [0,0]	[-,0] or [0,0]

Frequency of Price Reversal, Price Continuation and Price Unchanged were calculated for stocks that hit upper limits for each stock group. Similarly, frequency of Price Reversal, Price Continuation and Price Unchanged were calculated for stocks that hit lower limits for each stock group. These frequencies were statistically compared to determine whether Price Continuation occurs more for $Stock_{hit}$ than the other two stock groups. The test of significance was conducted at 0.01 and 0.05 level of significance.

The null hypothesis for delayed price discovery can be stated as follows:

HYPOTHESIS 2: H_0: *Ceteris paribus*, Price continuation behaviour of $Stock_{hit}$ is the same as the Price continuation behaviour of normal stocks as proxied by $Stock_{0.8}$ and $Stock_{0.9}$.

To be consistent with the methodology used by Kim and Rhee (1977), we did not exclude consecutive limit days from our sample since this would only underestimate the frequency of price continuation.

3.2.1 Empirical Results for Delay Price Discovery Hypothesis

As advocated by this hypothesis, we expected to see price continuation behaviour for $Stock_{hit}$ to be greater than normal to conclude that price limits delayed efficient price discovery.

Price behaviour of the two stock groups, $Stock_{0.9}$ and $Stock_{0.8}$ represented normal price behaviour since their price movements were not constrained by the price limits. Hence their price discovery process was not perturbed by price limits thereby following an efficient price discovery process. For this reason, we did not expect to see these stocks with a definite behavioral pattern in respect to Price Reversal and Price Continuation. In contrast, price movement for $Stock_{hit}$ group was dampened by the price limit thereby causing a delay in the price discovery process for this stock group. For this reason, we expect to see $Stock_{hit}$ group experience greater Price Continuation behaviour than the other two stock groups. Table 3, tabulates the frequency of Price Continuations, Price Reversals and No Change for all three stock groups.

Table 3. Frequency of price continuations and reversals for the entire sample

Price Behaviour	$Stock_{hit}$	$Stocks_{0.90}$	$Stock_{0.80}$	$Stock_{hit}$ - $Stock_{0.90}$ (z-value)	$Stock_{hit}$	-$Stock_{0.90}$ (z-value)
Upward Price Movements						
Continuation	0.713	0.440	0.322	0.274 (6.907)	0.391	(10.486)
Reversal	0.121	0.292	0.266	-0.171 (-4.7060	-0.145	(4.118)
No change	0.166	0.268	0.411	-0.103 (-2.909)	(-0.246)	(-6.260)
Downward Price Movements						
Continuation	0.400	0.102	0.042	0.298 (2.207)	0.358	(4.010)
Reversal	0.200	0.729	0.750	-0.529 (-2.660)	-0.550	(-2.840)
No change	0.400	0.169	0.208	0.231 (1.374)	0.192	(1.055)

For the upper limit hit, $Stock_{hit}$ experienced Price Continuation 71.3% of the time; Price Reversal 12.1% of the time and No Change 16.6% of the time. The observations for $Stock_{0.9}$ showed a contrasting pattern, with the frequencies of Price Continuation, Price Reversal and price No Change at about the same level Price Continuation occurred 44.0% of the time, Price Reversal occurred 29.2% of the time and No Change 26.8% of the time. For $Stock_{0.8}$, the respective frequencies were even closer; the Price Continuation occurred 32.2% of the time, Price Reversal occurred 26.6% of the time and No Change 41.4% of the time.

For the lower limit, $Stock_{hit}$ experienced Price Continuation 40.0% of the time; Price Reversal 20.0% of the time and No Change 20.0% of the time. The observations for $Stock_{0.9}$ and $Stock_{0.8}$ showed a contrasting pattern, the frequencies of Price Reversal were more dominant at 72.9% and 75.0% respectively.

The above observation seems to support the delayed price discovery hypothesis for several reasons. First, Price Continuation occurred more frequently for $Stock_{hit}$ than for $Stock_{0.9}$ and $Stock_{0.8}$ for both the lower and upper limits. The *z*-statistics calculated to measure the differences in Price Continuation frequency between the stock groups were statistically significant for both the upper and lower price limits. For the upper price limits, the *z*-statistics for differences in Price Reversal frequency between $Stock_{hit}$ and $Stock_{0.9}$ was at 6.907 (much greater than 1.96, our hypothesis rejection criteria). Meanwhile the *z*-statistics for $Stock_{hit}$ and $Stock_{0.8}$ was at 10.486 (again much greater than the value set in our hypothesis rejection criteria). For the lower price limits, the *z*-statistics were much lower at 2.207 (differences between Price Continuation frequency of $Stock_{hit}$ and $Stock_{0.9}$) and 4.010 (differences between Price Continuation frequency of $Stock_{hit}$ and $Stock_{0.8}$). These observations suggest that price limits delay the price discovery process and cause the prices to resume its Price Continuation trend after Day 0. These observations also suggest that the price limits seem to induce overreaction behaviour instead of preventing it.

Second, the frequencies of Price Reversal were greater for $Stock_{0.9}$ and $Stock_{0.8}$ as compared to $Stock_{hit}$ for both upper and lower price limits. This implies that the stocks that have not experienced price constraint as a result of imposition of price limits experienced Price Reversal more frequently in the absence of price limits. This again suggests that price limits seem to prevent prices from reaching their equilibrium prices on Day 0. These observations are consistent with the observation by Kim and Rhee (1977) on TSE who concluded that there is evidence to support the delayed price discovery hypothesis as a result of imposition of price limits and that price limits do not seem to prevent overreaction behaviour.

George and Hwang (1995) and Lehmann and Modest (1994a; b) observed that the above behaviour can also caused by the maximum price variation rules rather than price limits. For this reason, Kim and Rhee (1977)performed a further test to determine the actual cause of this behaviour. As KLSE has not imposeed price variation rules, no further tests were required to be performed.

3.3 The Trading Interference Hypothesis

The Trading Interference Hypothesis postulates that if there is trading interference for a stock, the trading volumes for the stock are expected to increase on the subsequent day.

Thus for $Stock_{hit}$, where the price limits interfere with stocks liquidity, the trading volumes for this stocks are expected to increase after the limit-hit day, while trading volume for the other two stock groups are expected to stabilise or decrease after the limit-hit day.

To test the hypothesis, we needed to examine and compare the trading activity behaviour of all three stock groups each day from Day-5, five days prior limit hit day, to Day 0, the limit hit day and Day+5, five days after limit hit day. We used turnover ratio to measure the trading activity:

EQUATION 2- Turnover Ratio

$$\text{Turnover ratio: } TA_{i,j} = TVOL_{t,j}/SOUT_{t,j}$$

where $TVOL_{t,j}$ - trading volume for each stock j on day t

$SOUT_{t,j}$ - total number of shares outstanding for stock j on day t

The ratio was calculated for each stock group and the percentage change in trading activity from the previous day was calculated using the following formula:

EQUATION 3- Percentage Change in Trading Activity

$$\text{Percentage change in trading activity} = LN(TA_{j,t} / TA_{j,t-1})*100.$$

where LN -natural logarithm

We then calculated the daily mean of percentage change for each Stock *j* and compared the daily means for each stock category for each day *t*. Wilcoxon singed-rank test was used to test the hypothesis at 0.01 and 0.05 significance level.

Formally, the null hypothesis for the trading interference can be stated as follows:

HYPOTHESIS 3- The Trading Interference Hypothesis

H_0: *Ceteris paribus*, trading activity behavior for $Stock_{hit}$ is as normal (as proxied by $Stock_{0.8}$ and $Stock_{0.9}$) after limit-hit day.

To be consistent with the methodology used by Kim and Rhee (1977) we excluded the consecutive limit-days.

3.3.1 Empirical Results for Trading Interference Hypothesis

We expected to find the trading activities, as represented by turnover ratio for $Stock_{hit}$ group, to increase after limit-hit-day. This is because price limits are expected to prevent rational trading on the hit-day and interfere with the liquidity. As a result, the $Stock_{hit}$ group was expected to be intensely traded on the subsequent trading days. Consequently, the trading activity for $Stock_{hit}$ group was expected to remain high after limit-hit-day. In contrast, the trading activity for the other two groups, $Stock_{0.9}$ and $Stock_{0.8}$ were expected to stabilise or

Table 4. Trading interferences: upper limit reaches

Day	$Stock_{hit}$	vs	$Stock_{0.90}$	$Stock_{hit}$	vs	$Stock_{0.80}$	$Stock_{0.90}$	vs	$Stock_{0.80}$
-5	45.53%		28.76%	45.53%		22.47%	28.76%		22.47%
-4	-26.56%		-17.77%	-26.56%		-23.09%	-17.77%		-23.09%
-3	30.71%	>	28.11%	30.71%		29.32%	28.11%		29.32%
-2	4.99%		-10.25%	5.04%	>	-14.37%	-10.25%		-14.37%
-1	61.85%		48.10%	61.85%		44.11%	48.10%		44.11%
0	132.73%		125.02%	132.73%	>>	93.89%	125.02%	>>	93.89%

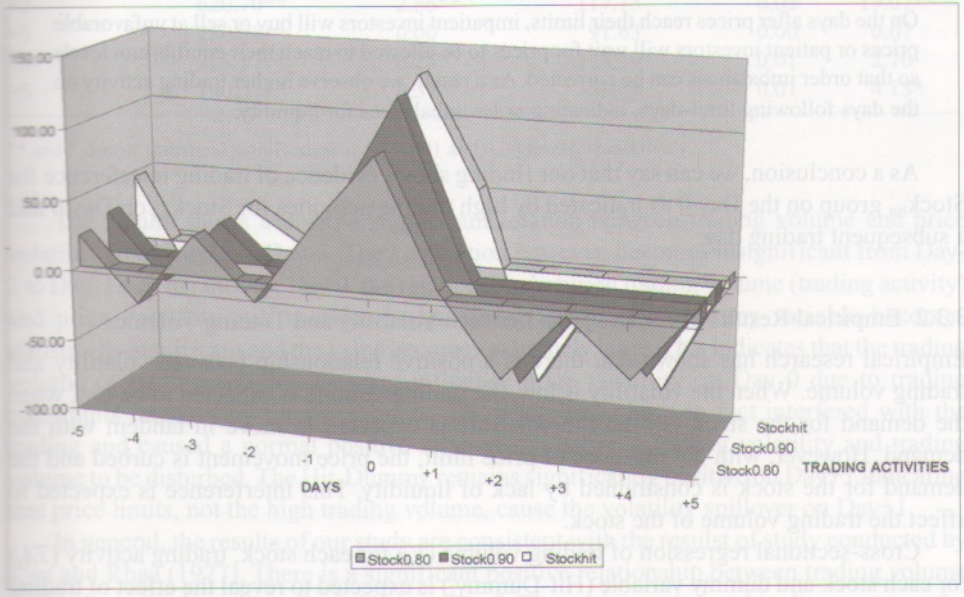

Figure 2. Trading activities for Day -10 to Day + 10

decrease. This is because the trading of these stock groups were not affected by the price limits.

Table 4 and Figure 2 summarise the day-to-day trading activities for each stock group. We observed that the trading activities are highest on Day 0 for all three stock groups, $Stock_{hit}$, $Stock_{0.9}$ and $Stock_{0.8}$. The trading activities remain significantly high for $Stock_{hit}$ on the Day+1

We observed that the trading activities were highest on Day 10 for all three stock groups, $Stock_{hit}$, $Stock_{0.9}$ and $Stock_{0.}$ The trading activities remained significantly high for $Stock_{hit}$ and stabilised for the other two stock groups. From Day+2 to Day+4, the trading activities for all three stock groups showed an overall decline.

These observations suggest that the price limits seem to interfere with trading for $Stock_{hit}$ on Day 0. Traders can no longer transact these stocks freely on the hit-day because the trading for these stocks had been temporarily halted. This would cause order imbalance and

interference to liquidity. As a result, stocks traders are forced to wait for the subsequent day to take their trading position, causing the trading activity to remain high. In contrast, stock traders can freely transact $Stock_{0.9}$ and $Stock_{0.8}$ because their price movements are not constrained by the price limits. Therefore there is no interference to the liquidity. As a result demand and supply for the stocks could be realised on the hit-day itself. Consequently, the trading activity for these stock groups would stabilise on the subsequent trading days.

The results of our study are consistent with a similar study conducted by Kim and Rhee (1977) on the Taiwan stock market. Kim and Rhee (1977) explain this phenomena by quoting the explanation given by Lehman and Modest(1994) who conduced a similar study on the Tokyo Stock Exchange:

> On the days after prices reach their limits, impatient investors will buy or sell at unfavorable prices or patient investors will wait for prices to be allowed to reach their equilibrium levels so that order imbalances can be corrected. As a result, we observe higher trading activity on the days following limit-days, indicating order imbalances for liquidity.

As a conclusion, we can say that our finding shows evidence of trading interference for $Stock_{hit}$ group on the Day 0 as indicated by high trading activities for $Stock_{hit}$ on Day 0 and a subsequent trading day.

3.3.2 Empirical Results of Relationship between Volatility and Trading Volume

Empirical research has shown that there is a positive relationship between volatility and trading volume. When the volatility is low, the trading volume is expected to be low, when the demand for the stock is high the volatility is expected to move in tandem with the demand. However, with the presence of price limit, the price movement is curbed and the demand for the stock is constrained by lack of liquidity. This interference is expected to affect the trading volume of the stock.

Cross-sectional regression of trading volume (V_j) for each stock, trading activity (TA_j) for each stock and dummy variable ($Hit\text{-}Dummy_j$) is expected to reveal the effect of trading interference on trading volume. Among the signs showing the effect of trading interference on the trading volume as reported by Kim and Rhee(1977) are: trading activity variable to be significantly positive on all pre-limit days; trading activity variable to be insignificant on the limit-hit day signifying lack of positive relationship between volume and trading activity due to trading constraint imposed by price limits; the dummy variable to be significantly positive on the limit-hit day showing that the volatility can be explained by dummy (price-limit-hit) variable; dummy variable to remain significant a few days after the limit-hit day.

Table 5 summarises the regression results on the relationship between volatility and trading volume.

From the table we observe that trading activities variable are significantly positive from Day-5 to Day-3 and become statistically insignificant from Day-2 to Day-1. On Day 0, the trading activities remain insignificant but the Hit-Dummy variable becomes relatively large and statistically significant. The Hit-Dummy remains relatively large and statistically significant on the following trading day, Day+1. Thereafter, the Hit-Dummy variable becomes statistically insignificant.

Table 5. Relationship between volatility and volume

Day	Intercept	Trading activity	Hit-Dummy	Adj. R^2	*f*-value
-5	125.32**	0.63**	-143.52	0.03	9.72**
-4	221.74**	0.41**	-143.44	0.01	4.24*
-3	218.85**	0.39*	-164.40	0.01	2.65
-2	198.82**	0.15	80.78	0.00	1.79
-1	374.73**	0.15	80.78	0.00	2.29
0	5618.99**	-0.12	4474.26**	0.01	5.24**
+1	769.95**	-0.08	2270.80*	0.01	2.59
+2	620.70**	2.86**	-117.15	0.05	19.07**
+3	250.98**	0.00	91.63	0.00	0.67
+4	228.17**	0.25	113.29	0.01	2.70
+5	190.57**	0.37**	-53.61	0.01	4.13*

** and * denote statistical significance at the 0.001 and 0.05 levels, respectively.

The results shows a positive significant relation between trading volume and price volatility from Day-5 to Day-3. The association however, becomes insignificant from Day-2 to Day-1. On the hit-day, Day 0, the relationship between trading volume (trading activity) and price volatility still remains insignificant but the Hit-Dummy variable becomes statistically significant and the value becomes extremely large. This indicates that the trading volume or trading activity does not influence price volatility on Day 0 due to trading constraints imposed by the price limits. The price limits have in fact interfered with the trading and caused a normal positive relationship between trading volatility and trading volume to be disturbed. The Hit-Dummy remains significantly positive on Day+1 indicating that price limits, not the high trading volume, cause the volatility spillover on Day+1.

In general, the results of our study are consistent with the resulst of study conducted by Kim and Rhee (1977). There is a significant positive relationship between trading volume and trading activity prior to limit-hit days Day 0. The positive relationship disappears on the limit-hit day, Day 0, due to trading interference cause by the price limits. One Day+1, Hit-Dummy remains statistically significant indicating that price-limit-hit continues to explain the high volatility on this day. Subsequent to Day+1, Hit-Dummy becomes statistically insignificant indicating a lack of association between price limits and volatility.

We conclude that on Day 0, the price limits caused trading interference and disturbed a normal positive relationship between volatility and trading volume. The price limits also caused volatility to spillover on trading days subsequent to Day 0.

4. Conclusions and Implications

The above results seem to show that there is evidence of volatility spillover for $stock_{hit}$ which experienced price limits hit. The volatility remains high six days after the limit hit day and stabilises onwards. This seems to imply that price limits enforced on the KLSE have induced the volatility to spillover to the next trading days.

The findings from the Delay Price Discovery hypothesis appear to suggest that there is evidence of delay price discovery effect for stocks that have experienced price limit hit. This finding is supported by the fact that price continuation behaviour occurred more frequently for stocks that had experienced price limits hit than normal stocks. This finding appears to suggest that price limits disturb an efficient price discovery process on the limit-hit day. This finding also appears to suggest that the price limits disturb liquidity on the hit day causing order imbalance. As a consequence, the share was constrained from discovering its equilibrium price, causing demand or supply to be unrealised on the hit day. This implies that price limits are not effective in curbing price movement after the limit hit day. The price is likely to continue to slide down after the lower limit hit or the price is likely to continue to climb after the upper limit hit. These findings also seem to suggest that price limits induce over-reaction behaviour.

The findings from the Trading Interference Hypothesis seem to indicate that there is evidence of trading interference effect to stocks that have experienced price limit hit. This finding is concluded based on the fact that the trading activities for stocks that have experienced limit hit are statistically higher a day after the limit hit day. This finding appears to imply that price limits cause order imbalance and interference to liquidity. As a consequence, stocks traders are forced to wait for the subsequent trading days to take their trading position, causing the trading activities to remain high on post-limit trading day.

The finding from the effect of trading interference on trading volume reinforced our earlier finding on trading interference hypothesis. The results suggest that there is significant positive relationship between trading volume and trading activity prior to the hit day. The price limits however, seem to cause the positive relationship between trading volume and trading activity to disappear from the hit day onwards. This implies that price limits cause trading interference.

Overall, our evidence appears to suggest that price limits cause higher volatility level, delay efficient price discovery process and interfere in trading activity.

Our findings give several implications to investors and regulatory agencies. To investors, the findings seem to suggest that they should exercise extreme caution when trading excessively volatile stocks. Even though the returns are expected to be high, the risks are very high. Investors are likely unable to liquidate their trading position on the limit-hit day because the liquidity is expected to be badly affected. The trading halt on this stock is expected to cause price movements to be constrained thereby affecting liquidity.

Second, the finding of the study seems to suggest that volatility is indeed irrational. Therefore, investors, particularly retail investors and inexperienced investors, should exercise extreme caution when trading in the stock market.

To regulatory agencies, the findings seem to suggest that it is timely to review the price limits enforced with the objectives of softening the effect on efficient price discovery process and reducing the interference to trading activity while improving the level of effectiveness of price limits. The review is thought to be timely because the price limits have not been revised over the last nine years although the market structure and economic fundamentals have evolved greatly over the same period. Changes in market structure and economic fundamentals, globalisation of financial markets and the advent of advanced information technology may have transformed the characteristics of market volatility.

Apart from the above implications, regulatory agencies also should reinforce market surveillance activity and capability to identify the source of excessive volatility. Four known sources are fundamentals, institutional, speculation and manipulation. The fourth source of excessive volatility - manipulation of the market is unhealthy - thus it should be dealt with appropriately. However, market volatility caused by the other three elements is part of market mechanism and is therefore necessary to the market process. Without these elements, there would be no volatility and the market will be as good as dead.

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