Dias, Rui; Teixeira, Nuno; Pardal, Pedro et al.

Article

Volatility transmission between ASEAN-5 stock exchanges : an approach in the context of China's stock market crash

International journal of corporate finance and accounting

International Journal of Corporate Finance and Accounting
Volume 10 • Issue 1

Volatility Transmission Between ASEAN-5 Stock Exchanges:

An Approach in the Context of China's Stock Market Crash

Rui Dias, School of Business Administration, Polytechnic Institute of Setúbal, Portugal
https://orcid.org/0000-0002-6138-3098

Nuno Teixeira, School of Business Administration, Polytechnic Institute of Setúbal, Portugal

Pedro Pardal, School of Business Administration, Polytechnic Institute of Setúbal, Portugal*

Teresa Godinho, School of Business Administration, Polytechnic Institute of Setúbal, Portugal
https://orcid.org/0000-0002-1996-6417

ABSTRACT

This article aims to analyse risk transmission among the financial markets of China and ASEAN-5 in the context of the 2015 Chinese stock market crash. For this purpose, the authors test if (1) the volatility resulting from the 2015 stock market crash has positively influenced risk transmission among ASEAN-5 and China markets and (2) increased risk perception has led to a negative reaction from investors, both in ASEAN-5 as in China markets. The results imply an enhancement of the asymmetric effect, suggesting that during the crash, market volatility responded more significantly to bad news than to good news. In the post-crash, volatility dropped expressively. During the crisis, risk transmission was significant to the point of jeopardising portfolio diversification in the ASEAN-5 markets. In the post-crash, markets tended to balance, mitigating the risk very significantly. The authors believe that there are opportunities for international investors to readjust their portfolios in these regional markets.

KEYWORDS

Arbitrage, ASEAN-5, Comovements, GARCH Models, Portfolio Diversification, Risk Transmission, Stock Market Crash, Volatility

INTRODUCTION

The recent Chinese stock market crash (2015-2016) withstands the interest in examining the effects of volatility in ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore and Thailand) markets, providing hedge implications, asset allocation, trading strategies and portfolio diversification. From the end of 2014 to the first half of 2015, China experienced a booming market. The Shanghai-Hong Kong Stock Connect

DOI: 10.4018/IJCFA.319711

*Corresponding Author

seemed to serve as a new channel of foreign capital entry to mainland China, possibly contributing to a significant increase in bubble creation in these regional markets. The following stock market crash was very significant. This crash stemmed from China's diminishing economic growth, which led to a significant drop in the country's imports and exports (Salidjanova and Koch-Weser, 2015).

Given China's influence on the global economy, this financial crisis is expected to have a significant impact on its trading partners, especially those in the ASEAN-5 region, especially due to its exposure to the risk arising from China's exports. Moreover, the collapse may also have been caused by the surprise of the RMB devaluation and the consequent panic in the Chinese financial market, which was eventually transmitted to other trading partners. The newly introduced circuit breaker mechanism, which aimed to avoid systemic risks, has been suspended, contributing to the collapse of the market. Therefore, it is essential to analyse the repercussions of the shocks in China and to examine the financial links in terms of source, magnitude and evolution in the volatility spillovers on these regional markets (Hung, 2019; Sanusi, Singagerda, and Septarina, 2019; Vu, 2019).

Whatever the perspective of analysis, an evident fact involving volatility, is its relationship with the instability and turbulence of financial markets, as well as with investors' behaviour. Thus, a correct analysis of volatility estimation will become important, not only for the outline of a good asset management strategy, but also for understanding the moments of uncertainty in financial markets (Potjagailo, 2017; Abad, Alsakka, and ap Gwilym, 2018).

Therefore, this study aims to analyze risk transmission among the ASEAN-5 and China markets, in the context of the stock market crash, in China, in the year 2015. The sample is partitioned into three sub-periods, comprises daily quotations of analysed markets, for the period from December 1, 2014 to January 30, 2019. To achieve the research objective, analysis is divides in two steps: *i*) volatility resulting from 2015 stock market crash positively influenced risk transmission among ASEAN-5 and China markets; (ii) increased risk perception has provoked a negative reaction from investors in the ASEAN-5 and China markets. The results suggest that, during the crash sub-period, the highlight of the asymmetric effect intensified volatility reaction to bad news, rather than to good market news, proving the presence of volatility in these regional markets. However, in the *post*-crash, volatility dropped expressively, significantly reversing the signals. During the crash, there was a significant risk transmission, to the point of questioning portfolio diversification in the ASEAN-5 markets. However, in the *post*-crash, markets tended to balance, mitigating risk in a very significant way. In view of this evidence, the authors believe that there are conditions for international investors to readjust their portfolios in these regional markets. This evidence confirm the research questions.

As mentioned above, this article analyses the behaviour of ASEAN-5 and China's financial markets before, during and after the 2015-2016 collapse, from a risk transmission perspective. Therefore, this research aims to fill this gap and contribute to the existing literature, as follows. Firstly, the authors believe that studing the possible links between China and the ASEAN-5 regional markets will create very relevant evidence on the dynamics amongst these regional markets. Secondly, the dynamic GARCH and EGARCH models are applied in order to exploit the risk concerning the six stock exchanges (ASEAN-5 and China), providing clarity on their synchronisations. Thirdly, this article uses a sample period covering the most recent chinese stock market crash, in 2015-2016, examining its impact on the ASEAN-5 financial markets.

In terms of structure, the article is organised into 5 sections. Section 1 presents the current introduction, section 2 provide a discussion based on a literature review to the topic of volatility in financial markets, section 3 describes data and methodology and section 4 shows the results and its discussion. Finally, section 5 displays the conclusion.

LITERATURE REVIEW

Volatility is a very relevant, particularity in financial markets, although it is not directly observable and therefore it is considered that, its estimation or forecast is more difficult to analyze. Binomial risk /profitability is a very relevant topic for certain category of investors, namely those that do not show risk aversion and are willing to carry out high-risk transactions. This relationship becomes a crucial problem for financial markets, when the purpose is to estimate and predict risk, as well as investments' profitability (Hung, 2019). Currently, the variance of asset prices (volatility) is likely, one of the most important information for financial market investors. In times of uncertainty and turbulence in the financial markets, its correct forecast allows profitability strategies' anticipation for shares affected by performance of the issuing company, as well as, by the economic conjuncture (Sanusi, Singagerda, and Septarina, 2019; Vu, 2019).

Oh et al. (2010), Nartea, Ward, and Yao (2011), Tan, Wong, and Elshareif (2015), Li and Giles (2015), Lee and Goh (2016), Caporale et al. (2017) analyzed the volatility among ASEAN stock exchanges. Oh et al. (2010) show a partial market integration in the pre-crisis, but in the post-crisis, complete integration predominates. Additionally, the asset diversification benefits of long-term portfolio of ASEAN-5 basin become smaller, as markets are integrated in the pre and post-crisis. Nartea, Ward, and Yao (2011) found a positive relation between volatility and profitability in Malaysia, Singapore, Thailand, Indonesia and no relationship in the Philippines. The trading strategy of idiosyncratic volatility may result in the occurrence of significant profitability in Malaysia, Singapore, Thailand, and to some extent, in Indonesia. In these cases, Tan, Wong, and Elshareif (2015) support the rejection of efficient market hypothesis, even when the models integrate unexpected volatility changes. The authors also provide significant empirical evidence for a positive risk-profitability exchange in stock markets. In addition, stock markets are more sensitive to global events than local ones. With the exception of the Philippines, asymmetric responses to good news and bad news are also part of market behavior. Li and Giles (2015) found significant one-way impacts and volatility of the U.S. market on emerging markets in Japan and other Asian countries. It was also found that volatility spillovers between the U.S. market and Asian markets were stronger and two-way, during the Asian financial crisis. In addition, over the past five years, the synchronization between the Japanese market and other emerging Asian markets, become more significant. Lee and Goh (2016) show that the U.S. market is the main source of risk transmission, therefore ASEAN markets tend to react more significantly to unfavorable news from the U.S. market. Caporale et al. (2017) suggest that high (low) exchange rate volatility is associated with stock (bonds) entries from Asian countries toward the U.S., in all cases except for the Philippines. Thus, capital control mechanisms may be effective tools to stabilize the foreign exchange market, in countries where flows affect exchange rate volatility.

Shen (2018), Saiti and Noordin (2018), Hung (2019), Sanusi, Singagerda, and Septarina (2019), Vu (2019) examined the profitability and volatility spillovers amongst international markets and major Asian stock exchanges. Shen (2018) evidences the existence of volatility spillovers from the U.S. to the major Asian stock exchanges, suggesting that these are highly integrated stock exchanges, in terms of risk transmission. Shocks in the U.S. market have substantially increased Value at Risk (VaR) in Asian markets, except in China and Russia. On the other hand, price falls in Asian markets also have a weaker but significant predictive power in the U.S. market. Saiti and Noordin (2018) indicate that Islamic Asian and international stock indices are more or less volatile than their conventional peers. From the correlation analysis, the authors showed that Japan's conventional and Islamic MSCI indexes (Morgan Stanley Corporation Indexes) offer more diversification benefits, when compared to Southeast Asia, China, Hong Kong, and India. On the other, hand, in terms of international portfolio diversification, the results tend to suggest that the U.S. MSCI conventional and Islamic indices offer more diversification benefits when compared to the UK, Canada, France, Germany and Switzerland. Hung (2019) shows, as his main empirical result, that Chinese market volatility had a significant impact on other markets. The results of his study also indicate that stock markets are more integrated, due to the financial crisis. Sanusi, Singagerda, and Septarina (2019) found that scale exponents are associated with specific markets' characteristics, including ASEAN member countries, and can be used to differentiate markets at their stage of development. The study showed persistence and long memories, which may be beneficial for investors, since these markets present some predictability. Vu (2019) shows that oil price fluctuations have a positive effect on stock profitability, implying that rising levels of future uncertainty in oil prices leads to a downward movement in stock markets. The results illustrate that, in analyzed countries, the previous negative shocks on the current volatility of shares' profitability had a higher effect than positive shocks.

Risk in financial markets is widely studied outside the Asian context, for example Basdekis (2010) conducted an empirical investigation on risk in the equity cost in the European Union (EU), with risk being measured in terms of legal, political and monetary factors. To answer the research questions the author used a capital asset pricing model, applied to the sample for two periods, with reference to the official incorporation of each country into the EU. Evidence shows that the preceding risk variables in the formation of the equity cost and the discrepancy between the convergence rates of new and old members are significant. Other example comes from Dvorak and Podpiera (2021), where they investigated the hypothesis that the increase in stock prices was a result of the repricing of systematic risk, in accordance with the integration of candidate countries into the world market. The authors show that changes in firm-level stock prices are positively related to the difference between a firm's local and world market betas. These results are robust to controlling for changes in expected earnings, country effects, and other controls, although the magnitude of the effect is not very large. The differences between the local and world betas explain almost 22% of the stock price increase.

To summarize, Forbes and Rigobon (2002) and McKinnon and Schnabl (2003) showed that China played a stabilizing role in the Asian region during the 1997 financial crisis, as its economy was not affected. According to the studies of Yu, Fung and Tam (2010) and Huyghebaert and Wang (2010), the likelihood of the 2008 financial turmoil influencing China's stock market was relatively low, because its stock market was isolated from the rest of the world. Given this evidence, the challenge of this study is to assess whether china's market remains immunized before the ASEAN-5 markets, considering the 2015-2016 stock market crash, and thus, contributing to develop a greater knowledge about main Asian markets.

DATA AND METHODOLOGY

Data on the opening, maximum, minimum and closing prices of all six markets were obtained from the Thomson Reuters platform. The quotes are in local currency, in order to mitigate exchange rates distortions. Data period comprises daily quotations from January 5, 2015 to January 31, 2019. The sample was divided into three sub periods: a *pre-crash* sub period, corresponding to the time interval between January 5, 2015 and June 11, 2015; a sub-period of *crisis*, which identifies the stock market crash and covering the sub-period between June 12, 2015 and January 30, 2016; and a third sub-period from 1 February 2016 to 31 January 2019, which we designate as *post*-crash sub period (Ahmed and Huo, 2018). (table 1)

Table 1.
Sample: Countries and respective indexes

Country / Region	Index
INDONESIA / ASEAN-5	Jakarta Stock Exchange Composite Index
MALAYSIA / ASEAN-5	FTSE Bursa Malaysia Index
PHILIPPINES / ASEAN-5	Philippines Stock Exchange PSEi Index
SINGAPORE / ASEAN-5	Singapore Exchange - SGX
TAILANDIA / ASEAN-5	Stock Exchange of Thailand
CHINA / ASIA	Shanghai Stock Exchange Composite Index

Source: Own elaboration

As for methodology, the research design followed several stages. The sample was characterized by using descriptive statistical instruments and the Jarque-Bera adherence test (1980). The evaluation of the time series stationarity was performed through the ADF, PP and KPSS tests, which allows measuring the price indexes' variance stability of analyzed financial markets, in different sub-periods under study. To corroborate stationarity, structural breaks were tested through Clemente, Montañés and Reyes (1998) model. To estimate risk transmission amongst markets, it was used the Spearman's Rank Correlation Coefficients and homoscedastic teste t to assess whether the level of variance has changed between sub-periods. To check if volatility has non-negative coefficients and prove if the volatility process is stationary, it was used the GARCH (1,1) methodology. To estimate whether positive shocks cause less severe volatility than negative shocks, the option was to use the EGARCH (1,1) model. To test the absence of autocorrelation in the squares of standardized residual, it was followed the Ljung-Box test (Ljung and Box, 1978). Finally, to verify the persistence of variance, the authors used the ARCH-LM test (Engle, 1982) to models residuals, as it checks whether the GARCH and EGARCH models are capable of modeling the conditioned heteroscedasticity and also allowing to assess the robustness of the models.

These type of models have been used in previous and recent studies, such as the case of Basdekis et al. (2022) that measured risk quantification using the Value at Risk (Var) model, namely several parametric (MGARCH) and non-parametric (i.e., historical simulation) Value at Risk models are applied to the returns of the TC5 and TC7 spot and one- and three-month futures markets. According to the results, simple and non-parametric GARCH models are proposed for risk management purposes for the spot and futures markets. The results are consistent for long and short positions. According to the results, the non-parametric simple GARCH models perform better in risk management for both spot and futures markets. The results are consistent for both long and short positions. As for Angelidis and Skiadopoulos (2008) measured the rate of freight by the VaR approach. A variety of parametric and non-parametric VaR methods are applied, backtesting is performed in two steps by means of statistical tests and a subjective loss function using Expected Deficit, respectively. The authors show that the simplest non-parametric methods are efficient for measuring freight rate risk.

Instead Kavussanos and Dimitrakopoulos (2011) analyzed volatility to determine the best method to extrapolate medium-term risk forecasts from high-frequency data, the authors evidence that medium-term risk exposures can be accurately estimated using an empirical scaling law that outperforms the conventional scaling laws of the square and root of the time tail index. Regarding market risk model selection for short-term investment horizons, the findings contradict most studies on conventional financial assets: interestingly, quantification of market risk favors simpler specifications such as GARCH and historical simulation models.

Complementary and with regard to the used measure of volatility and according to Andersen and Bollerslev (1998), Beltratti and Morana (1999), Gallant, Hsu, and Tauchen (1999), Alizadeh, Brandt and Diebold, 2002), Poon and Granger (2003), DiSario, Saraoglu, McCarthy, and Li (2008), Dooley and Hutchison (2009), Asgharian and Nossman (2011), Grammatikos and Vermeulen (2012), Delatte, Gex, and López-Villavicencio (2012), Falagiarda and Reitz (2015) and Berg and Vu (2019), the closing prices of assets or markets, causes relevant information about the price path, within the reference period.

Parkinson (1980) suggested an alternative expression to measure volatility, assuming that a trendless Brownian geometric movement describes asset prices, starting from the maximum price and the minimum price. The expected value of the square of the difference D_t is:

$$ED_t^2 = 4In\left(2\right)\sigma^2 \quad (1)$$

The estimate of volatility is measured by:

$$\sigma^2 = \frac{1}{4In\left(2\right)} \frac{1}{N} \sum_{t=1}^{N} D_t^2 \tag{2}$$

From this expression, the authors can evaluate that the variance estimate is simply a constant $\frac{1}{4Ln\left(2\right)} \approx 0,361,$ multiplied by the square of the mean difference.

A proxy of variance can be given by:

$$\sigma_{r,t}^2 = \frac{1}{4Ln\left(2\right)} D_t^2 \approx 0,361 D_t^2 \tag{3}$$

A new volatility estimation methodology was used by Garman and Klass (1980), considering the opening (O_t), closing (C_t), maximum (H_t) and minimum L_t prices given by the equation:

$$\sigma_{r,t}^2 = 0,5\left[In\left(\frac{H_t}{L_t}\right)\right]^2 - \left[2In\left(2\right) - 1\right]\left[In\left(\frac{C_t}{O_t}\right)\right]^2 \tag{4}$$

Based on the estimation of Garman and Klass (1980), Rogers, Satchell, and Yoon (1994), developed the following variance estimator:

$$\sigma_{r,t}^2 = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left(In\frac{H_t}{C_t}\right)\left(In\frac{H_t}{O_t}\right) + \left(In\frac{L_t}{C_t}\right)\left(In\frac{L_t}{O_t}\right)} \tag{5}$$

RESULTS

Figure 1 shows oscillations in first differences, in ASEAN-5 and China financial markets. The sample comprises the period from January 5, 2015 to January 31, 2019, being a period of great complexity, as it covers the stock market crash in China. The analyzed financial markets indexes clearly reveal the experienced instability, in these markets, in the years 2015-2016.

Table 2 shows the main descriptive statistics of the volatility measure, referring to the 6 financial markets under analysis, as well as, the Jarque-Bera adherence test. The analyses of the descriptive statistics allow us to verify positive daily averages in all markets. China is the market that presents the highest standard deviation, but the highest level of kurtosis is verified in Singapore. On the other hand, all series showed signs of deviation from the normality hypothesis, given the skewness and kurtosis coefficients. Additionally, the skewness and kurtosis coefficients are statistically different from those of a normal distribution.

In order to estimate volatility, contrary hypotheses were crossed, allowing to assess the lags as well, in particular, ADF tests (Dickey and Fuller, 1981), PP (Perron and Phillips, 1988) and the KPSS test (Kwiatkowski, Phillips, Schmidt and Shinb, 1992). The majority of the tests, for the presence of unit roots, show stationarity, with the exception of China and Malaysia markets, which reject the hypothesis in the KPSS test (table 3).

Figure 1.
Evolution, in the first annual differences, of the six financial markets in the period of 05/01/2015 to 30/01/2019 Source: Own elaboration. Note: Thomson Reuters: 5 january 2015, 1063 point data

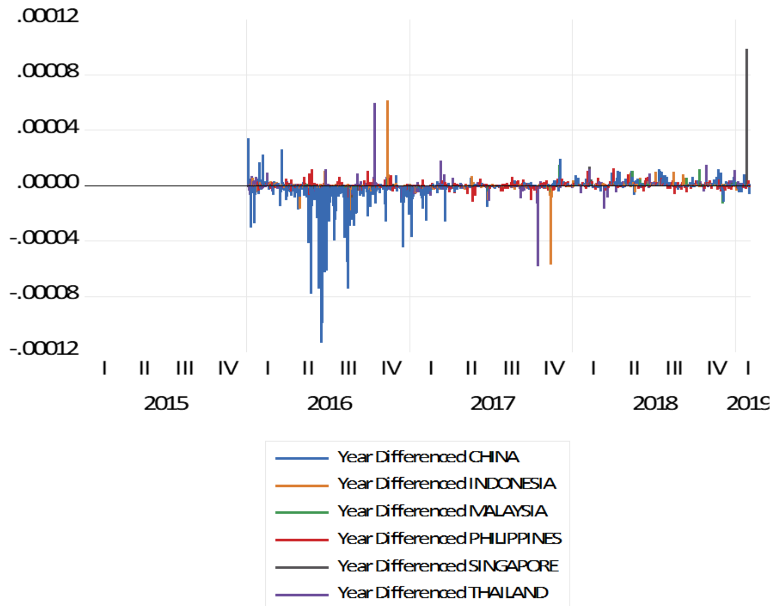

Table 2.
Descriptive statistics of the 6 markets in the whole period

	CHINA	INDONESIA	PHILIPPINES	MALAYSIA	SINGAPORE	THAILAND
Mean	3.99E-06	1.20E-06	7.82E-07	3.30E-07	5.80E-07	1.21E-06
Std. Dev.	9.57E-06	1.59E-06	2.39E-06	9.21E-07	3.13E-06	2.70E-06
Skewness	6.281597	3.456076	18.93838	9.948962	29.59783	13.80056
Kurtosis	53.40282	19.81517	468.3704	128.9782	929.6606	268.1438
Jarque-Bera	119623.6***	14653.40***	9664854.***	721145.7***	38224381.***	3150462.***
Sum	0.004247	0.001281	0.000832	0.000351	0.000618	0.001293
Sum Sq. Dev.	9.74E-08	2.70E-09	6.09E-09	9.02E-10	1.04E-08	7.76E-09
Observations	1064	1064	1064	1064	1064	1064

Source: Own elaboration.
Note: ***, **, *, represent significance at 1%, 5% and 10%, respectively. Volatility measure of Rogers, Satchell and Yoon (1994).

Table 4 shows the structural breakdowns of the six markets under analysis, through Clemente et al. (1998) test, in the period from January 2015 to January 2019, showing the turbulence experienced in these markets in the period of the 215 China's stock market crash. The China market broke in August 2015 and the markets of the Philippines, Singapore and Thailand followed the same trend. However, the financial markets of Indonesia and Malaysia show the most significant structural breakdowns in 2016 and 2018, respectively.

The graphical representation of prices volatility series of the ASEAN-5 and China markets were a first indication that indexes' volatilities are concentrated in certain periods, forming volatility

Table 3.
Statistical tests of price volatilities of the of the 6 markets in the whole period

	CHINA	INDONESIA	PHILIPPINES	MALAYSIA	SINGAPORE	THAILAND
ADF	-6.09 (3)***	-9,52 (6)***	-29.67 (0)***	-29.61 (0)***	-32.16 (0)***	-21.15 (0)***
PP	-20.89 (18)***	-48,31 (28)***	-30.54 (14)***	-30.39 (11)***	-32.16 (2)***	-21.29 (1)***
KPSS	**1.17 (23)*** **	0,31 (28)	0.33 (15)	**0,72 (12)** **	0,22 (3)	0.29 (11)

Source: Own elaboration.

Note: In the ADF test we used the Lag (Automatic Length based on SIC) in PP (BandWidth (Newey-West automatic) using Bartlett Kernel) in KPSS (BandWidth (Newey-West automatic) using Bartlett Kernel). The lateral values in parentheses refer to lags. ***, **, *, represent significance at 1%, 5% and 10%, respectively. Volatility measure of Rogers, Satchell and Yoon (1994).

Table 4.
Unit root tests with structural breakdowns by Clemente, Montañés and Reyes (1998) for the 6 markets, in the full period

Index	t_statistic	Break Date
CHINA	-31.8405***	12/08/2015
INDONESIA	-32.1202***	14/11/2016
PHILIPPINES	-32.6979***	10/08/2015
MALAYSIA	-32.2834***	30/05/2018
SINGAPORE	-32.2649***	24/08/2015
THAILAND	-32.7678***	24/08/2015

Source: Own elaboration

Note: ***, **, *, represent significance at 1%, 5% and 10%, respectively. Volatility measure of Rogers, Satchell and Yoon (1994).

clusters. Thus, and in order to analyze the links between the various markets and possible risk transmission amongst them, it was used the Spearman's Rank Correlation Coefficients model. The correlation coefficients in the pre-crash period evidence that these markets have very low levels of integration, with negative correlations, specifically among the relation between ASEAN-5 markets and China market. However, ASEAN-5 markets have significant correlations within them, with the exception of market pairs Singapore/Indonesia and Singapore/Thailand. On the contrary, during the stock market crash, the correlations between ASEAN-5 and China markets was high and significant. When compared to the pre-crash sub-period, markets with low levels of correlation with China change substantially. These evidence are in line with the results suggested by the authors Shen (2018), Hung (2019), Sanusi, Singagerda, and Septarina (2019), which show that the Chinese market volatility has had a significant impact on other markets.

In the post-crash, results show that these markets lowered, significantly, their correlation levels, namely the ASEAN-5 markets and China market. The market pairs Indonesia/Singapore, Indonesia/Thailand, Malaysia/Singapore, Malaysia/Singapore and Malaysia/Thailand increased *post*-crash correlations, which shows that the 2015-2016 stock market crash increased synchronization among The ASEAN-5 markets.

Table 5 shows the results of the homoscedastic t test, to risk transmission between *pre*-crash and the crash sub-periods. The results suggest the existence of 20 pairs rejecting the null hypothesis and identifying risk transmission between markets (in 30 possible combinations). However, the remaining pairs, specifically 10 of them, with significant correlation coefficients, did not allow to measure an increase in variance, and it cannot be affirmed the rejection of the null hypothesis. The markets that most affected their peers were China, Singapore and Thailand (4 out of 5 possible). The Malaysian, Philippine and Indonesian markets passed on risk to three and two markets, respectively.

The Malaysian market infected the other markets, but has not been infected by them. The existence of risk transmission between the ASEAN-5 and China markets during the 2015-2016 stock market crash suggests that these stock exchanges are highly integrated in terms of risk transmission. Thus, the shocks in the China market substantially increased the risk in the ASEAN-5 markets. These results support the first research question and follow the evidence of the authors Li and Giles (2015), Shen (2018), Hung (2019) and Vu (2019), who found that volatility spillovers among markets are stronger in periods of financial turbulence.

Table 6 presents the results of the homoscedastic t test, to the effect of risk transmission among the ASEAN-5 and China regional markets, resulting from the stock market crash. The results suggest that, although the coefficients show correlation of 5% significance, there was no rejection of the null hypothesis. In view of these indications, volatility decreases significantly in these regional markets. Thus, evidence seems to show that, from February 2016 to January 2019, these markets tended towards balance, enabling portfolios diversification strategies. These suggestions are corroborated by the authors Saiti and Noordin (2018) that show that portfolio diversification strategies may be a hypothesis to be developed by international investors.

When there is some correlation between volatility and the occurrence of significant losses in the stock markets, this relationship is called the asymmetric effect (or leverage effect). To analyze the asymmetric effect, it was used the EGARCH (1,1) model (*Exponential Generalized Autoregressive Conditional Heteroscedasticity*) from price volatility. The number of lags to include in the models is based in the information criterion SBIC (Schwarz Bayesian information criterion).

Table 7 shows the estimates of the GARCH (1,1) models, carried out on price volatilities. All coefficients of the estimated models show the expected signs, i.e., the coefficients are non-negative, which ensures a positive value of the conditioned variance. Of all the coefficients of variance equation,

Table 5.
Results of risk transmission, price volatility, between Pre / Crash sub-periods

Markets	t-statistic	Results	Markets	t-statistic	Results
INDONESIA / MALAYSIA	0.47	Nonexistent	SINGAPORE / INDONESIA	2.08**	Transmission
INDONESIA / PHILIPPINES	0.89	Nonexistent	SINGAPORE / MALAYSIA	1.21	Nonexistent
INDONESIA / SINGAPORE	1.05	Nonexistent	SINGAPORE / PHILIPPINES	1.61*	Transmission
INDONESIA / THAILAND	1.87**	Transmission	SINGAPORE / THAILAND	2.42**	Transmission
INDONESIA / CHINA	2.82***	Transmission	SINGAPORE /CHINA	3.34***	Transmission
MALAYSIA / INDONESIA	1.44*	Transmission	THAILAND / INDONESIA	1.98**	Transmission
MALAYSIA / PHILIPPINES	0.94	Nonexistent	THAILAND / MALAYSIA	1.10	Nonexistent
MALAYSIA / SINGAPORE	1.08	Nonexistent	THAILAND / PHILIPPINES	1.49*	Transmission
MALAYSIA / THAILAND	1.79*	Transmission	THAILAND / SINGAPORE	1.64*	Transmission
MALAYSIA / CHINA	2.65**	Transmission	THAILAND / CHINA	3.23***	Transmission
PHILIPPINES / INDONESIA	1.61*	Transmission	CHINA / INDONESIA	1.89**	Transmission
PHILIPPINES / MALAYSIA	0.67	Nonexistent	CHINA / MALAYSIA	0.98	Nonexistent
PHILIPPINES / SINGAPORE	1.23	Nonexistent	CHINA / PHILIPPINES	1.39*	Transmission
PHILIPPINES / THAILAND	1.99**	Transmission	CHINA / SINGAPORE	1.53*	Transmission
PHILIPPINES / CHINA	2.91***	Transmission	CHINA / THAILAND	2.25**	Transmission

Source: Own elaboration

Notes: Critical values correspond to a one-tailed significance on the right, 2.7638 (1%), 1.8125 (5%) and 1.3722 (10%). ***, **, * indicate significant results at 1%, 5% and 10%, respectively.

Table 6.
Results of risk transmission, price volatility, between Post / Crash sub-period

Markets	t-statistic	Results	Markets	t-statistic	Results
INDONESIA / MALAYSIA	-0.28	Nonexistent	SINGAPORE / INDONESIA	0.08	Nonexistent
INDONESIA / PHILIPPINES	-0.22	Nonexistent	SINGAPORE / MALAYSIA	-0.17	Nonexistent
INDONESIA / SINGAPORE	-0.74	Nonexistent	SINGAPORE / PHILIPPINES	-0.12	Nonexistent
INDONESIA / THAILAND	-0.64	Nonexistent	SINGAPORE / THAILAND	-0.52	Nonexistent
INDONESIA / CHINA	-0.51	Nonexistent	SINGAPORE /CHINA	-0.39	Nonexistent
MALAYSIA / INDONESIA	-0.24	Nonexistent	THAILAND / INDONESIA	-0.18	Nonexistent
MALAYSIA / PHILIPPINES	-0.44	Nonexistent	THAILAND / MALAYSIA	-0.42	Nonexistent
MALAYSIA / SINGAPORE	-0.93	Nonexistent	THAILAND / PHILIPPINES	-0.37	Nonexistent
MALAYSIA / THAILAND	-0.84	Nonexistent	THAILAND / SINGAPORE	-0.83	Nonexistent
MALAYSIA / CHINA	-0.72	Nonexistent	THAILAND / CHINA	-0.64	Nonexistent
PHILIPPINES / INDONESIA	-1.51	Nonexistent	CHINA / INDONESIA	-2.56	Nonexistent
PHILIPPINES / MALAYSIA	-1.84	Nonexistent	CHINA / MALAYSIA	-2.86	Nonexistent
PHILIPPINES / SINGAPORE	-2.29	Nonexistent	CHINA / PHILIPPINES	-2.64	Nonexistent
PHILIPPINES / THAILAND	-2.13	Nonexistent	CHINA / SINGAPORE	-3.21	Nonexistent
PHILIPPINES / CHINA	-2.05	Nonexistent	CHINA / THAILAND	-3.05	Nonexistent

Source: Own elaboration

Notes: Critical values correspond to a one-tailed significance on the right, 2.7638 (1%), 1.8125 (5%) and 1.3722 (10%). ***, **, * indicate significant results at 1%, 5% and 10%, respectively.

only the coefficient β of the Indonesia index, in the pre-crash sub-period, was not statistically significant. The remaining coefficients of the variance equation showed statistical significance, at the level of 1%. This confirms the existence of ARCH and GARCH effects on the variance. On the other hand, during the stock market crash, the sum of GARCH model coefficients is less than 1 in all indexes and sub-periods, with the exception of the Philippine market. Nevertheless, the volatility process is mostly stationary. These results partially corroborate the second research question, following the evidence suggested by the authors Sanusi, Singagerda, and Septarina (2019) and Vu (2019).

Table 8 shows the results of the estimation of the EGARCH methodology (1.1), carried out at price volatilities. Specifically, when the asymmetric coefficient has a negative sign, positive shocks cause less volatility than negative shocks of the same size. From the analysis of the estimates of the EGARCH models (1.1), it is suggested that all ¡ coefficients, present during the pre-crash period,

Table 7.
Results of estimation, price volatility, GARCH (1,1)

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	THAILAND	CHINA
	β	β	β	β	β	β
PRE-CRASH	**0.5362**	0.9064***	0.6367**	0.8801***	0.9657***	0.6023**
CRASH	0.6805***	0.8336***	**1.100**	0.3343**	0.7743***	0.9122***
POST-CRASH	0.9057***	0.8358***	0.9336***	0.9557***	0.9242***	0.6000***

Source: Own elaboration.

Note: ***, **, *, represent significance at 1%, 5% and 10%, respectively.

mostly negative signal, with the exception of the Malaysian and Singapore markets. Additionally, results show that the asymmetric effect is robust, i.e., volatility is very significant during the stock market crash, which means that bad news had a very significant impact on these regional markets. However, in the *post-crash,* ¡ coefficients show both positive and significant signs, which clearly demonstrates the recovery of these markets after the *chaos* of 2015 and 2016. These results partially corroborate the second research question, being aligned with the authors Amira,Taamouti, and Tsafack (2011), Nartea, Ward, and Yao (2011), Li and Giles (2015), Lee and Goh (2016),Chiang and Chen (2016), Chen et al. (2017), and Shen (2018), who shown that there are asymmetric coefficients in periods of market turbulence.

The absence of autocorrelation in the squares of standardized residuals, was tested using the Ljung-Box (Ljung and Box, 1978) test, whose results, for the GARCH model (1,1), are presented in Appendix A. The results show, for a 5% level of significance, the existence of a strong tendency to accept the null hypothesis, suggesting that the standardized residuals are not correlated. To verify the persistence of variance, the ARCH-LM test (Engle, 1982) was applied to the models' residuals (see Appendix A). From the individual analysis of each of the coefficients and their probability values, it could be concluded that they are not statistically different from zero, which demonstrates the robustness in estimation.

In order to verify the correct specification of the EGARCH models (1,1), residuals' behavior is analyzed to understand whether they exhibited the same performance as those from a white noise process. To this end, the Ljung-Box tests (Ljung and Box, 1978) as well as ARCH-LM (Engle, 1982) were used, and statistical results are presented in Appendix B. The results of the Ljung-Box tests on the residual of the EGARCH models (1,1) show a strong tendency towards the acceptance of the null hypothesis and, consequently, the acceptance of the absence of correlation in standardized residuals. These results were corroborated by the ARCH-LM test, which suggest a data series residuals' bleaching of the data series under analysis. Specifically, the series' residuals proved to be sufficiently whitened by the models, and therefore, there is reason to believe that they have the capacity to model the conditioned heteroscedasticity, and thus, the statistical inference of the model is robust.

CONCLUSION

This article analyzes risk transmission concerning the ASEAN-5 and China markets, in the 2015-2016 stock market crash context. To this end, we have constructed a measure of volatility that is based on the opening, closing, maximum and minimum prices. The sample comprises the period from December 1, 2014 to January 30, 2019, divided into three sub-periods. For this analysis, we intended to answer two questions, in particular, to understand whether: *i*) volatility arising from the 2015 stock market crash positively influenced risk transmission between the ASEAN-5 and China markets; ii) increased risk perception has led to a negative reaction from investors in the ASEAN-5 and China markets. We conducted two groups of statistical tests for this purpose. The first estimated whether

Table 8.
Results of the estimation, price volatility, EGARCH (1,1)

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	THAILAND	CHINA
	¡	¡	¡	¡	¡	¡
PRE-CRASH	-0.8949***	**0.8701*** **	-0.2862*	**-0.0579**	**-0.4854**	-0.6589***
CRASH	-0.4908***	-0.1716***	-0.2325***	-0.1373***	-0.2825***	-0.2406***
POST-CRASH	**0.9703*** **	**0.9404*** **	**0.9856*** **	**0.9825*** **	**0.9733*** **	**0.9951*** **

Source: Own elaboration.
Note: ***, **, *, represent significance at 1%, 5% and 10%, respectively.

the ASEAN-5 and China markets had high levels of volatility as a result of the 2015-2016 crash, for assessing whether the increase in correlations results in risk. For this purpose, it was estimated the Spearman's Rank Correlation Coefficients model, as well as the homoscedastic t . The second group of statistical tests estimate the GARCH model (1.1), to examine the sensitivity of volatility, as well as the Model EGARCH (1,1) to analyze asymmetry.

The results of the first group of tests suggest the existence of partial risk transmission amongst markets during the stock market crash period with the existence of 20 market pairs with significant risk (in 30 possible combinations). Thus, during the crash period there was a significant risk transmission to the point of jeopardizing portfolio diversification in the ASEAN-5 markets. However, when assessing the post-crash sub-period, the risk was not significant. Markets tended to balance mitigating the risk very significantly. These results support the first research issue.

As for the second group of tests, the estimation of the GARCH model (1.1), exhibit that the sum of the estimated coefficients matched the expected signs, i.e., the coefficients were non-negative, ensuring a positive value of the conditioned variance. From all the variance equation coefficients, only the β coefficient of the Indonesian index has not revealed to be statistically significant, in the *pre*-crash sub-period. The remaining coefficients of the variance equation showed statistical significance, at the level of 1%. This confirms the existence of ARCH and GARCH effects on the variance. On the other hand, during the stock market crash, the sum of the GARCH model coefficients is, in all indexes and sub-periods, less than 1, except for the Philippine market. Nevertheless, the volatility process is mostly stationary. As for the estimation of the EGARCH models (1.1), the ¡ coefficients present, mostly, negative signs during the pre-stock market crash, with the exception of the Malaysian and Singapore markets. Additionally, results show that the asymmetric effect is robust, i.e. volatility was very significant during the stock market crash, which means that bad news, rather than good news, had a very significant impact on these regional markets. Yet, in the *post-crash,* the ¡ coefficients showed positive and significant signs, which clearly demonstrates the recovery of these markets after the 2015-2016 disorder. These results are partially aligned with the second research issue, i.e., that during the stock market crash period the investors reacted negatively. Globally, this evidence supports the idea that international investors would be able to readjust their portfolios in these regional markets.

With regard to suggestions for future investigations, we believe that they should go through studying intraday data, to improve the analysis on volatility. In addition, future studies should include and combine macroeconomic and financial variables to help explain the phenomenon of risk transmission between markets, in particular in Asian markets, which have different characteristics from other regional markets.

REFERENCES

Abad, P., Alsakka, R., & ap Gwilym, O. (2018). The influence of rating levels and rating convergence on the spillover effects of sovereign credit actions. *Journal of International Money and Finance*, *85*, 40–57. Advance online publication. doi:10.1016/j.jimonfin.2018.03.005

Ahmed, A. D., & Huo, R. (2018). AC. *Economic Modelling*. Advance online publication. doi:10.1016/j.econmod.2018.09.029 PMID:29948969

Alizadeh, S., Brandt, M. W., & Diebold, F. X. (2002). Range-Based Estimation of Stochastic Volatility Models. *The Journal of Finance*, *57*(3), 1047–1091. doi:10.1111/1540-6261.00454

Amira, K., Taamouti, A., & Tsafack, G. (2011). What drives international equity correlations? volatility or market direction? *Journal of International Money and Finance*, *30*(6), 1234–1263. doi:10.1016/j.jimonfin.2011.06.009

Andersen, T. G., & Bollerslev, T. (1998). Answering the Skeptics: Yes, Standard Volatility Models do Provide Accurate Forecasts. *International Economic Review*, *39*(4), 885. Advance online publication. doi:10.2307/2527343

Angelidis, T., & Skiadopoulos, G. (2008). Measuring the market risk of freight rates: A value-at-risk approach. *International Journal of Theoretical and Applied Finance*, *11*(5), 447–469. Advance online publication. doi:10.1142/S0219024908004889

Asgharian, H., & Nossman, M. (2011). Risk contagion among international stock markets. *Journal of International Money and Finance*, *30*(1), 22–38. Advance online publication. doi:10.1016/j.jimonfin.2010.06.006

Basdekis, C., Christopoulos, A., Gkolfinopoulos, A., & Katsampoxakis, I. (2022). VaR as a risk management framework for the spot and futures tanker markets. *Operations Research*, *22*(4). Advance online publication. doi:10.1007/s12351-021-00673

Basdekis, H. (2010). European Union enlargement and equity cost: An empirical analysis on risk sharing and market integration. *International Journal of Financial Services Management*, *4*(3), 153. Advance online publication. doi:10.1504/IJFSM.2010.034550

Beltratti, A., & Morana, C. (1999). Computing value at risk with high frequency data. *Journal of Empirical Finance*, *6*(5), 431–455. doi:10.1016/S0927-5398(99)00008-0

Berg, K. A., & Vu, N. T. (2019). International spillovers of U.S. financial volatility. *Journal of International Money and Finance*, *97*, 19–34. Advance online publication. doi:10.1016/j.jimonfin.2019.05.010

Caporale, G. M., Menla Ali, F., Spagnolo, F., & Spagnolo, N. (2017). International portfolio flows and exchange rate volatility in emerging Asian markets. *Journal of International Money and Finance*, *76*, 1–15. Advance online publication. doi:10.1016/j.jimonfin.2017.03.002

Chen, J., Jiang, F., Liu, Y., & Tu, J. (2017). International volatility risk and Chinese stock return predictability. *Journal of International Money and Finance*, *70*, 183–203. Advance online publication. doi:10.1016/j.jimonfin.2016.08.007

Chiang, T. C., & Chen, X. (2016). Empirical Analysis of Dynamic Linkages between China and International Stock Markets. *Journal of Mathematical Finance*. 10.4236/jmf.2016.61018

Clemente, J., Montañés, A., & Reyes, M. (1998). Testing for a unit root in variables with a double change in the mean. *Economics Letters*, *59*(2), 175–182. doi:10.1016/S0165-1765(98)00052-4

Delatte, A. L., Gex, M., & López-Villavicencio, A. (2012). Has the CDS market influenced the borrowing cost of European countries during the sovereign crisis? *Journal of International Money and Finance*, *31*(3), 481–497. Advance online publication. doi:10.1016/j.jimonfin.2011.10.008

Dickey, D., & Fuller, W. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, *49*(4), 1057–1072. doi:10.2307/1912517

DiSario, R., Saraoglu, H., McCarthy, J., & Li, H. (2008). Long memory in the volatility of an emerging equity market: The case of Turkey. *Journal of International Financial Markets, Institutions and Money*, *18*(4), 305–312. doi:10.1016/j.intfin.2007.01.001

Dooley, M., & Hutchison, M. (2009). Transmission of the U.S. subprime crisis to emerging markets: Evidence on the decoupling-recoupling hypothesis. *Journal of International Money and Finance*, *28*(8), 1331–1349. doi:10.1016/j.jimonfin.2009.08.004

Dvorak, T., & Podpiera, R. (2021). European Union Enlargement and Equity Markets in Accession Countries. SSRN *Electronic Journal*. 10.2139/ssrn.888051

Engle, R. F. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica*, *50*(4), 987. doi:10.2307/1912773

Falagiarda, M., & Reitz, S. (2015). Announcements of ECB unconventional programs: Implications for the sovereign spreads of stressed euro area countries. *Journal of International Money and Finance*, *53*, 276–295. Advance online publication. doi:10.1016/j.jimonfin.2015.02.005

Forbes, K. J., & Rigobon, R. (2002). No contagion, only interdependence: Measuring stock market comovements. *The Journal of Finance*, *57*(5), 2223–2261. Advance online publication. doi:10.1111/0022-1082.00494

Gallant, A. R., Hsu, C. T. C.-T., & Tauchen, G. (1999). Using Daily Range Data to Calibrate Volatility Diffusions and Extract the Forward Integrated Variance. *The Review of Economics and Statistics*, *81*(4), 617–631. doi:10.1162/003465399558481

Garman, M., & Klass, M. (1980). On the Estimation of Security Price Volatilities from Historical Data. *The Journal of Business*, *53*(1), 67–68. doi:10.1086/296072

Grammatikos, T., & Vermeulen, R. (2012). Transmission of the financial and sovereign debt crises to the EMU: Stock prices, CDS spreads and exchange rates. *Journal of International Money and Finance*, *31*(3), 517–533. doi:10.1016/j.jimonfin.2011.10.004

Huang, B. N., Yang, C. W., & Hu, J. W. S. (2000). Causality and cointegration of stock markets among the United States, Japan and the South China Growth Triangle. *International Review of Financial Analysis*, *9*(3), 281–297. doi:10.1016/S1057-5219(00)00031-4

Hung, N. T. (2019). Return and volatility spillover across equity markets between China and Southeast Asian countries. *Journal of Economics, Finance and Administrative Science*, *24*(47), 66–81. Advance online publication. doi:10.1108/JEFAS-10-2018-0106

Kavussanos, M. G., & Dimitrakopoulos, D. N. (2011). Market risk model selection and medium-term risk with limited data: Application to ocean tanker freight markets. *International Review of Financial Analysis*, *20*(5), 258–268. Advance online publication. doi:10.1016/j.irfa.2011.05.007

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shinb, Y. (1992). Testing the null hypothesis of stationary against the alternative of a unit root. *Journal of Econometrics*, *54*(1), 159–178. doi:10.1016/0304-4076(92)90104-Y

Lee, S. S. P., & Goh, K. L. (2016). *Regional and international linkages of the ASEAN-5 stock markets: A multivariate Garch approach*. Asian Academy of Management Journal of Accounting and Finance.

Li, Y., & Giles, D. E. (2015). Modelling volatility spillover effects between developed stock markets and Asian emerging stock markets. *International Journal of Finance & Economics*, *20*(2), 155–177. Advance online publication. doi:10.1002/ijfe.1506

Ljung, G. M., & Box, G. E. (1978). On a measure of lack of fit in time series models. *Biometrika*, *65*(2), 297–303. Advance online publication. doi:10.1093/biomet/65.2.297

McKinnon, R., & Schnabl, G. (2003). Synchronised Business Cycles in East Asia and Fluctuations in the Yen/Dollar Exchange Rate. *World Economy*, *26*(8), 1067–1088. Advance online publication. doi:10.1111/1467-9701.00563

Nartea, G. V., Ward, B. D., & Yao, L. J. (2011). Idiosyncratic volatility and cross-sectional stock returns in Southeast Asian stock markets. *Accounting and Finance*, *51*(4), 1031–1054. Advance online publication. doi:10.1111/j.1467-629X.2010.00384.x

Oh, S.-L., Lau, E., Puah, C.-H., & Abu Mansor, S. (2010). Volatility Co-movement of ASEAN-5 Equity Markets. *Journal of Advanced Studies in Finance*.

Parkinson, M. (1980). The Extreme Value Method for Estimating the Variance of the Rate of Return. *The Journal of Business*, *53*(1), 61–65. doi:10.1086/296071

Perron, P., & Phillips, P. C. B. (1988). Testing for a Unit Root in a Time Series Regression. *Biometrika*, *2*(75), 335–346. doi:10.1080/07350015.1992.10509923

Poon, S.-H., & Granger, C. W. J. (2003). Forecasting Volatility in Financial Markets: A Review. *Journal of Economic Literature*, *41*(2), 478–539. doi:10.1257/.41.2.478

Potjagailo, G. (2017). Spillover effects from Euro area monetary policy across Europe: A factor-augmented VAR approach. *Journal of International Money and Finance*, *72*, 127–147. Advance online publication. doi:10.1016/j.jimonfin.2017.01.003

Rogers, L. C. G., Satchell, S. E., & Yoon, Y. (1994). Estimating the volatility of stock prices: A comparison of methods that use high and low prices. *Applied Financial Economics*, *4*(3), 241–247. doi:10.1080/758526905

Saiti, B., & Noordin, N. H. (2018). Does Islamic equity investment provide diversification benefits to conventional investors? Evidence from the multivariate GARCH analysis. *International Journal of Emerging Markets*. 10.1108/IJoEM-03-2017-0081

Salidjanova, N., & Koch-Weser, I. (2015). China ' s Economic Ties with ASEAN : A Country-by-Country Analysis. U.S.-China Economic and Securirty Review Commission, Staff Research Report.

Sanusi, A., Singagerda, F. S., & Septarina, L. (2019). *The volatility model of the ASEAN Stock Indexes*. Investment Management and Financial Innovations. doi:10.21511/imfi.16(1).2019.18

Shen, Y. (2018). International risk transmission of stock market movements. *Economic Modelling*, *69*, 220–236. Advance online publication. doi:10.1016/j.econmod.2017.09.022

Tan, H. B., Wong, M. F., & Elshareif, E. E. (2015). *The impact of volatility shifts on market efficiency: The case of four emerging southeast Asian stock markets*. Global Business and Economics Review. doi:10.1504/GBER.2015.068568

Vu, T. N. (2019). Impact of Crude Oil Price Volatility on Southeast Asian Stock Returns. *International Journal of Economics and Finance*, *11*(4), 40. Advance online publication. doi:10.5539/ijef.v11n4p40

APPENDIX

Appendix A. Results of the Ljung-Box and LM tests on GARCH (1,1)

	INDONESIA			MALAYSIA			PHILIPPINES			SINGAPORE			THAILAND			CHINA		
	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST
LB: $Q^2_{(10)}$	6.0273	12.1420	**16.6840***	9.0495	5.0409	8.3718	3.5426	10.2520	13.9150	4.4321	8.1699	3.3677	8.4615	4.6196	9.3314	5.7209	9.3642	18.3450
LM test: $F_{(10)}$	0.2723	0.7311	0.1210	0.7515	0.4377	1.4279	0.6100	0.4344	0.9389	0.3252	**1.7475***	0.6860	0.5658	1.5731	0.9653	0.3623	0.9302	**4.4464*****

Source: Own elaboration.

Note: This table presents the results of the Ljung-Box, ARCH-LM tests, applied to the residuals of the EGARCH model (1.1), the various indices in the three sub-periods, and considering both lag 10. * **, **, *, represent significance at 1%, 5% and 10%, respectively.

Appendix B. Results of the Ljung-Box and LM tests on EGARCH (1,1)

	INDONESIA			MALAYSIA			PHILIPPINES			SINGAPORE			THAILAND			CHINA		
	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST	PRE	CRASH	POST
LB: $Q^2_{(10)}$	5.4675	12.9260	**16.0540***	14.0540	6.2401	8.2677	2.8175	5.5291	14.1700	3.8898	10.1770	3.7855	8.1663	4.6419	9.8355	6.8008	6.7251	10.4230
LM test: $F_{(10)}$	0.5106	1.1109	0.1258	0.8457	1.0771	**1.7853***	0.6762	0.0842	0.8566	0.5109	1.4754	0.5508	0.6653	**2.3561****	0.7363	1.1679	0.5099	0.6357

Source: Own elaboration.

Note: This table presents the results of the Ljung-Box, ARCH-LM tests, applied to the residuals of the EGARCH model (1.1), the various indices in the three sub-periods, and considering both lag 10. * **, **, *, represent significance at 1%, 5% and 10%, respectively.

Rui Dias is a PhD in Finance from the University of Évora - Institute for Advanced Studies and Research. Assistant Professor in the Accounting and Finance Department of the School of Business Administration, Polytechnic Institute of Setúbal. Researcher at the University of Évora (CEFAGE). Author of more than 25 articles in specialized magazines and conferences.

Nuno Teixeira is a PhD in Management from ISCTE - University Institute of Lisbon. Professor in the Accounting and Finance Department of the School of Business Administration, Polytechnic Institute of Setúbal. Researcher and consultant in Finance, Strategy, Entrepreneurship, Internationalization and Management Control Systems. Author of books and of several articles in journals and in conferences in his areas of research.

Pedro Pardal is a PhD in Accounting from ISCTE - University Institute of Lisbon. Professor in the Accounting and Finance Department of the School of Business Administration, Polytechnic Institute of Setúbal. Researcher and consultant in the areas of Finance, Accounting and Management Control Systems. Author of book chapters and articles in journals and conferences.

Teresa Godinho has a Master's in Accounting from ISCTE - University Institute of Lisbon. Assistant Professor in the Accounting and Finance Department of the School of Business Administration, Polytechnic Institute of Setúbal. Author of articles in specialized magazines and conferences.