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Price limit bands, asymmetric volatility and stock market anomalies: Evidence from emerging markets☆

Hisham Farag

Helwan University, Cairo, Egypt

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ABSTRACT

I investigate the effects of imposing different bands of price limits on stock returns and volatility in the Egyptian (EGX), Thai (SET) and Korean (KRX) stock exchanges. In addition, the paper examines whether the switch from narrow price limits (NPL) to wider price limits (WPL) structurally alters volatility and the day of the week anomaly. Using the extended EGARCH and PARCH asymmetric volatility models, I found that the switch from NPL to WPL structurally altered both asymmetric volatility and the day of the week anomaly in the EGX, SET and KRX. I argue that the price discovery mechanism is disrupted due to the switch as closing prices do not fully reflect all information arrived in the market when prices hit the limits and that is reflected on volatility and market efficiency.

1. Introduction

Price limits are regulatory tools in both equity and futures markets in which further trading is prevented for a period of time with the intention of cooling market traders' emotions and reducing price volatility.[1] The trigger for such limits is when prices hit particular pre-specified price boundaries.[2] The proponents of price limits argue that they are efficient in reducing price volatility and providing time for both brokers and investors to adjust their portfolio positions. However, the opponents claim that these regulatory tools are useless as they lead to spreading out price volatility over a longer time, delaying price discovery, and

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E-mail address: h.farag@bham.ac.uk.

[1] Kim and Yang (2004) argue that there are three main categories of circuit breakers, namely, price limits, firm-specific trading halts and market-wide circuit breakers.

[2] Price limits have a long history and were first implemented in the Japanese rice futures market (the Dojima exchange) in the eighteenth century (see Chung and Gan, 2005). In 1917, price limits on cotton futures contracts were used in the US. The Chicago Board of Trade (CBOT) adopted this regulatory tool in 1925 (Kim and Yang, 2004).

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interfering with trading activity. See for example; Santoni and Liu (1993), Subrahmanyam (1994), Kim and Rhee (1997), Phylaktis, Kavussanos, and Manalis (1999), Lee and Chung (1996) and Ryoo and Smith (2002).

The efficient market hypotheses (EMH) state that stock prices should reflect all information disseminated in the market, so that price limits or any other regulatory policies may have a negative impact on stock markets (trading interference and volatility spillover hypotheses). In addition, imposing these regulatory polices implies a degree of market inefficiency and a clear violation of the semi-strong efficient market hypothesis, as price limits prevent stock prices from reaching their equilibrium levels (Kim & Rhee, 1997). Lee and Chung (1996) and Ryoo and Smith (2002) argue that price limits result in clear violation of the weak form market efficiency hypothesis as information is not fully reflected in closing prices when prices hit the limits in the Korean stock market. The existing body of the literature documents that price limits have three main effects namely volatility spillover, delayed price discovery mechanism and trading interference (Kim and Rhee, 1997). Lehmann (1989), Kim and Rhee (1997), and Lee, Ready, and Seguin (1994) among others argue that price limits interfere with the price discovery mechanism as imposing limits prevents prices from reaching their equilibrium levels and cause price volatility to spread out over the subsequent trading days following limits hit.

On the other hand, emerging stock markets are known to be more volatile and less efficient than well established markets. In particular, thinly trading markets are likely to be more risky and therefore the effect of shocks is greater than in larger, established markets. The existing body of literature on price limits investigates narrow price limits in many stock exchanges i.e. Tokyo and Athens Stock Exchanges (Kim and Rhee, 1997; Phylaktis et al., 1999). The empirical findings of these papers are mixed, therefore we cannot really decide whether narrow price limits decrease volatility and cool down the market. A question therefore arises as to whether price limits do in fact reduce price volatility, and secondly, do price limit regimes structurally alter *daily* stock returns and volatility. Finally, is there a relationship between these regulatory policies and stock market anomalies such as the day of the week phenomenon? There are a few stock exchanges over the world that have experienced a transition from narrow price limit to a combination of wider price limits and trading halts. However, there are no other studies – to the best of my knowledge – that have empirically investigated the relative efficiency of the alternative price limit regimes and the potential effect on stock market anomalies such as the day of the week effect. I try to fill this gap by using data from the Egyptian stock exchange (EGX), stock exchange of Thailand (SET) and Korean stock exchange (KRX). This paper then has two main objectives; firstly, it investigates the effects of imposing different bands of price limits on stock returns, volatility and the day of the week anomaly in the EGX, SET and KRX. Secondly, the paper examines whether the switch from narrow price limits (NPL) to wider price limits (WPL) structurally alters daily stock returns, volatility and the day of the week anomaly.

Using the extended EGARCH and PARCH time varying conditional variance models, I find that daily stock returns in EGX, SET and KOSPI are characterised by EGARCH and PARCH asymmetric volatility models with a generalised error distribution. Volatility persistence and clustering are highly significant for the three indices. I also found that negative shocks (bad news) have greater impact on conditional volatility compared with positive shocks (good news) for EGX30, SET and KOSPI. Thursday and Friday have positive and highly significant impact on returns for the SET and EGX30 respectively. However and consistent with the literature, Monday effect is reported in the SET. Results also show that there is no day of the week effect on returns in the KRX. Results suggest that the switch from narrow price limits (NPL) to wider price limits (WPL) structurally affects both asymmetric volatility and the day of the week anomaly in the Egyptian, Thai and Korean stock exchanges. Finally, The Power ARCH parameters are highly significant and their size is bigger within WPL windows. This suggests that the switch from NPL to WPL has significant and positive impact on conditional volatility of EGX30, SET and KOSPI market indices.

The paper has clear policy implications for the regulators in emerging markets as it investigates whether narrow or wider bands of price limits leads to more stock price stability and cool down emerging market volatility. Moreover as the paper links between the different regulatory policies and the day-of-the-week anomaly, it highlights potential causes of market inefficiency. The rest of the paper is organised as follows. Section 2 presents the literature survey and hypotheses development. Section 3 provides a brief background of the price limit regimes in EGX, SET and KRX. Section 4 describes the dataset. Sections 5 and 6 present details of the econometric modelling and the empirical results respectively. A conclusion is presented in a final section.

2. Literature review and hypotheses development

In this section I present the literature survey and hypotheses development. I classify the literature review into three main building blocks namely, price limits and volatility, price limits and market efficiency and day of the week effect on returns and volatility.

2.1. Price limits and volatility

The effects of price limits on volatility are extensively investigated in the literature, however the results are mixed. The proponents of price limits argue that these regulatory tools are efficient in cooling the market down and reduce price volatility. See for example Lauterbach and Ben-Zion (1993), Nath (2005), Kim, Yague, and Yang (2008a,b) and Berkman and Lee (2002). On the other hand the opponents of price limits argue that imposing ceiling/floor limits results in an increase in price volatility rather than cooling down the market as was intended. See for example in NYSE, Subrahmanyam (1994), Santoni and Liu (1993), Corwin and Lipson (2000) and Edelen and Gervais (2003). Another much smaller strand of the literature claims that price limits result in spreading out price volatility (volatility spillover hypothesis) and disrupt price discovery mechanism, in addition, they interfere with trading activity (Lee et al., 1994). George and Hwang (1995) and Kim and Rhee (1997) find evidence of delayed price discovery and volatility spillover hypotheses in Tokyo stock exchange. They argue that volatility is spread out over few days subsequent to limits hit and price limits prevent stock prices from reaching their equilibrium levels.

On the other hand, Lee et al. (1994) investigate the effect of trading halts/circuit breakers on volatility in the NYSE. They find evidence that trading halts fail to reduce price volatility and to cool the market down as was intended. Moreover, they also find that price are much noisier post trading halts due to speculative trading, overreactive behaviour and excessive media coverage which results in dispersion of investors' belief about equilibrium prices and leads to an increase in both trading volume and volatility. Christie, Corwin, and Harris (2002) and Kim et al. (2008a,b) find similar results in the US (Nasdaq) and the Spanish stock exchange respectively. In emerging markets, Phylaktis et al. (1999) examine the information and overreaction hypotheses in the Athens stock exchange[3] and find that price limits have no effect on volatility as they could not prevent excessive pessimism (optimism) being acted upon. Huang, Fu, and Ke (2001) find consistent results with the information and overreaction hypotheses as they find evidence of overnight price continuation following limits move and price reversals three days following limits hit in Taiwan. Chan, Kim, and Rhee (2005) find that there is no effect of price limits on the information asymmetry in the Kuala Lumpur Stock Exchange (KLSE). Bildik and Gülay (2006) and Chen, Rui, and Wang (2005) find evidence of the volatility spillover hypothesis in Istanbul and Chinese stock exchanges respectively. Finally, Berkman and Lee (2002) find substantial increase in price volatility and decrease in trading volume within wider price limits regime in the Korean stock exchange.

2.2. Price limits and market efficiency

The second building block of the literature survey is the effect of price limits on market efficiency; a much smaller strand of the literature have investigated the effect of regulatory policies on the market efficiency. Lee and Chung (1996) find evidence that price limits lead to market inefficiency in the Korean stock exchange. They argue that closing prices do not fully reflect all information arrived in the market as price limits interfere in trading mechanism and prevent stock prices from reaching their equilibrium levels. Interestingly, Ryoo and Smith (2002) find no evidence of the random walk hypothesis within narrow price limits band in the Korean stock exchange. However, within wider limit bands (15%) the random walk hypothesis was detected. Kohers,

[3] The Information hypothesis, states that in efficient markets where equilibrium price and volatility are driven by the arrival of information, there should be no difference in volatility as a result of the removal/imposition of a price limit. The overreaction hypothesis on the other hand, states that traders tend to overreact to information and subsequently correct their initial judgements. (Farag and Cressy, 2012).

Kohers, Pandey, and Kohers (2004) find that the day of the week anomaly is no longer prevailing in 1990s due to the enhancements in market efficiency in 22 developed markets. Recently, Farag and Cressy (2012) investigate the effect of regime change from narrow price limits to circuit breakers on the information arrival modes and the efficiency of the Egyptian stock market. They find evidence of the Mixture of Distributions Hypothesis (MDH) within the narrow price limit regime; however, they find that the Sequential of Information Arrival Hypothesis (SIAH) is prevailing within circuit breakers regime as new information spread out to all market participants over a period of several days subsequent to limit hits.

2.3. Day of the week effect on return and volatility

Few studies have investigated the day of the week effect on return and volatility using time varying conditional volatility models. See for example Berument and Kiymaz (2001), Kiymaza and Berument (2003), Baker, Rahman, and Saadi (2008), Ouzsoy and Güven (2006), Berument and Dogan (2012) and Charles (2010).[4] Berument and Kiymaz (2001) use the symmetric modified GARCH (1, 1) model and find evidence of the day of week effect on returns and volatility in the US. They also report that the highest volatility is observed on Fridays. Kiymaza and Berument (2003) using GARCH model find that the release of the macro economics news has an impact on the day of the week anomaly in the US and UK markets. Recently, Berument and Dogan (2012) investigate the stability of stock returns volatility for the US market indices. They find evidence that the day of the week anomaly varies across markets when conditional variance is allowed to vary across the days of the week. Charles (2010) investigates the day of the week effects on volatility in France, Germany, US, UK and Japan using asymmetric GARCH models and find evidence that the day of the week effect is sensitive to the time varying estimation model. However, they find that the day of the week effect on the conditional variance does not improve the forecasted volatility. Baker et al. (2008) find that Tuesday has the highest conditional volatility in the Canadian stock market. In addition, the distribution assumptions of stock returns in time varying conditional volatility models might lead to variant day of the week effect.

In emerging markets, Aggarwal and Rivoli (1989) find significant negative returns on Tuesday in Hong Kong, Malaysia, the Philippines, and Singapore. However, they attribute this to the Monday effect in the New York Stock Exchange (NYSE), as these markets are 13 hours ahead of the NYSE. Alexakis and Xanthakis (1995) using EGARCH-M, find a structural break in both volatility and the day of the week anomaly in the Greek stock exchange as the result of the changes in regulations. Monday effect was found pre event, however Tuesday effect was reported post event. Choudhry (2000) finds evidence of the day of the week anomaly on returns and volatility in seven Asian countries. They argue that these effects are not identical for all stock markets due to a potential spillover from the Japanese stock market. Chandra (2006) find consistent results with Choudhry (2000). Their results show that the day-of-the-week effect on returns and the conditional correlations varies in Asia-Pacific equity markets. Ouzsoy and Güven (2006) investigate the turn of the month (TOM) effect[5] in Istanbul stock exchange (IUSE). They find – using EGARCH model – highly significant returns for the periods surrounding the TOM anomaly (days -4 to -2 and $+5$ to $+9$). Based on the above discussion I formulate the following hypotheses:

H1. Daily stock returns are characterised by asymmetric volatility.

H2. The switch from narrow price limits (NPL) to wider price limits (WPL) structurally alters the day of the week anomaly.

H3. The switch from narrow price limits (NPL) to wider price limits (WPL) structurally alters stock returns volatility.

[4] The literature on the day of the week anomaly has extensively used ordinary least squares regression. See for example, Gibbons and Hess (1981), Rogalski (1984), Jaffe and Westerfield (1985), Smirlock and Starks (1986), Board and Sutcliffe (1988), Aggarwal and Rivoli (1989), Solnik and Bousquet (1990), Balaban (1995), Arsad and Coutts (1997), Tong (2000), Ouzsoy and Güven (2003) and Tonchev and Kim (2004).

[5] The last trading day of the previous month and the first four trading days of the current month.

3. Price limits in EGX, SET and KRX

EGX trading regulations initially (in February of 1997) maintained a 5% ceiling/floor restriction over a stock's price, compared to its closing price in the previous trading session. On 21 July 2003, the EGX commenced a new price ceiling system, whereby the daily price limit was widened to $\pm 20\%$ and if the stocks weighted average price exceeded ± 10 % from its opening price during the trading session, the trading would be halted for half an hour. When the session was resumed, if the stock's weighted average price exited the 20% band, trading on this stock would be halted until the end of the session. It is worth mentioning that the normal trading days in the EXG is from Sunday to Thursday.

SET initially (before December 1st 1997) introduced symmetric $\pm 10\%$ price limits on daily closing prices. The regulator in the SET – due to the growth in market capitalisation – widened the upper and lower limit bands to $\pm 30\%$ over a stock's price, compared to its closing price in the last trading session. To mitigate any potential volatility and to protect investors, and when the SET market index falls by 10% compared to its closing price in the last trading session trading would be halted for 30 minutes and if the SET index falls by 20% the trading would be halted for 60 minutes.

Before April 1995 KRX maintained 4.6% price limits per day (ceiling/floor) on closing prices. The Korean regulator adjusted the price limits over the period 1995–1998 due to market expansion to 6% (from April 1995–November 1996), 8% (from November 1996 to March 1998), 12% (from March to December 1998) and finally to 15% (from December 1998 to date).

4. Data

Daily closing price data were collected from DataStream database for EGX30 (1998–2011), SET (1995–2011) and KOSPI (1989–2011). The EGX30 was initially launched in 2003 as a free-float market capitalisation weighted index and was retroactively computed as of 1 January 1998 with a base value of 1000 points. The EGX30 is, like most world indices, weighted by the market capitalisation of its constituent stocks. It avoids cross holdings and industry concentration and excludes bankrupt companies and any companies ‘consumed’ in merger and acquisition deals. To reflect market activity, the index is rebalanced and updated every six months.

SET composite is a market capitalisation weighted price index for all common stocks listed in the main board of the stock exchange of Thailand. SET was initially launched in April 1975 with base points of 100. SET is adjusted as the result of corporate actions e.g. IPO and exercised warrants. The SET composite index excludes stocks that have been suspended from trading for more than a year. Due to the remarkable growth in the Korean stock exchange (KRX), the regulator adopted a market capitalisation based index, namely KOSPI (Korea Composite Stock Price Index) index in January 1983 with base points of 1000. The total number of the constituents of KOSPI is 35 stocks, and the index is adjusted regularly to well represent the market prices.

5. Econometric modelling

In this section I present the econometric models used to examine the testable hypotheses.

5.1. Daily returns

The return variable R_t is defined as the log of the index's proportional price change over one day.

$$R_t = \ln(p_t/p_{t-1}) \tag{1}$$

where p_t is the closing price of the stock in day (t).

5.2. Asymmetric volatility models: EGARCH and PARCH estimations

To investigate the effects of different bands of price limits on stock returns and volatility and whether the change in regulatory policies from (NPL) to (WPL) affects both returns, asymmetric volatility[6] and the day of the week anomaly, I estimate the Exponential Asymmetry GARCH model (EGARCH of Nelson (1991)) and (PARCH of Taylor (1986) and Schwert (1989)) for the EGX30, SET and KOSPI market indices and for two subsamples namely NPL and WPL.[7] The EGARCH and PARCH models have many advantages over the symmetric GARCH as the estimation has no negative parameters (both log (σ_t^2) and σ_t^δ are positive), and so, no non-negativity constraints need to be imposed on the model parameters as in TARCH-GJR model.

I augment both EGARCH and PARCH models by adding the day of the week dummies as in Eq. (2) following Berument and Dogan (2012). The main motivation for using these two models is the leverage effect and to capture the long memory stock returns behaviour (see Kiymaza and Berument (2003) and Farag and Cressy, 2012).[8]

$$R_t = \alpha_n \sum_{n=1}^{5} Dum + \sum_{i=1}^{p} \alpha_i R_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \varepsilon_t \qquad (2)$$
$$\varepsilon_t \sim GED(0, h_t)$$

where $\alpha_1 \sum_{j=1}^{5} Dum$ are dummy variables for the day of the week. They each take the value of 1 on the respective day of the week and 0 otherwise. The serial correlation of the error series noted above suggests that we should model daily returns as an ARMA process. ε_t follows the Generalised Error Distribution (GED) with mean zero and conditional variance h_t as suggested by Nelson (1991)[9] as in Eq. (3).

$$I(\Theta)_t = \ln\left(\frac{v}{\lambda}\right) - \left(\frac{1}{2}\right)\left|\frac{\varepsilon_t}{h_t \lambda}\right|^v - \left(1 + \frac{1}{v}\right)\ln(2) - \ln\left(\Gamma\left(\frac{1}{v}\right)\right) - 0.5\ln\left(h_t^2\right) \qquad (3)$$

where $\lambda = \exp((-1/v)\ln(2) + (1/2)\ln(\Gamma(1/v) - (1/2))\ln(\Gamma(3/v)))$, and v is a tail thickness parameter. When $v = 2$, u_t has a Standard normal distribution. Finally, I use the Berndt–Hall–Hall–Hausman (BHHH) technique to maximise the log likelihood function of the GED.

Following Berument and Dogan (2012) and Kiymaza and Berument (2003), I incorporate the day of the week in the conditional variance equation for both EGARCH and PARCH to model the conditional variability in stock returns. Therefore, I allow the constant term of the conditional variance equation to vary for each day. I exclude the dummy variable for Tuesday to avoid the dummy variable trap in the conditional variance equation. The conditional variance equation of EGARCH is presented below.

$$\ln\left(\sigma_t^2\right) = \omega + \sum_{j=1}^{q} \beta_j \ln\left(\sigma_{t-j}^2\right) + \sum_{k=1}^{r} \gamma_k \frac{\mu_{t-k}}{\sqrt{\sigma_{t-k}^2}} + \sum_{i=1}^{p} \alpha_i \left[\frac{|\mu_{t-i}|}{\sqrt{\sigma_{t-i}^2}} - \sqrt{\frac{2}{\pi}}\right] + \eta \sum_{j=1}^{4} DUM_t \qquad (4)$$

[6] I use the sign and size bias tests of Engle and Ng (1993) on the raw data to explore the nature of time-varying volatility. Significant sign and size bias tests suggest that the asymmetric GARCH models are likely to be a better fit to stock return volatility.

$$\hat{u}^2{}_t = \phi_0 + \phi_1 S_{t-1}^- + \phi_2 S_{t-1}^- u_{t-1} + \phi_3 S_{t-1}^+ u_{t-1} + v_t$$

$\hat{u}_t^2$ is the standardized residual of the estimated ARMA process or GARCH model which equals ε_t/h_t. S_{t-1}^- is dummy variable takes the value of 1 if $\hat{u}_{t-1} < 0$ and zero otherwise, S_{t-1}^+ dummy variable picks out observations with positive innovations $S_{t-1}^+ = 1 - S_{t-1}^-$, v_t is IID error term. A joint test statistic is formulated in the standard fashion by calculating TR^2 from the above equation which will asymptotically follow x^2 distribution with 3 degrees of freedom under the null hypothesis of "no asymmetric effects".

[7] OLS is initially estimated to examine the day of the week effect however, the model is subject to heteroskedastic error term and thus the standard errors are likely to be underestimated.

[8] To capture the long memory behaviour and following the referee comments, the model may be estimated using the FIEGARCH and FIEGARCH-M models. However – according to the assumptions of the FIEGARCH – the autocorrelations of absolute returns always increase with the magnitude of the asymmetry regardless of its sign, in addition, the number of risk factors will increase when including more lags (see Christensen & Nielsen, 2007). I used the Power ARCH model to capture stock returns long memory behaviour in this paper however I intend to further investigate this phenomenon and the effect of the different short and long memory models on the day of the week effect in a future research.

[9] I used Student-t distribution following Baker et al. (2008) in addition to the GED and obtained similar results.

where:

$\ln(\sigma_t^2)$ is the conditional variance of return at time (t)
$\beta_j \ln(\sigma_{t-j}^2)$
is the conditional variance at time (t-1)

$\alpha_i \left[\frac{|\mu_{t-i}|}{\sqrt{\sigma_{t-i}^2}} - \sqrt{\frac{2}{\pi}} \right]$

is the effect of the shock (i.e. new information arrival) on conditional volatility.
$\gamma_k \frac{\mu_{t-k}}{\sqrt{\sigma_{t-k}^2}}$ is the effect of positive and negative shocks on conditional volatility (leverage effect).
$\sum_{j=1}^{5} Dum_t$ is a set of dummy variables takes the value of 1 on the respective day of the week and 0 otherwise.

On the other hand, the PARCH or Power ARCH model was initially introduced by Taylor (1986) and Schwert (1989) as the standard deviation GARCH. Ding, Granger, and Engle (1993) generalise this model with the Power ARCH specification to capture the long memory behaviour of stock returns. In his model the power parameter (δ) of the standard deviation is estimated rather than imposed as in Eq. (3)

$$\sigma_t^\delta = \omega + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^\delta + \sum_{i=1}^{p} \alpha_i \left(|\mu_{t-i}| - \gamma_i \mu_{t-i} \right)^\delta + \eta \sum_{j=1}^{4} DUM_t \tag{5}$$

where $\delta > 0, |\gamma_i| \le 1$ *for* $i = 1,.....r, \gamma_i = 0$ *for all* $i > r$, *and* $r \le p$

The power term δ captures both conditional standard deviation (when $\delta = 1$) and conditional variance (when $\delta = 2$). I use the Power ARCH model or PARCH as it not only captures the long memory behaviour of stock returns but the model also incorporates six other ARCH model extensions as special cases[10] (Charles, 2010).

Leverage effect (the effect of positive and negative shocks on the future conditional volatility) is allowed and the parameter γ is expected to be negative in sign (in EGARCH model) if the relationship between return and volatility is negative. The leverage effect can be tested by the hypothesis that $\gamma < 0$. The impact is asymmetric if $\gamma \ne 0$ in both EGARCH and PARCH models. The volatility persistence is measured by β to examine whether big (small) shocks are followed by bigger (smaller) shocks in both models.

6. Empirical results

Table 1 presents the descriptive statistics for the EGX30, SET and KOSPI market indices respectively.

The average returns for the overall sample of the EGX30, SET and KOSPI are 0.05%, −0.002% and 0.01% respectively. We notice that the highest daily returns are reported at the end of the trading week 0.17% on Thursday and 0.25% on Friday for the EGX30 and SET respectively. However the highest average daily returns observed for KOSPI (0.07%) is on Wednesday. Consistent with the literature, negative average daily returns are found on Mondays for the three indices. Skewness, Kurtosis and the highly significant Jarque–Bera statistics, show that EGX30, SET and KOSPI returns are leptokurtic, negatively skewed and fat-tailed relative to the normal distribution.

Table 2 presents the diagnostic tests for the EGX30, SET and KOSPI market indices respectively.[11] The Q_{20} Box and Pierce tests for serial correlation on the first 20 lags of standardised residuals reject the null hypothesis that stock returns are serially uncorrelated. They are positively correlated through time. The Ljung–Box and LMARCH tests reject the null hypothesis that there is no ARCH effect. Thus we can apply the GARCH models with confidence that volatility converges to a long run value around a deterministic trend.

I examine the stationarity of daily returns by using the Augmented Dickey Fuller (ADF) with lag length determined by Akaike Information Criterion (AIC) and the KPSS test with lag length determined by the

[10] ARCH when $\delta = 2$, $\gamma_i = 0$, and $\beta_j = 0$, GARCH when $\delta = 2$ and $\gamma_i = 0$, GJR-GARCH when $\delta = 2$. The Threshold ARCH of Zakoian (1994) when $\delta = 1$, the non linear ARCH of Higgins and Bera (1992) when $\delta = 2$ and $\gamma_i = 0$ and finally the log-ARCH of Geweke (1986) when $\delta = 0$.

[11] I estimate the diagnostic tests for two sub samples namely NPL and WPL and obtained similar results. Results are available from the author upon request.

Table 1
Descriptive statistics for daily stock returns.

	Mean	Max	Min	Std. dev.	Skew	Kurt	Jarque Bera
EGX 30							
Sun	0.0016	0.1838	−0.1104	0.0205	0.7300	13.164	3026.72***
Mon	−0.0007	0.0731	−0.1052	0.0165	−0.6847	7.1704	550.72***
Tue	−0.0005	0.0634	−0.1799	0.0188	−1.4667	15.716	5016.78***
Wed	0.0004	0.0684	−0.0935	0.0174	−0.4888	6.3423	364.80***
Thurs	0.0017	0.1041	−0.1110	0.0170	−0.0647	9.0868	1105.81***
All days	0.0005	0.1838	−0.1799	0.0178	−0.3124	11.911	12064.96***
SET							
Mon	−0.0028	0.1259	−0.1256	0.0215	0.4321	8.2747	951.10***
Tue	−0.0006	0.1030	−0.1723	0.0186	−0.6884	14.1393	4467.03***
Wed	0.0010	0.1143	−0.1252	0.0199	0.1451	7.5617	748.67***
Thurs	−0.0004	0.1043	−0.0765	0.0187	0.6176	7.6052	809.89***
Fri	0.0025	0.1219	−0.1123	0.0185	0.6572	10.9996	2330.39***
All days	−0.00002	0.1259	−0.1723	0.0189	0.2287	10.0858	9438.69***
KOSPI							
Mon	−0.0005	0.1002	−0.1237	0.0220	0.0736	6.5344	615.26***
Tue	−0.00003	0.0664	−0.0779	0.0159	−0.0290	5.9042	413.09***
Wed	0.0007	0.0816	−0.1280	0.0170	−0.3380	7.8997	1193.66***
Thurs	0.0002	0.1128	−0.0991	0.0179	0.0817	7.8721	1161.49***
Fri	0.0003	0.0737	−0.1117	0.0173	−0.5328	7.2243	933.19***
All days	0.0001	0.1128	−0.1280	0.0181	−0.1214	7.4287	4828.84***

This table reports the descriptive statistics of daily stock returns for the EGX30, SET, and KOSPI market indices. ***, **,* indicate significance at the 1%, 5% and 10% levels.

Newey–West Bandwidth selection criterion. Results show that daily stock return of EGX30, SET and KOSPI are stationary.[12] I use the Chow breakpoint test for each index subsamples (NPL and WPL) to examine whether there is a structural change in the estimated return equation due to regime switch from NPL to WPL.[13] Results show that there is a significant difference in the estimated return equations for both EGX30 and SET, which indicates structural change in the return time series due to the switch from the NPL to WPL. F statistic is highly significant ($p < .001$), also the log likelihood ratio and Wald statistic are highly significant for EGX30 and SET market indices.[14] However results of Chow test for KOSPI market index suggest that there is no structural break due to the regime switch. Finally, the Engle and Ng's F. test is reasonably significant confirming the leverage effect, so that asymmetric GARCH models are best fit stock returns volatility in EGX30, SET and KOSPI market indices.[15]

Table 3 presents the results of the day of the week effect on both return and asymmetric volatility using the EGARCH and PARCH asymmetric volatility models. Results show that Thursday has positive and highly significant return for the EGX30. However and consistent with the literature, there is Monday effect in the SET as Monday has negative and significant return for the two estimated models in addition, Friday is found to have positive and highly significant returns. For the KOSPI, results show that there is no day of the week effect on returns in the KRX, however Monday is found to have negative returns. The results presented in Table 3 are consistent for both EGARCH and PARCH models.

[12] The null hypothesis of the ADF is “stock returns are stationary and the null hypothesis of the KPSS” is “stock returns are nonstationary”.

[13] The F-statistic is based on the comparison of the restricted and unrestricted sum of squared residuals.

[14] Results are not presented but available from the author upon request. The log likelihood ratio statistic is based on the comparison of the restricted and unrestricted maximum of the (Gaussian) log likelihood function; however the Wald statistic is computed from a standard Wald test of the restriction that the coefficients on the equation parameters are the same in all subsamples. Both the LR test and Wald statistic have an asymptotic x^2 distribution with degrees of freedom equal to $(m\text{-}l)k$ under the null hypothesis of no structural change, where (m) is the number of subsamples.

[15] The results of Engle and Ng sign and size bias tests also show that negative shocks (bad news) and positive shocks (good news) have a different impact upon future volatility for EGX30, SET and KOSPI market indices.

Table 2
Diagnostic tests.

	ADF	KPSS	Q(20)	Q2(20)	LM ARCH	Chow stat.	EN
EGX 30	−49.3601***	0.3592	189.21***	629.86***	24.5436***	3.9914***	2.8049**
SET	−43.5310***	0.4609	109.22***	1532.5***	35.9087***	8.8902***	1.9835**
KOSPI	−72.6864***	0.1239	31.837**	1295.3***	23.6723***	1.6881	2.4702**

The table reports tests for serial correlation (Box and Pierce), ARCH effects (Ljung–Box and Lagrange Multiplier), stationarity (Augmented Dickey Fuller or ADF and Kwiatkowski, Phillips, Schmidt and Shin or KPSS) and finally the Chow break point test. ***, **, * indicate significance at the 1%, 5% and 10% levels.

On the other hand, the estimated conditional variance suggests that, daily stock returns are characterised by EGARCH and PARCH asymmetric volatility models with a generalised error distribution (GED parameter < 2 in all windows). Volatility persistence measured by β is highly significant and quite high (0.89, 0.93 and 0.94 on

Table 3
The day of the week effect on return and asymmetric volatility.

	EGX30		SET		KOSPI	
	EGARCH	PARCH	EGARCH	PARCH	EGARCH	PARCH
Mean equation						
Sun	0.0004 (0.0005)	0.0005 (0.0005)				
Mon	−0.00001 (0.0004)	0.00008 (0.0004)	−0.0010** (0.0004)	−0.0009** (0.0004)	−0.0002 (0.0004)	−0.0002 (0.0004)
Tue	−0.00003 (0.0005)	−0.00003 (0.0005)	−0.0002 (0.0004)	−0.0002 (0.0004)	−0.0005 (0.0003)	−0.0005 (0.0003)
Wed	0.0001 (0.0004)	0.00007 (0.0005)	0.0005 (0.0004)	0.0005 (0.0004)	0.0006* (0.0003)	0.0005 (0.0003)
Thurs	0.0014*** (0.0004)	0.0015*** (0.0004)	−0.0002 (0.0004)	−0.0002 (0.0004)	0.0005 (0.0003)	0.0004 (0.0003)
Fri			0.0013*** (0.0004)	0.0012*** (0.0003)	0.0006 (0.0004)	0.0006 (0.0004)
Conditional variance equation						
ω	−0.4660*** (0.0852)	0.0002 (0.0001)	−0.3728*** (0.1016)	0.00002 (0.00004)	−0.7336*** (0.0652)	−0.0004 (0.0003)
α	0.3009*** (0.0193)	0.1640*** (0.0136)	0.1845*** (0.0169)	0.1060*** (0.0130)	0.2142*** (0.0159)	0.1064*** (0.0095)
γ	−0.0216* (0.0124)	0.0815** (0.0401)	−0.0404*** (0.0093)	0.1848*** (0.0404)	−0.0637*** (0.0082)	0.2818*** (0.0389)
β	0.9548*** (0.0064)	0.8340*** (0.0122)	0.9775*** (0.0041)	0.8839*** (0.0116)	0.9801*** (0.0033)	0.8921*** (0.0088)
Sun	0.1309 (0.0911)	0.0002 (0.0002)				
Mon	−0.4266*** (0.1206)	−0.0004** (0.0002)	0.3389** (0.1494)	0.00039** (0.0002)	0.6723*** (0.0834)	0.0009** (0.0004)
Wed	−0.1877* (0.1092)	−0.0001 (0.0001)	0.1504 (0.1524)	0.00001 (0.0001)	0.4773*** (0.0934)	0.0006* (0.00035)
Thurs	−0.2018* (0.1069)	−0.0002 (0.0002)	−0.1233 (0.1262)	−0.0001 (0.0001)	0.3873*** (0.0777)	0.00049* (0.0003)
Fri			−0.1034 (0.1188)	−0.0001 (0.0001)	0.4775*** (0.0754)	0.0007* (0.0004)
δ		1.4622*** (0.11269)		1.8239*** (0.2539)		1.4555*** (0.1713)
GED	1.3157	1.3153	1.1312	1.1516	1.4459	1.4456
LLR	10102.14	10097.63	12359.55	12373.06	16404.28	16403.39
Q(20)	14.842	14.925	12.324	21.995	27.767*	16.452
Q2(20)	18.514	20.052	0.7699	6.6835	20.414	23.776
LM ARCH	1.0394	1.273801	0.1127	0.3290	0.9919	1.1273

The table presents the results of the day of the week effect on both returns and conditional variance using EGARCH and PARCH formulation of Eqs. (4) and (5). ***, **,* indicate significance at the 1%, 5% and 10% levels.

average) for the EGX30, SET and KOSPI respectively. Volatility clustering measured by α is also highly significant for the EGX30 SET and KOSPI; this suggests that, the bigger the shocks to the system the higher the volatility clustering (short-run volatility[16]).

Results show that the leverage effect is significant as $\gamma \neq 0$ for the EGX30, SET and KOSPI; therefore negative shocks (bad news) have greater impact on conditional volatility compared with positive shocks (good news), (Farag and Cressy, 2012). The Power ARCH parameter δ is highly significant for the three indices; this suggests that the PARCH model is well specified and fits the distributional assumptions of EGX30, SET and KOSPI market indices. I control for the day of the week in the conditional variance equations of EGARCH and PARCH to allow the constant term of the conditional variance equation to vary for each day. I exclude Tuesday dummy to avoid the dummy variable trap. Results show that Monday has a negative and significant impact on conditional volatility for the EGX30; however, the estimated volatility is likely to be higher on Sunday. Volatility is likely to increase on Monday for SET and KOSPI as Monday is found to be positive in sign and significant. We notice also that the day of the week effect on conditional volatility for the KOSPI is the highest compared with EGX30 and SET as positive and significant coefficients are reported for both EGARCH and PARCH models. These results are consistent with Berkman and Lee (2002) and Ryoo and Smith (2002).

Furthermore, we can reject the null that the residuals are serially uncorrelated and homoskedastic as the results of the Ljung–Box $Q_{(20)}$ and Ljung–Box $Q^2_{(20)}$ for serial correlation and the LMARCH for heteroskedastisity are insignificant for the extended EGARCH and PARCH models.[17] Finally, I investigate the existence of nonlinear dependence of the residuals in Eqs. (4) and (5) using the BDS test. The reported z values are statistically insignificant[18]; therefore we cannot reject the null hypothesis that the series in question is i.i.d. This suggests that the residuals are linearly dependent and the model is well specified (see Brock, Dechert, Scheinkman, & LeBaron, 1996). In sum the results presented in Table 3 show that daily stock returns in EGX30, SET and KOSPI are best characterised by asymmetric volatility models. Thus I cannot reject the first hypothesis.

Table 4 presents the results of regime switch from NPL to WPL on both asymmetric volatility and the day of the week phenomenon using the PARCH asymmetric volatility model.[19] The results of the mean equation show that there is no day of the week effect during the strict narrow price limit band (± 5) for the EXG30, however, Thursday effect (positive and highly significant coefficient) is clear within the wider price limit band. For the SET index, we notice that Monday effect disappeared when regulator widened the limit bands to 30%. However, I find that Thursday has negative and significant impact on stock returns within NPL window while Friday has a positive and highly significant impact on stock returns within WPL window for the SET.

Although the results presented in Table 3 do not support the day of the week effect for the KOSPI, I find that this phenomenon is structurally altered due to the switch. Monday and Tuesday have negative and significant impact on reruns within NPL window however Wednesday, Thursday and Friday have positive and highly significant effects on the stock returns for the KOSPI within WPL window. The results of the mean equations also suggest that the day of the week phenomenon has structurally altered due to the switch from NPL to WPL for the KOSPI.

Table 4 presents similar results of those presented in Table 3, as daily stock returns and volatility are characterised by PARCH asymmetric volatility model with a generalised error distribution (GED parameter < 2 in all windows). The coefficients of volatility clustering, persistence and leverage (α, β and γ) are highly significant however, their size is bigger within WPL window for EGX30, SET and KOSPI indices. For example, volatility clustering coefficients (α) increase from 10% to 19%, 7% to 10% and 16% to 18% for the EGX30, SET and KOSPI respectively. We also notice that the leverage effect is structurally altered from negative and significant within the NPL window to positive and highly significant within WPL

[16] Kim and Rhee (1997) found that volatility is spread out over 3–4 days following limits hit.

[17] I also find insignificant Engle and Ng, Sign and size bias test, indicating that including the leverage effect in EGARCH and PARCH models eliminates both sign and size effects. Results of EN are not presented but available from the author upon request.

[18] Results are not presented and available from the author upon request.

[19] I estimate the effect of regime switch from NPL to WPL on both asymmetric volatility and the day of the week phenomenon using the EGARCH asymmetric volatility model and obtained similar results. Results are available from the author upon request.

Table 4
The effect of regime switch on the day of the week and asymmetric volatility.

	EGX 30		SET		KOSPI	
	NPL	WPL	NPL	WPL	NPL	WPL
Mean equation						
Sun	0.00004 (0.0006)	0.0011 (0.0008)				
Mon	0.0001 (0.0005)	−0.0005 (0.0008)	−0.0033*** (0.0011)	−0.0004 (0.0004)	−0.0012** (0.0006)	0.0004 (0.0005)
Tue	−0.0007 (0.0006)	0.0010 (0.0008)	−0.0013 (0.0009)	0.00004 (0.0005)	−0.0016*** (0.0005)	0.0003 (0.0004)
Wed	0.0001 (0.0006)	−0.0001 (0.0007)	0.0011 (0.0016)	0.0007* (0.0004)	−0.0002 (0.0005)	0.0011** (0.0005)
Thur	0.0010 (0.0008)	0.0020*** (0.0007)	−0.0028** (0.0012)	−0.00002 (0.0005)	−0.0008* (0.0005)	0.0013*** (0.0005)
Fri			0.00005 (0.0011)	0.0014*** (0.0003)	−0.0003 (0.0006)	0.0013*** (0.0005)
Conditional variance equation						
ω	0.0005 (0.0004)	0.0002 (0.0003)	−0.0003 (0.0006)	0.00002 (0.00002)	−0.0017 (0.0011)	−0.0005 (0.0004)
α	0.1099*** (0.0166)	0.1907*** (0.0234)	0.0733*** (0.0258)	0. 1056*** (0.0141)	0.1618*** (0.0177)	0.1824*** (0.0108)
γ	−0.1626** (0.0800)	0.3969*** (0.1006)	0.0649*** (0.1631)	0.1586*** (0.0427)	0.2365*** (0.0522)	0.4038*** (0.0705)
β	0.8639*** (0.0141)	0.8966*** (0.0216)	0.8918*** (0.0215)	0.9316*** (0.0126)	0.8330*** (0.0184)	0.9194*** (0.0089)
Sun	0.0006 (0.0005)	0.0002 (0.0003)				
Mon	−0.0010 (0.0008)	−0.0003 (0.0004)	0.0003 (0.0007)	0.00008 (0.0001)	0.0038 (0.0025)	0.0006 (0.0006)
Wed	−0.0001 (0.0005)	−0.0002 (0.0003)	0.0014 (0.0032)	0.00003 (0.00006)	0.0019 (0.0014)	0.0009 (0.0008)
Thur	−0.0007 (0.0006)	−0.0001 (0.0003)	−0.0003 (0.0008)	−0.00008 (0.00003)	0.0017 (0.0011)	0.0006 (0.0006)
Fri			0.00006 (0.0004)	−0.00006 (0.00007)	0.0026 (0.0018)	0.0006 (0.0006)
δ	1.2174*** (0.1351)	1.4580*** (0.2930)	1.4684** (0.6156)	1.8149*** (0.2686)	1.1722*** (0.1764)	1.4556*** (0.2163)
GED	1.2338	1.4922	1.2668	1.1459	1.4986	1.4028
LLR	5642.77	4484.17	1598.58	10792.54	6954.58	9494.134
Q(20)	26.031***	8.8073	18.465	14.769***	6.5230	20.668
Q2(20)	34.965***	15.544	17.383	2.6567	25.099	20.533
LM ARCH	1.2849	0.7681	0.8366	0.3110	1.3643	0.9844

The table presents the results of the effect of regime switch on the day of the week and volatility using PARCH formulation of Eq. (5).
***, **,* indicate significance at the 1%, 5% and 10% levels.

window for the EXG30 market index. Therefore negative shocks have greater impact on future volatility within wider price limit window in the Egyptian stock exchange.[20]

The Power ARCH parameters δ are highly significant for all windows however their size is bigger within WPL window. This suggests that the switch from NPL to WPL has significant and positive impact on conditional volatility of EGX30, SET and KOSPI market indices. The results also show that the day of the week effect on the conditional variance does not structurally altered due to the switch from NPL to WPL for EGX30, SET and KOSPI. Finally, The Box and Pierce Q_{20}, Ljung–Box, Q^2_{20}, Lagrange Multiplier (LMARCH) and the BDS tests suggest that the extended PARCH model is well- specified. In brief, the results reported in Table 4 suggest that the switch from NPL to WPL structurally affects stock returns, asymmetric volatility (for the three market indices) and partially

[20] I estimate the modified EGARCH and PARCH models by including a dummy variable takes the value of 1 if WPL regime is in operation on day t and zero otherwise. I find consistent results with Farag and Cressy (2012), as the switch to a WPL regime actually increases volatility as the dummy variable coefficient is found to be positive in sign and highly significant.

affect the day of the week phenomenon in the EGX30 and SET market indices. Therefore I cannot reject the second and the third hypotheses.

7. Conclusions

The main objective of this paper is to investigate the effects of imposing different bands of price limits on stock returns and asymmetric volatility in EGX, SET and KRX. Secondly, the paper examines whether the switch from narrow price limits (NPL) to wider price limits (WPL) structurally alters asymmetric volatility and the day of the week anomaly. Using daily data of the EGX30, SET and KOSPI market indices, our results suggest that the switch from symmetric narrow price limits (NPL) to wider price limits (WPL) structurally affects stock returns, asymmetric volatility and the day of the week anomaly in both the Egyptian and Thai stock markets. Using the extended EGARCH and PARCH asymmetric volatility models I find that Thursday and Friday have positive and highly significant impact on returns for the EGX30 and SET respectively. However and consistent with the literature, Monday effect is observed for the SET. Results also show that there is no day of the week effect on returns in the KRX. On the other hand, the estimated conditional variance suggests that, daily stock returns are characterised by EGARCH and PARCH asymmetric volatility models with a generalised error distribution. The results of the regime change show that the switch from NPL to WPL has significant and positive impact on conditional volatility of EGX30, SET and KOSPI market indices. In addition, the day of the week phenomenon is structurally altered due to the switch.

I argue that the delayed price discovery hypothesis of Lehmann (1989), Lee et al. (1994) and Kim and Rhee (1997) may explain the above results; price limits prevent stock prices from reaching to their equilibrium levels as price limits disrupt trading mechanism and thus closing prices do not reflect the full information arrived in the market during the trading session (Farag and Cressy, 2012; Lee and Chung, 1996). Therefore price limits influence market efficiency and this explains the structural changes in volatility and the day of the week phenomenon between the two regimes.

In both EGX and SET the WPL regime is combined with a trading halt in which investors are allowed to adjust their portfolio positions. However, due to the lack of informational efficiency and the role of noise trading in emerging markets stock prices post halt period are likely to be much noisier and significantly different from equilibrium levels. Therefore higher volatility is expected when trading is resumed (Farag and Cressy, 2012; Lee et al., 1994; Tetlock (2007)). On the other hand, within NPL regime, trading is suspended until the end of the trading session when prices hit the limits, therefore, volatility is likely to spread out over subsequent trading days (volatility spillover hypothesis of Kim and Rhee (1997)) and thus lower volatility is expected within NPL. I argue that the price discovery mechanism differs between the two regimes and that is reflected on volatility and the informational efficiency. To conclude, switching from narrow price limits to wider limit bands increases volatility, disrupts trading mechanism and structurally alters the day of the week anomaly in the Egyptian, Thai and Korean stock exchanges.

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