Price Limit and Volatility in Taiwan Stock Exchange: Some Additional Evidence from the Extreme Value Approach

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We reexamine the effects of price limits on stock volatility of Taiwan Stock Exchange using a new methodology based on the Extreme-Value technique. Consistent with the advocates of price limits, we find that stock market volatility is sharply moderated under more restrictive price limits.

Keywords: Price limits; Extreme value theory; Volatility; Taiwan stock exchange.

1. Introduction
A great deal of theoretical and empirical research suggests that the microstructure of equity markets is an important determinant of securities market performance. There are several components in designing equity markets, such as trading mechanisms, market making and circuit breakers. After the stock market crash of October 1987, there were widespread concerns about the causes of the crash and whether the microstructure of the equity market should be closely monitored to protect the market from drastic fluctuations, and circuit breakers have been recommended as a mechanism

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for market stabilization. The most common and perhaps most primitive type of circuit breakers is the setting of price limits.\footnote{Price limits rules are applied in many stock markets around the world, including Austria, Belgium, France, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Spain, Switzerland, Taiwan, and Thailand. Price limits are also used in US the futures market.}

In this study, we compare volatility between three different price limits regimes applied on Taiwan Stock Exchange (TSE). We use a new methodology of comparing volatility based on the Extreme-Value approach. This study also aims to test the effect of price limits on the extreme-value parameters under different price limits regimes. The imposition of price limits affects the tails of the distribution of stock returns. If stock price reaches its limits, trading will be postponed on that stock. Price limits may cause volatility to spill over a longer period of time. This volatility spillover may affect the tails of the distribution of stock returns. Volatility spillover makes prices move smoothly and slowly to their equilibrium levels. However, in the absence of price limits, stocks are expected to react immediately to the new information and this will cause a big jump on prices that makes the tails of the distribution wider. Extreme Value Theory is expected to provide more accurate estimates of volatility on the markets that carry price limits. Fernandez (2003) argues that traditional parametric and non-parametric methods work well in areas of the empirical distribution where there are many observations, but they provide a poor fit to the extreme tails of the distribution. Extreme Value Theory offers a parametric estimate of tail distribution. To the best of our knowledge, our study is the first that tests the effect of price limits on volatility using Extreme Value Theory. It is also the first study that tests the effect of price limits on the Extreme Value parameters under different price limits regimes.\footnote{Bali and Neftci (2001) used the extreme value approach to estimate exceedances the term structure of interest rate volatility and they show that the standard approach that uses normal density overestimates the volatility of interest rate changes.}

The remainder of the paper is organized as follows. Section 2 reviews previous literature. Section 3 introduces the methodology employed in the study. Section 4 describes the data. The empirical findings are presented and discussed in Section 5. Finally, Section 6 provides conclusions.

2. Literature Review

There has been much debate about the desirability of price limits. Advocates of price limits claim that price limits prevent extreme price movements in
two ways. First, price limits literally set a ceiling and a floor in the range in which the price can move within a trading day. Second, price limits provide a cooling-off period (see Anderson, 1984; Arak and Cook, 1997; Greenwald and Stein, 1991; Ma, Roa and Sears, 1989a, 1989b; Chou et al., 2000; Lee and Kim, 1995; Kim and Rhee, 1997; Lee and Chung, 1996; Bernstein, 1987; Brennan, 1986; Koders, 1993). Other proponents claim that price limits facilitate price discovery by providing a “time-out” to pause, evaluate stock prices and publicize order imbalances to attract value traders and to cushion violent movements in the market. Price limits are also said to reduce the potential default risk (Brennan, 1986; Moser, 1990; Ma et al., 1989b), and counter overreaction (Cho et al., 2003).

On the other hand, critics of price limits posit that price limits reduce market liquidity by artificially interfering with trading activity. This problem caused by price limits is known as the trading interference hypothesis (see Fama, 1989; Telser, 1989; Lehmann, 1989; Lauterbach and Ben-Zion, 1993; and Kim and Rhee, 1997). In addition to the liquidity problem, the delay in price discovery is another costly problem induced by price limits. This happens because price limits prevent prices from reaching their equilibrium level effectively (see Fama, 1989; Lehmann, 1989; Lee et al., 1994; Figlewski, 1984; Kim and Rhee, 1997; Meltzner, 1989; Miller et al., 1987; Telser, 1981; Lee and Kim, 1995; Ma et al., 1989a, 1989b; Chiang et al., 1997; Kim and Rhee, 1997). The effects of trading interference using price limits may also weaken market efficiency (Fama, 1989; Lehmann, 1989; Lee et al., 1994). Instead of reducing volatility, price limits may cause volatility to spread over longer periods of time, because limits prevent one-day large enough adjustment, and prevent immediate correction in order imbalance (see Kim and Rhee, 1997; Lehmann, 1989; Fama, 1989; Kyle, 1988; Kuhn et al., 1991; Lee and Kim, 1995). Kim and Sweeney (2000) also argue that price limits can affect trading behaviour on non-limit hit days. In their model, informed traders strategically time their trading, taking the existence of price limits into account.

Phylaktis et al. (1999) and Nickolaos and Tsritakis (2005) examined the effect of price limits on stock price volatility in the Athens Stock Exchange. They compare volatility before and after the year 1992 (the year that ASE adopted price limits). Their results show that price limits have no effect on volatility. Chen (1993) applies an event-study methodology and a GARCH model to test the differences in volatility under several price limits regimes associated with the Taiwan Stock Exchange. His results suggest that price limits tend to slightly exacerbate price volatility; price limits rules did not
provide a cooling off effect on stock volatility except for the case of the tightening of the limits in October 1987. Kim (2001) compares volatility between six different price limits regimes applied on Taiwan Stock Exchange using the Levene test of volatility. The main conclusion of his paper suggests that stock market volatility is usually not lower (higher) when price limits are made narrower (wider). Yen and Yen (2001) apply spectrum analysis to examine the impact of price limits on stock price movements in Taiwan Stock Exchange. By comparing the two sub-periods falling between February 19, 1974, and December 18, 1978, as demarcated by a change of price limits from $\pm 3\%$ to $\pm 5\%$ on June 16, 1974, they found that a more narrow price limits reduces volatility in stock price at the expense of a longer adjustment period. By comparing the two sub-periods falling between January 1, 1987, and November 13, 1988 as demarcated by a change of price limits from $\pm 5\%$ to $\pm 3\%$ on October 26, 1987. In either volatility or speed of adjustment, no significant difference was found. The authors infer from the above empirical findings that the efficacy diminishes once the investors more or less anticipate the effects of the regulatory changes. In current study, we view the extreme value approach as an alternative way to re-examine the impact of price limits on stock price volatility which allows for weights of extreme returns.

3. Methodology

Extreme value theory is concerned with the modeling of extreme events and several authors in the last decade have noted it is relevant to the modeling of extreme price movements. It should be noted that though several authors have investigated the statistical distribution of returns and have concluded that returns are “fat tailed”, an overall fit of such process to historical data might not provide an adequate framework for analyzing extreme events. Instead, it is suggested that one should use EVT methodology.\(^3\) In this paper, we use this methodology to estimate the stock market volatility under the difference price limits regimes to see if more restrictive price limits in Taiwan lead to lower volatility. The basics of the statistical ideas are as follows.

Let \(\{X_t\}\) be a stochastic process representing the daily changes in stock market returns. We are concerned with the behaviour of the maximal and minimal changes in stock market returns. To find a limiting distribution for maxima \(X_{\text{max}}\), the maxima are transformed such that the limit distribution

\(^3\)General texts on EVT include Falk \textit{et al.} (1994) and Embrechts \textit{et al.} (1997).
of the new variable is non-degenerate. The simplest transformation is the standardization process. $X_{\text{max}}$ is transformed using a location parameter, $\alpha_i$, and a scale parameter, $\beta_i$ as follows:

$$x_i = \frac{(X_{\text{max}} - \alpha_i)}{\beta_i},$$

where $\alpha_i$ and $\beta_i$ can be observed as the mean and volatility of the extremes, respectively. One tries to find the $F(\cdot)$ as follows:

$$F(\beta_i x_i + \alpha_i) \rightarrow H(x),$$

where $H(x)$ is the cumulated distribution function defined as $P((X_{\text{max}} - \alpha_i)/\beta_i \leq x)$. There are three possibilities for the $H(x)$ in the case that the observations are independent identity distribution (i.i.d). These three parameters can be expressed in the generalized Pareto distribution of the form:

$$H(x) = \begin{cases} 
1 - (1 + \xi x)^{-1/\xi} & \text{if } \xi \neq 0 \\
1 - \exp(-x) & \text{if } \xi = 0 
\end{cases}$$

(3)

where

$$x = \frac{(X_{\text{max}} - \alpha)}{\beta} \geq 0 \quad \text{if } \xi \geq 0$$

$$0 \leq x = \frac{(X_{\text{max}} - \alpha)}{\beta} \leq -1/\xi \quad \text{if } \xi < 0.$$

The parameter $\xi$ is called the tail index and is related to the shape of the underlying distribution $F(\cdot)$. So called thin-tailed distributions, like the normal distribution, lead to the Gumbel case, $\xi = 0$; while fat-tailed distributions, like Student’s $t$-distribution and Pareto Distribution, lead to the Fréchet case, $\xi > 0$.

The above system is a standard parametric case and can be solved by maximum likelihood methodology. The generalized Pareto distribution in (3) has a density function such as:

$$h(x) = \begin{cases} 
\frac{1}{\beta} (1 + \beta x)^{-(1+\beta)/\beta}, & \beta \neq 0 \\
\frac{1}{\beta} \exp(-x), & \beta = 0 
\end{cases}$$

(4)

which produces the following log-likelihood function:

$$\ln L((\alpha, \beta, \xi)X_{\text{max}}) = -n \ln \beta - n \left( \frac{1 + \xi}{\xi} \right) \sum_{i=1}^{n} \ln(1 + \xi (X_{\text{max}} - \alpha)/\beta)$$

(5)

differentiating the log-likelihood function with respect to $\alpha$, $\beta$, and $\xi$ produces the first-order conditions of the maximization problem. Clearly, there
are no explicit solutions to these nonlinear equations. Thus, numerical procedures are called for.\footnote{For example, Prescott and Walden (1983) suggest variants of the Newton-Raphson scheme to solve a set of nonlinear equations given by the first-order conditions.}

4. Data

Similar to Kim (2001), we choose TSE because it has 11 different price limits regimes between the periods of 1962–2004 (see Kim, 2001). According to the Taiwan Stock Exchange Fact Book (2005), the number of listed companies on the TSE at the end of 2004 is 697. Daily closing prices are available only for the period 1987–2004. Daily closing prices for all live companies (697 companies) are downloaded from Datastream. The data also includes 74 dead companies that are also downloaded from Datastream. The total number of live and dead companies analyzed in this study is 741 companies.

Our sample period includes three different price limits regimes: the first price limits regime applied during the period October 27, 1987 to November 13, 1988, daily price limits were 3%. The second price limits regime applied during the period November 14, 1988 to October 10, 1989 gave daily price limits of 5%. Finally, the third price limits regime applied during the period October 11, 1989 to April 31, 2004, daily price limits was 7%.

Panel A of Table 1 provides summary statistics of TSE returns over the three regimes periods. The descriptive statistics over the three periods highlight the following: first, mean returns in the second price limit regime (November 14, 1988 to October 10, 1989) are slightly larger than in the first (October 27, 1987 to November 13, 1988) and third (November 11, 1989 to April 31, 2004) regime periods. Second, unconditional variances increased substantially in the third regime period.\footnote{The unconditional variances from the three regimes are statistically different using the Levene test for the homogeneity of variances ($F$-value = 185.29).} Particularly, moving from the first regime to the second and the third one, where the price limits were made less restrictive (from 3%, 5%, and 7%, respectively), we observe that the unconditional variance of stock returns increases, which is consistent with the view of the conventional wisdom and that of most regulators.\footnote{All pairwise variance differences are statistically significant using the $F$-statistic on the ratio of the two variances.} Finally, the change of price limits regimes has major effects on other descriptive statistics as well. Skewness and kurtosis increased substantially when moved
Table 1. Summary statistics.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>Max.</th>
<th>Min.</th>
<th>Std. Dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Jarque–Bera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Basic descriptive statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regime I</td>
<td>274</td>
<td>0.266</td>
<td>3.00</td>
<td>−3.00</td>
<td>2.012</td>
<td>−0.151</td>
<td>2.639</td>
<td>2.549</td>
</tr>
<tr>
<td>Regime II</td>
<td>236</td>
<td>0.375</td>
<td>5.00</td>
<td>−5.00</td>
<td>2.532</td>
<td>−0.071</td>
<td>3.056</td>
<td>0.232</td>
</tr>
<tr>
<td>Regime III</td>
<td>3928</td>
<td>0.271</td>
<td>7.00</td>
<td>−7.00</td>
<td>3.887</td>
<td>0.069</td>
<td>7.109</td>
<td>2767.0***</td>
</tr>
</tbody>
</table>

Panel B: Extreme daily stock returns

<table>
<thead>
<tr>
<th></th>
<th>Regime I</th>
<th>Regime II</th>
<th>Regime III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.04</td>
<td>0.69</td>
<td>−0.149</td>
</tr>
<tr>
<td>Max.</td>
<td>3.00</td>
<td>5.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Min.</td>
<td>−3.00</td>
<td>−5.00</td>
<td>−7.00</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>3.42</td>
<td>3.98</td>
<td>4.08</td>
</tr>
</tbody>
</table>

Notes: 1. Extreme values of daily returns changes are defined as excess over the threshold, which is set as the two standard deviations away from the sample mean of returns.
2. The symbol “***” denotes the rejection of normality at 1% significance level.

Table 2. Maximum likelihood estimates of the generalized Pareto distribution.

<table>
<thead>
<tr>
<th></th>
<th>Shape ($\xi$)</th>
<th>Location ($\alpha$)</th>
<th>Scale ($\beta$)</th>
<th>Log-Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regime I</td>
<td>−0.43598 (−2.5785)</td>
<td>0.07064 (3.6521)</td>
<td>0.07589 (4.8488)</td>
<td>1428.221</td>
</tr>
<tr>
<td>Regime II</td>
<td>−0.86066 (−2.1115)</td>
<td>0.08942 (4.0892)</td>
<td>0.09461 (4.9046)</td>
<td>1467.860</td>
</tr>
<tr>
<td>Regime III</td>
<td>−0.95112 (−2.4403)</td>
<td>0.18247 (5.4701)</td>
<td>0.19084 (5.4035)</td>
<td>1584.092</td>
</tr>
</tbody>
</table>

Notes: Asymptotic t-statistics are given in parentheses.

from more to less restrictive price limits regimes (where Jarque–Bera test statistics reject normality in the third regime).

Following the Extreme Value Theory, we defined the extremes as excesses over high thresholds. Specifically, the extreme changes are defined as those more than two standard deviations away from the sample mean of daily stock market returns, which correspond to approximately 2% of the right and left tails of the distribution. Panel B of Table 2 displays means, standard deviations, and maximum and minimum values of the extremes. Interestingly, the ratio of the extreme daily returns out of the total number of observations increased substantially when moved from more to less restrictive price limits regimes.

5. Results

In this paper, we investigate the effect of price limits on stock volatility in the TSE using the Extreme-Value method. We hypothesize that the imposition of more restrictive price limits tend to increase the tail index of the equity returns distribution (tail thickness of a distribution) by reducing the
probability of extreme returns, which in turn moderate the volatility of equity returns.⁷

Table 2 reports the maximum likelihood estimates of the location \((\alpha)\), scale \((\beta)\) and shape \((\xi)\) parameters, and the maximum log likelihood value of the generalized Pareto distribution for each price limit regime. As expected, it has indicated that the extreme return movements for all price limit regimes are created from Fréchet extreme-value distribution. The shape parameters for all price limits regimes are significantly less than zero. The most negative shape parameters are generated in a less restrictive price limits (regime III) period. This implies the higher probability to observe large price changes during less restrictive price limits periods than more restrictive price limit periods. Another indication that the returns are more extreme in less restrictive price limits regimes is exhibited by the location parameter estimates. The estimated location parameter \((\alpha)\) in the less restrictive price limits regime is relatively larger than its counterparts in more restrictive regimes (Regimes I and II). This indicates simply that the numbers of the extremes in regimes II and I are smaller than its counterpart in regime III.

![Volatility of extreme returns](image)

Fig. 1. Volatility of extreme returns.

⁷See, for example, Galbraith (2004).
The volatility of the extremes measured by estimated scale parameter \((\beta)\) increases gradually as we go from regime I to regime II to regime III. Particularly, when we go from regime I to regime II, where price limits are relaxed (from 3% to 5%), we find that volatility of the extremes increases. Likewise, going from regime II to regime III, when price limits are further relaxed (from 5% to 7%), we again observe that volatility increases. These results confirmed the hypothesis that the stock market is less volatile when price limits are more restrictive. Figure 1 depicts the volatility of extremes over different price limits range. Again, we can see that the stock market is less volatile when price limits are more restrictive. Therefore, it seems that restrictive price limits moderate the volatility in the TSE. As it now stands, conclusive evidence has to await further studies in view of the inconsistent empirical findings documented in the literature.

6. Conclusion

The main contribution of this paper is that it utilizes a new methodology of comparing volatility based on the Extreme-Value approach to test the effect of price limits on the stock market volatility. Using data from the TSE, the paper finds that the returns carry more extremes and volatility of the extremes is higher when price limits are less restrictive. Therefore, we can tentatively conclude that restrictive price limits moderate volatility, at least for the TSE. This conclusion is consistent with the conventional wisdom and the view of most regulators.

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References


