International Journal of Economic Research

ISSN : 0972-9380

available at http: www.serialsjournals.com

Volume 14 • Number 15 (Part 4) • 2017

Contagion Effect of the Financial Crisis from US to ASEAN Countries in Stock Exchanges: Approach by Nonparametric and Copulas

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ABSTRACT

This research utilizes non-parametric methodologies namely Chi-plots, Kendall-plots and parametric Copulas approaches (Clayton, Gumbel and Normal) to determine the dependence structure, which means tail-dependence among different financial markets. The study examines the financial markets, specifically stock exchange markets from the United States (US) and ASEAN nations, such as Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam from 2000 to 2016. In the previous financial crisis, the findings show that Indonesia, Philippines and Thailand share similarities of dependence by left side. However, both Vietnam and Malaysia do not demonstrate the left-tail dependence with the US. Meanwhile, the post-crisis period witnesses that Indonesia, Malaysia, Philippines, Singapore and Thailand have right tail dependence with the US stock exchange markets whereas Vietnam is the typical inverse case. Most ASEAN countries have no sufficient evidence to observe contagion risk after the financial crisis. Only Vietnam is incurred this adverse phenomenon.

JEL Classification: G14, G15, G17.

Keywords: Contagion risk, ASEAN, US, Chi-plots, Kendall-plots, Copulas.

1. INTRODUCTION

Recently, the financial market in the world has witnessed many failures of organizations and financial institutions, namely the US stock market crisis in 1929, the OPEC oil price crisis in 1973, the East Asian financial crisis in 1997 and the subprime crisis in the US in 2007. As can be observed, the crisis seems to

have seldom happened but in recent years, it has happened frequently and has negatively affected many stock markets in terms of both scale and extent of losses.

In the era of economic integration, the different economies are interconnected through economic and political treaties. In other words, most of the countries in all over the world always want to be linked together into alliance, an economic strong block, and develop together. Beside the positive side, this linking will create really serious consequences when one or several countries that play an important role in the alliance have a sign of crisis. In the last nineteenth and early twentieth centuries, there were very few concepts of contagion as well as the effects of contagion of risk. Even in the crisis of 1929-1933, the managements and the economists are concerned only with the economic collapse of a nation, with little regard for its spread. Until the end of the twentieth century, the beginning of the twenty-first century, as trade between nations in the world has become stronger, economic agreements between countries have become more widespread, and national alliances are more closely linked in terms of both economically and politically. At this point, the contagion of risk is more commonly mentioned as the losses caused by this risk is enormous on an almost global scale. Recognizing the importance of studying the contagion and the contagion of risk, scientists and economists have focused on studying, making concept and measurement of this contagion.

So far there has been no agreement on the definition of contagion in financial and the method of identifying the contagion. Forbes & Rigobon (2002) shows that a country would experience contagion phenomenon as considerable rise in cross-market connection after a big shock to another country (or of a group of regions). These two authors also suggest the distinction between interdependence and the contagion.

Although there is much debate about the definition of contagion, there is a widely and fully acknowledged view of the contagion of risk in finance, which is the point of view on the main themes: (i) the contagion channels or transmission mechanism of contagion like trade relations between the two countries, (ii) the methods of detecting the transmission mechanism manifests through the transmission rate of rapid or slow spread (Kolb 2011).

According to Masson (1998), Postgate et. al., (2008) the contagion can be divided into two categories, contagion and spillover, which differ in terms of scale and effect. In addition, when studying with the contagion, economists mentioned other terms such as interdependence, co-movement, and dependence structure.

Contagion in finance affects the behavior of the four actors - Governments, financial institutions, investors and borrowers. The contagion effect explains the contagion of the economic crisis or the boom across countries or regions. This phenomenon can happen in a country as well as globally. To limit the losses and risks of this economic block, many scientists have measured the dependence of the stock markets (characteristic of a country's economy) together to manage risk, which is better than simply based on qualitative policies. So far, there have been many methods of measuring the level of dependence between different stock markets. If we measure linear dependence between stock markets, we use the same linear correlation coefficient with covariance to calculate. Moreover, the most important assumption of this approach is that the variables must have a standard distribution. However, if a linear dependence does not exist between markets, or there is only nonlinear dependence, then the correlation coefficient and

covariance for calculations will lead to inaccurate conclusions. Therefore, the problem is that if there is a non-linear dependency between markets, which method should be used for measurement. Moreover, when there are large fluctuations, especially the crises that make yields of markets have a thick tail distribution, the calculation will be more difficult. And to solve this problem, it is possible to model the dependency between random variables using the Copulas parameter method.

The collapse of financial sector in the United States in the period of 2007 caused severe damage to the world economy, namely the collapse of financial institutions, a slump in manufacturing and international trade, as well as a significant increase in the unemployment rate. Consequently, many studies on the effect of this contagion have been made, but most studies on the impact of the contagion have focused mainly on developed economies like Britain, Germany, France, Japan, EU, BRICS, etc. In addition, there are a number of studies that use different methods to examine the impact of this contagion on the booming economies such as Singapore and China as well as the economy have fast growing like Vietnam, but this number is very modest. ASEAN is a new economic organization with a young age, have strong trade relations with other countries, especially the ASEAN-US Action Plan 2016-2020, including economic sector, this is a clearer illustration of the growing cohesion between ASEAN and the United States. Up to now, there have been no studies in Vietnam about the contagion of risk of crisis in the United States to ASEAN countries. By using the Copulas parametric method in conjunction with the non-parametric method as Chi-plots, Kendall-plots, with the expectation of attempting to find out the impact of the crisis of 2007 on ASEAN to international investors can identify chances for international portfolio diversification and risk management, policy formulation to track the contagion of the financial crisis, as well as to fill the huge gap in research.

The second part of the following sections illustrates a concept of the studies previously related to this study. Section 3 summarized the theory of study methodology, including non-parametric method Chi-plots, K-plots and three copulas family to analyzing dependency structure among seven stock markets in the pre and post crisis period. Section 4, this study result presents and analysts with dependency structure. Finally, section 5 summarized study result.

2. LITERATURE REVIEW

In this section, we will discuss recent studies about the application of Copulas in measuring the contagion of risk and different methodologies to compare with the results of using Copulas. Most the previous papers on contagion in financial sector are about the crises in the 1980s and 1990s, but the studies that are attracting more attention are those on the recent sub-prime mortgage crisis in the United States.

First, this paper based on Nguyen et. al., (2017) in examining the contagion risk among the US, Vietnam and China market. The authors use daily dataset of three countries from January 2003 to October 2011. Moreover, the non-parametric method Chi-plots and Kendall-plots are employed to show the dependency among these countries then use the parameter method as Copulas function to analyze the degree of risk contagion between US market, Vietnam and China, as well as measure losses through parameters expressed by Copulas function. The results of the study identified the presence of dependency on the left tails before and after the financial crisis. There is a robustness to depend on structure between the US and Vietnam equity markets. However, the US and Shanghai markets have certain levels of dependence on the left-hand tail before 2007, but there is no proof of post-crisis dependence. Meanwhile, the US and Shenzhen

capital markets are independent before and after the crisis. The Shenzhen stock market is less affected by a critically negative event in the biggest stock market, US. Therefore, for this combination, there is likely to diversify risk when the US investors made their decision in the Shenzhen market after this period. These findings contribute empirical evidence to the existing literature.

Bartram & Wang (2015) examined the extent and determinants of dependence among European stock markets using a conditional Copulas model analyzing 10 sectors in 12 European countries and 8 countries not in Europe. The results show that the dependence of the stock market among these countries is escalating around the bankruptcy of Lehman Brothers - the cause of the US financial crisis. Additionally, Boubaker & Sghaier (2014) have investigated the US equity market in association with four well-established stock markets, such as France, Britain, Germany and Japan, during the recent global financial crisis (2007-2009) using the Copulas extracting different time period for extreme vale model. The findings show that there is a symmetric dynamic dependence between stock markets in Japan and the US, and an asymmetric one existing between the stock markets in Europe and the US.

Interestingly, before the financial crisis period, many Asia investors made their decisions to invest to the US securities to hedge for their portfolios. However, the collapse of banking system in the US cause the contagion risk to many countries due to the holding of these assets. Yang et. al., (2015) confirms that not only sub-prime mortgage trigger this phenomenon. Besides, this crisis is accumulated by the debt crisis from many European countries.

C. Nguyen (2013) recently assessed the change in the dependency structure between the US and Asian financial markets in both period of crisis by non-parameter and Copulas estimation. Their findings show the existence of a left-leaning tails between the stock markets in Indonesia, Thailand Singapore and Hong Kong and the US stock market in the post financial crisis. In contrast, their findings show no difference in structure to be depended between the stock market in US and the following countries: Japan, Malaysia and the Philippines.

For the BRIC countries (Brazil, China, India and Russia), Aloui et. al., (2011) assessed the impact of the spread between the BRIC and US stock markets during the global financial crisis by using Copulas Function, from April 22, 2004 to March 20, 2009. Their findings show a significant dependency structure between the US and BRIC markets. However, the impact on markets depending on the price of goods is stronger than the market for finished products. In order to interfere the results of Copulas' application in the measurement of contagion risk across countries, this study will review a number of papers on contagion risk using different methods.

Syllignakis & Kouretas (2011) used Engle's multi-dimension DCC GARCH model (2002) along with the weekly stock data of the country's stock indexes to find evidence of US, German and 7 Eastern and Central European markets (Slovenia, Poland, Estonia, Romania, Hungary, Slovakia and Czech) for the period 1997-2009. The author's findings show the impact of the spread between the US, Germany and Central and Eastern European stock markets during the US financial crisis of 2007-2009. In addition, the author compares the two 1997 crisis in Thailand and the subprime crisis in the United States, the results show that the crisis in the United States has greater impact than the monetary crisis in Thailand because of the collapse of a globally-connected banking system.

Similarly, Tudor (2011) evaluates the change of stock market dependence in the worldwide crisis between the six Central and Eastern European stock markets and the US equity market in the 2006- 2009,

using the Granger Causality Test and Impulse Response Analysis. The results show that both of them are strongly linked. In addition, the results of the study found that before the crisis, the CEE market was remarkably affected by innovations in the US market, so they were strongly influenced due to the crisis that has spread rapidly in the region.

Lee (2012) uses 20 international stock indexes worldwide, the United States, Canada, Mexico, Germany, Chile, Brazil, Argentina, France, England, Japan, Singapore, Korea Malaysia, China, Philippines, Taiwan Indonesia, Hong Kong, South-East Asia, Thailand, New Zealand and Australia, from 23 July 2006 to 22 January 2008, combined with the Heteroscedasticity Biases Based On Correlation Coefficients to explore the presence of the contagion effect because of the sub-prime contract emergency in the Unified States the subprime mortgage crisis in the United States. These estimations indicate the presence of the impact of the stock market contagion in Hong Kong, New Zealand, Australia and Taiwan.

In terms of Asian markets, Chang & Su (2010) uses the Glosten-Jagannathan-Runkle-GARCH approach in order to evaluate the impact of the stock market in Vietnam and the country's main trading partners, the United States, China, Singapore and Japan for the period 2002-2007. Their findings suggest a spillover effect between the US and Vietnam, Singapore, Japan, China stock market. Intriguingly, the stock market in Japan is likely to spread significantly to the Vietnamese one compared to other worldwide markets. Despite that, the authors detect a weak spillover effect between Vietnam and the US stock markets and this results in a low dependency between Vietnam and the United States.

The authors use an Asymmetric Generalized Dynamic Conditional Correlation Model to examine the impact of financial crisis for both markets (bond and stock ones). The scope of emerging economies are Israeli, South African, Turkish, Indonesian, Thailand, Czech Republic, Greece, Hong Kong and Singapore. Finally, Kenourgios & Padhi (2012) prove that there is a spillover effects between the largest stock market and emerging economies' ones in terms of the subprime mortgage crisis.

Interestingly, Wang & Nguyen Thi (2013) also investigated the widening and risking effects of stock markets in the United States and Vietnam, China with daily data in the period from 2006 to 2009 by using the Estimates of Bivariate Exponentially General Autoregressive Conditional Heteroscedasticity Models Using Conditional Correlation. The findings show proof of the spillover influences between China and Vietnam as well as United States due to the overwhelming mortgages in housing in the United States. Intriguingly, compared to the US stock market, the Chinese one is more widespread on the Vietnamese one.

Wang & Lai (2013) expanded their study scope from October 2006 to May 2012 and employed them to examine their impacts of the spread of equity markets among China, Vietnam, Singapore, Japan and the United States. In similar fashion, the researchers applied the bivariate model E-GARCH model and showed the spillover influences between the Vietnamese and the remaining stock markets existed.

In terms of Chinese studies, Zhang et. al., (2010) examined the relationship between two countries (China – the US) between December 12, 2001 and January 23, 2009 by employing the Dow Jones Industrial Average Index combined with the Shanghai Composite Index. The findings from the uniform checks confirm that there is no proof of a combination of a pair of equity markets. Nevertheless, Granger's causality test shows that changes in stock prices in the United States had a remarkable impact on the Chinese stock market during the later period. Employing the DCC-Multiple GARCH model, these findings confirmed that the oil spill was more volatile from the big one to the small one.

Hu (2010) utilized the Time-Varying Conditional Copulas method to check the dependency structure between the big one in Asia and the largest equity market. To be specific, the methodology of estimation of marginal distributions is called as EVB model (or known as Symmetrized Joe-Clayton Copulas with normal time). The results of the study indicate that, unlike the US market, the financial sector in China is distinct from the others. Additionally, compared to the US market, China has weakly depended in structure on other financial markets.

Similarly, Podobnik et. al., (2011) proposed the elimination of trending in cross-correlations analysis (DCCA). This methodology shows that that the US financial market has a weak influence on the Chinese market. On the contrary, the indicator from Germany (DAX) shows strong dependence to New York Stock Exchange Composite Index (NYSE). Tien Thuan (2011) uses the combination of GARCH and ARMA as well as EGARCH-ARMA to evaluate the direction of dependence between the US and Vietnamese securities markets from 2003 to 2009. The findings show that they are strongly connected in financial crisis. This result provides further evidence that Vietnam is a frontier market. Furthermore, it also suggests that fund managers should consider the movement of the US stock market before investing in Vietnam.

Dimitriou et. al., (2013) employed Multivariate Fractionally Integrated Asymmetric Power and ARCH to analyze the spreading influences of the place beginning crisis to emerging nations such as South Africa, Brazil, Russia, China, and India (known as BRICS) in the period 1997-2012. In the early stages, there is no contagion effects. However, after 2009, they are significantly depended. This finding is more important than downtrend markets.

3. THE DATA AND METHODOLOGIES

3.1. The Data and Descriptive Statistics

In this section, the data will be described detail based on descriptive statistical analysis. The authors used the daily data of indices from the ASEAN and US stock markets, taken directly from the DataStream. The data is from the beginning of August 2000 until the end of December 2016. Data are used by Thomson Reuters (2017) including VNI-Index, JCI-Index, SET-Index, PCOMP-Index, FSTAS-Index, FBMEMAS-Index respectively represent for the stock markets of Vietnam, Indonesia, Thailand, Philippines, Singapore and Malaysia, the S&P500 index represents for the US stock market. When collecting, we removed the indexes in Brunei, Laos, Cambodia and Myanmar in ASEAN because the stock markets in these countries were just established and are developing so there are not enough data to calculate. Collected markets are large and prestigious markets in the region that can represent the entire ASEAN region. Table 1 presents the summary of descriptive statistical results.

According to the statistical results, the average return of the ASEAN market is much higher than that of the US market (except Singapore), the highest in Indonesia (0.0007336) followed by Vietnam (0.000588). Therefore, when investing in ASEAN market, investors will achieve higher profit (much higher when investing in US market). Considering the standard deviation, the standard deviation gap between markets is not too large, this shows that the volatility of the markets does not differ too much. Therefore, according to the standard deviation, the risk of investing in the indexes is relatively similar to the investors. In particular, Vietnam is the most fluctuating market (with the highest standard deviation is 0.018375), which means the highest risk market and the least fluctuating market is Malaysia (with the lowest standard deviation 0.0094864).

Table 1
Descriptive statistics for equity markets tested

Variable	*Indonesia*	*Malaysia*	*Philippines*	*Singapore*	*Thailand*	*Vietnam*	*S&P500*
Mean	0.0007	0.0002	0.0005	0.0001	0.0005	0.0006	0.0001
Std. Dev.	0.0158	0.0095	0.0150	0.0133	0.0151	0.0184	0.0134
Min	–0.1293	–0.1325	–0.1364	–0.1334	–0.2034	–0.1353	–0.0947
Max	0.1032	0.0683	0.1550	0.1027	0.1058	0.1260	0.0702
Median	0.0013	0.0005	0.0004	0.0004	0.0007	0.0004	0.0007
Kurtosis	11.6496	26.4067	14.7834	14.7599	20.6651	8.9986	8.1936
Skewness	–0.8484	–1.4595	0.1895	–0.3314	–1.0884	–0.3109	–0.3431

Source: The authors.

Statistical results show that the ASEAN countries have very high maximum return (except Malaysia - the lowest value market), the highest in the Philippines (0.1550377). For the US market, the S&P500 has very low maximum return compared to ASEAN countries. So if investors want to receive unexpectedly high returns, they should invest in the Philippines market and that will not happen when investing in the US market.

Finally, consider two high-level elements: Kurtosis and Skewness. All indexes have higher kurtosis than normal distribution (kurtosis = 3), called Leptokurtic or Excess kurtosis (Excess kurtosis = Coefficient Kurtosis – 3). Leptokurtic distribution means that profit tend to move away from the average return value, fluctuations of the profit is very large, which may be very high on the positive side or may also be very low on the negative side of the average profit. Therefore, the higher coefficient of Excess kurtosis, the higher risk for investor when investing in the index. Of which, ASEAN countries have very high Kurtosis coefficient (the highest in the Malaysian market). In Vietnam, the Coefficient Kurtosis of the VNI-Index is lower, equivalent in the US market. This shows that the US market is safer for investors, or in other words, the probability of adverse events affecting the market in ASEAN countries is higher. As compared to other ASEAN countries, if only consider the coefficient Kurtosis, the safety for investors when invest in the Vietnamese market is the highest.

As for the Skewness factor, only the Philippines market has a positive Coefficient Skewness, which suggests that future profit in this market will rise higher than normal. This is a good news for investors when deciding to invest there. Conversely, other indexes have negative coefficient skewness, which means that on most of the days the indexes have a positive profit but there suddenly appears the days with a very negative profit. There are some days having very negative profit which are not reflected in the mean (positive average profit). However, in skewness it has negative coefficient, which means the days having positive profit are strongly influenced by a few days that have very negative profit. The sudden appearance of some negative profits is not good and is a risk to be avoided. If investors invest in a market with negative coefficient skewness, which means even if the average profit is positive, the probability of occurrence a negative profit is very high in the future. Therefore, investors should carefully consider Skewness factor before making an investment decision. Indexes in the Indonesian, Malaysian and Thai markets have significantly negative coefficient skewness (< –0.5). This shows that the probability of occurrence negative profit in the future for investors when investing in these indexes is higher when investing in the other indexes, meaning that the risk in these markets is higher.

Overall, according to the statistics of the research team, except the Kurtosis factor, the remaining factors between the ASEAN and US markets are quite similar. To study the contagion influences before and after the US subprime crisis, the authors look into three sets of data consisting of two sub-groups, before and after the crisis and the whole period of 2000-2016. The crisis period from August 2008 to April 2009, was examined for the sub-groups.

3.2. The Research Methodologies

Non-parametric approach (Chi-plots and K-plots) are utilized to determine the dependency structure among stock markets. At the same time, the authors use three families of Copulas including Gumbel, Clayton and Normal to analyse dependence structure. In addition, these Copulas families well represent right-tail, left-tail and independence- tails. Summarizing theory and research methodologies will be discussed in the next part.

3.2.1. Chi-plots and Kendall-plots

Chi-plots are based on the ranking of data and it is also graph to illustrate the spread over a wide area (λ_i, χ_i) for the movement by both variables in couple of (X_i, Y_i) with $i = 1, 2, \ldots, n$.

Assume that H is the joint distribution function between two continuous variables and F_n, G_n is the marginal function for X and Y, respectively with showing in point of data hereinafter:

$$H_i = \sum_{j \neq i} I(X_j \leq X_j, Y_j \leq Y_i)/(n-1)$$

$$F_i = \sum_{j \neq i} I(X_j \leq X_i)/(n-1)$$

$$G_i = \sum_{j \neq i} I(Y_j \leq Y_i)/(n-1)$$

In which, I(A) = 0 or 1, which depends on the event by A becoming true or false. Fisher and Switer suggest to draw (X_i, Y_i) by the calculation as follows:

$$X_i = \frac{H_i - F_i G_i}{\sqrt{F_i(1-F_i)G_i(1-G_i)}}$$

$$\lambda_i = 4S_i \max\left\{\left(F_i - \frac{1}{2}\right)^2, \left(G_i - \frac{1}{2}\right)^2\right\}$$

In which,

$$S_i = \text{sign}\left\{\left(F_i - \frac{1}{2}\right)\left(G_i - \frac{1}{2}\right)\right\}$$

The graph by chi-plots has the confidence interval, which receives value by $\pm c_p/\sqrt{n}$ (approximate at C_p at the significance level 95%, which is nearly 1.78). The (λ_i, χ_i) from the continuous independent variables and has tendency to stay in the same line. For the positive marginal dependence, the couple of (λ_i, χ_i) has a trend of spreading out the line above.

K-plots or called **Kendall-plots** is based on the ranking of data, which are collected by Quantile-Quantile-plot (QQ-plot) to test the normal features. The couple of data (X_i, Y_i) will transform into (W_i : n, H(i)) with $i = 1, 2, \ldots, n$.

Furthermore, the value of H(i) is defined as follows:

$$W_i : n = \omega k_0(\omega)\{K_0(\omega)\}^{i-1}\{1 - K_0(\omega)\}^{n-i}d\omega$$

But it has to satisfy the requirements here: H(i) < … < H(n). Interestingly, $W_i : n$ is the expected statistical value in ranking i from the random sample W = C(U, V) = H(X, Y) for the size with n (observations).

With the null hypothesis H_0, U and V (or called X and Y) are independent variables. The value of W_i: n is calculated by the formula above. In which,

$$K_0(\omega) = P(UV \le \omega = P\left(U \le \frac{\omega}{\nu}\right)d\nu = 1d\nu + \frac{\omega}{\nu}d\nu = \omega - \omega\log(\omega)$$

Then, k_0 is the relative density.

To sum up, both chi-plot and K-plot (or Kendall-plot) are used to define the dependence structure by the independent variables and it is appropriate to choose the well-matched tail dependence by one of the Copulas families. Like the test is asymptotic, its efficiency is related to the sample size. So, it is suggested the using of the larger sample size possible. Therefore, the authors make decisions of collecting data by each day for further testing.

3.2.2. Gumbel, Clayton and Normal

The scheme of Copulas approach for these security markets are illustrated as follows: Copulas theorem comes from Sklar (1959), in which $X_1, X_2, X_3, \ldots X_n$ are random variables with continuous distribution function $F_1, F_2, F_3, \ldots F_n$. It also has joint density function H according to the study of Ward et. al., (1959).

$$\exists C : [0, 1]^d \rightarrow [0, 1]$$

Satisfying the conditions hereinafter:

$$H(x) = C\{F_1(x_1), \ldots, F_d(x_d)\}\ x \in R^d$$

In which, the function C is called 'Copulas', with distribution into many sides and many marginal distribution is standard normal distribution. This property is practical for measuring dependence.

In order to run Copulas, the function must use pseudo-observations with formula:

$$\hat{U}_i = \frac{R_i}{m+1}, i \in \{1, \ldots, m\}$$

With the parameter $\frac{1}{m+1}$ so as to happen some concerns in marginal place for Copulas. The empirical Copulas for sample is defined as:

$$C_m(u) = \frac{1}{m}\sum_{i=1}^{m} 1(\hat{U} \le u), u \in [0, 1]^n$$

With I(A) is indicator function for A; and A is called 'event'.

In this research, there are three two-side Copulas to use for testing structure dependence such as Gumbel, Clayton and Normal.

Regarding Gumbel Copulas, there is a fundamental concept about this member in Copulas family:

$$C_\theta(u, v) = e^{-[(-\ln u)^\theta + (-\ln v)^\theta]^{1/\theta}}$$

In which, $\phi(t) = (-\ln t)^\theta$, $\theta \geq 1$ with the level of dependence in left-tail (λ_L) and right tail of (λ_U): $(\lambda_L) = 0$, $(\lambda_U) = 2 - 2^{1/\theta}$.

This family of Copulas could capture the upper tail dependence with the indicator (λ_U) for the previous mentioned dependence.

As regards Clayton Copulas, the approach begins with:

$$C_\theta(u, v) = (u^{-\theta} + v^{-\theta} - 1)^{-1/\theta} \quad và \; C_0(u, v) = \Pi = uv,$$

In which, $\phi(t) = \dfrac{t^{-\theta} - 1}{\theta}, \theta \geq 1$ with the left-tail (λ_L) and the right-tail (λ_U): $(\lambda_L) = 2^{-1}/\theta$, $(\lambda_U) = 0$.

This family of Copulas could capture the lower tail dependence with the indicator (λ_L) for the previous mentioned.

Related to Normal Copulas, this family does not capture the upper or lower tail and this parameter is stayed in range of ($0 \leq \theta \leq 1$).

$$C_\theta(u, v) = \int_{-\infty}^{\phi^{-1}(u)} dx \int_{-\infty}^{\phi^{-1}(v)} y \, \frac{1}{2\pi\sqrt{1-\theta^2}} \exp\left\{-\frac{x^2 - 2\theta xy + y^2}{2(1-\theta^2)}\right\}$$

Pseudo-maximum likelihood method is used for estimating parameters:

$$l(\theta) = l(\theta) = \sum_{t=1}^{T} \ln c(H_1(x_{1t}), H_2(x_{2t}), \ldots, H_m(x_{mt})) + \sum_{t=1}^{T} \sum_{j=1}^{m} \ln f_i(x_{jt})$$

In which, θ is set parameters of marginal distribution and Copulas.

Estimated parameters by Maximum likelihood method is:

$$\widehat{\theta_{MLE}} = \max_{\theta \in \Theta} l(\theta)$$

Note: Pseudo-maximum likelihood method is established similarly above however based on pseudo observations.

Log-likelihood value is used to choose tailored Copulas in its families. Maximal Log-likelihood value will indicate most suitable Copulas families to represent dependence structure. All of Copulas functions are tested by goodness-of-fit based on Prokhorov (2008), and if the value of Copulas function is greater than alpha, it will be most suitable to represent dependence structure. However, based on the study of Embrechts (2009), it has 99,9% of Copulas application to dismiss goodness-of-fit test.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1. Non-parametric Estimation and Drawings

The estimations demonstrated by Chi-plots as well as Kendall-plots will be presented and analyzed in the pictures below. Research data is divided into two groups, including pre-crisis and post-crisis periods. The purpose of the Chi-plots and Kendall-plots non-parametric graph analysis is to examine the existence of structure depended between the ASEAN equity market and the US stock market or between countries and the United States and whether they vary at different stages. Furthermore, that the tail dependence structure exists as left or right ones will be detected by analyzing the tail Chi-plots.

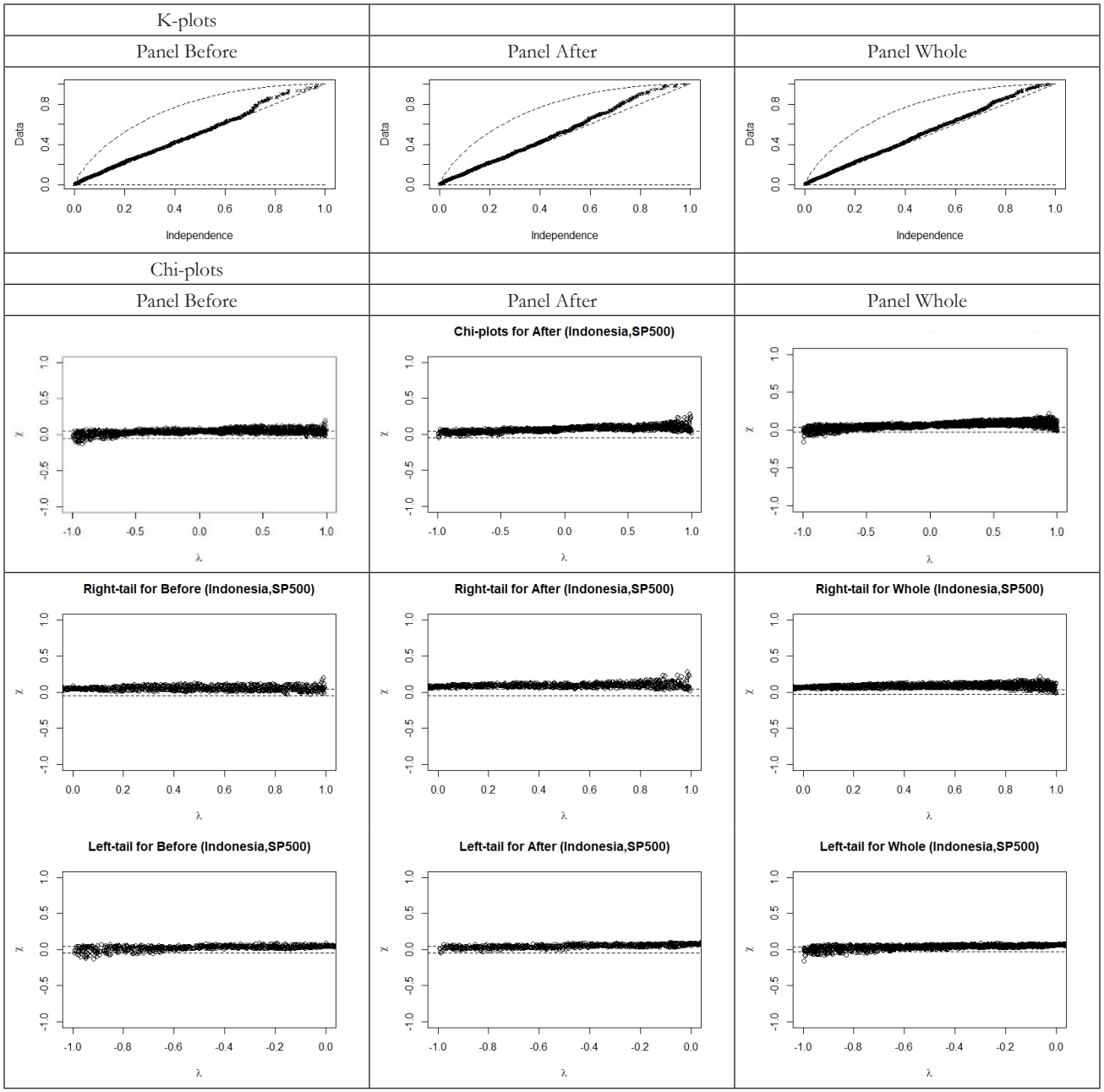

Figure 1: The Indonesia and US stock markets from August 2000 to December 2016

Figure 1 presents the dependence between the U.S. and Indonesia market through Chi-plots and K-plots. The K-plots indicate that there is a interrelationship between the U.S. and Indonesia equity markets before and after crisis, as well as in the whole period when the points do not lie along the 45-degree diagonal line at the tail of the graph. Moreover, the Chi-plots show the existence of a left side of structure in dependence from the period before 2007 and after 2007 between the two stock markets on the grounds that many of the points are outside Chi-plots' two control lines (+/- 0.05) in the left-tail plots. In the post-crisis period, the two markets have a right-tail dependence, demonstrated by the Chi-plots showing the points outside the two control lines. Similarly, the Chi-plots for the entire period also demonstrate that both periods of the market are structurally dependence on the right tail.

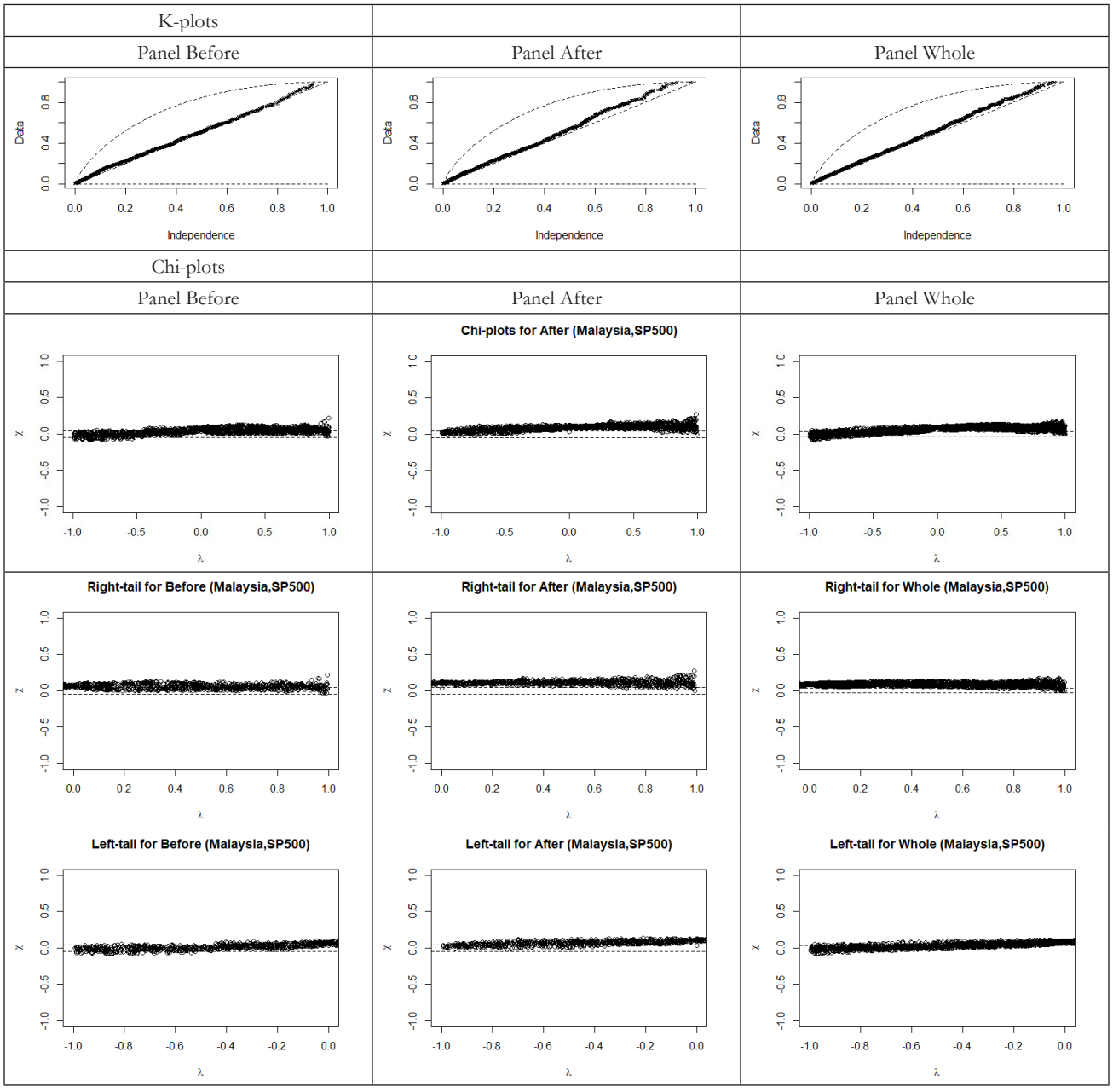

Figure 2: The Malaysia and US stock markets from August 2000 to December 2016

Figure 2 presents the interrelationship between Malaysian and US stock markets. K-plots indicate that there is no evidence about the tail shape for two equity markets on structure before the period of collapsing because the points are almost linearly distributed along the 45-degree line on the graph. However, in the post-crisis period, the points on the graph do not lie linearly along the 45-degree line at the tail end of the graph, which means the presence of a tail-dependence structure between the two stock markets. K-plots for the whole period also indicate that two stock markets experience the dependence on tail. The results are similar for both Chi-plots and K-plots, in the pre-crisis phase there is no tail-dependence structure between the two markets due to the fact that the Chi-plots for the left and right tail indicate that the points are almost within the confines of the two trust lines. However, in the post-crisis period as well as in the whole period, the Chi-plots more indicate that between the two stock markets, there is a right-tail dependence structure when many plots are outside the two control lines of the right-tail Chi-plots graph in post-crisis period, as well as in the whole period.

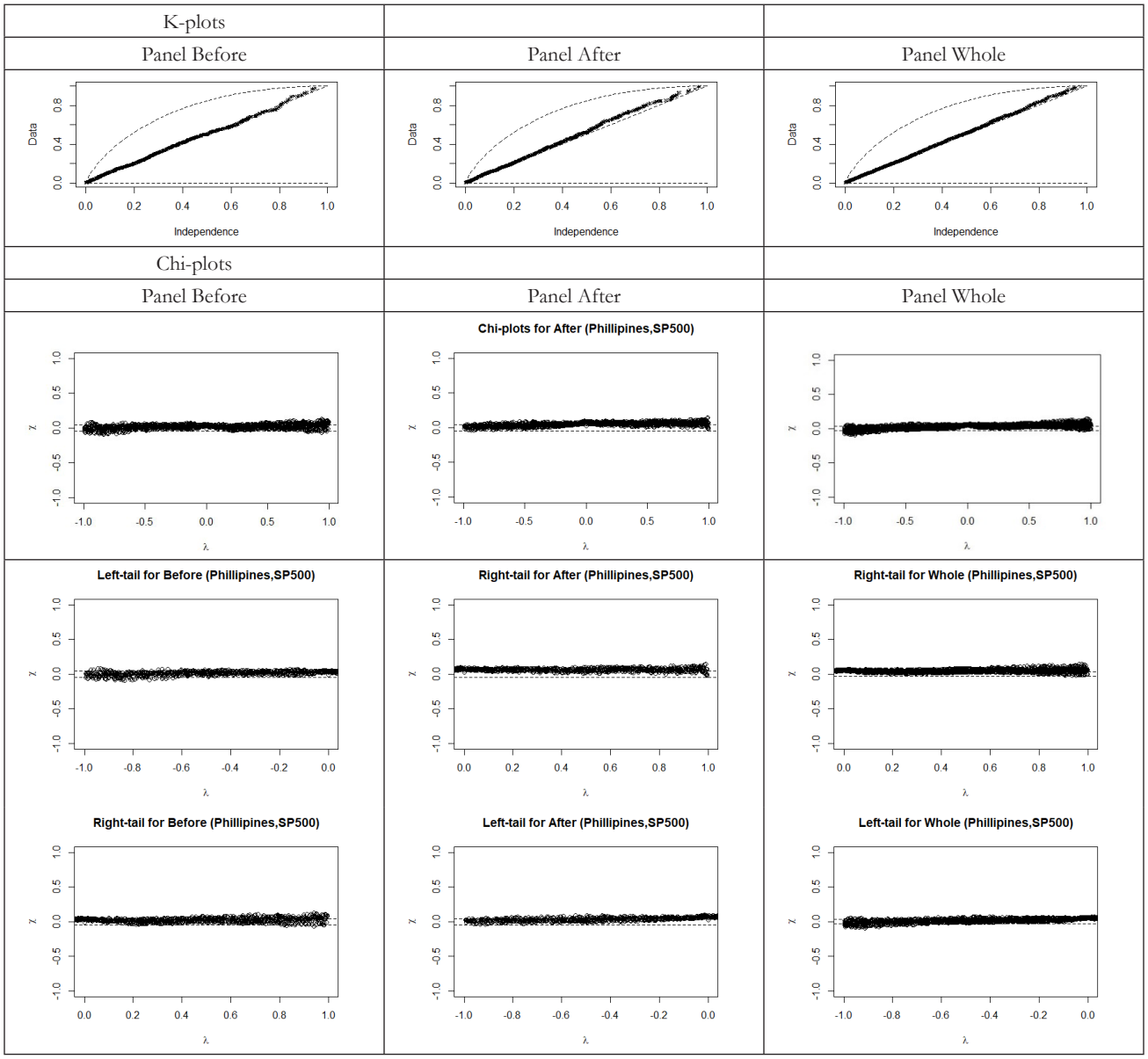

Figure 3: The Philippines and US stock markets from August 2000 to December 2016

The determination of dependence structure based on K-plots and chi-plots between the US and the Philippines are illustrated in Figure 3. The results of the K-plots analysis show that there is no tail-dependence structure between the two stock markets in the whole period when the points lie linearly along the 45-degree line. However, in the pre- and post-crisis period there exists a tail-dependence structure between a pair of them because the points do not lie along the 45-degree line at the tail of the two graphs. Furthermore, the Chi-plots also indicates that, between the two stock markets, there is a left-tail dependence structure in the pre-crisis period and in the whole period, with the evidence that the points are outside the two limit lines in both Chi-plots for the left tail. The result of Chi-plots is different from that of K-plots on the dependence structure in the whole period. The right-tail Chi-plots indicate that at the later stage between the US and Philippine stock markets there is a right-tail dependence structure, which is similar to the plotted line by K-plots.

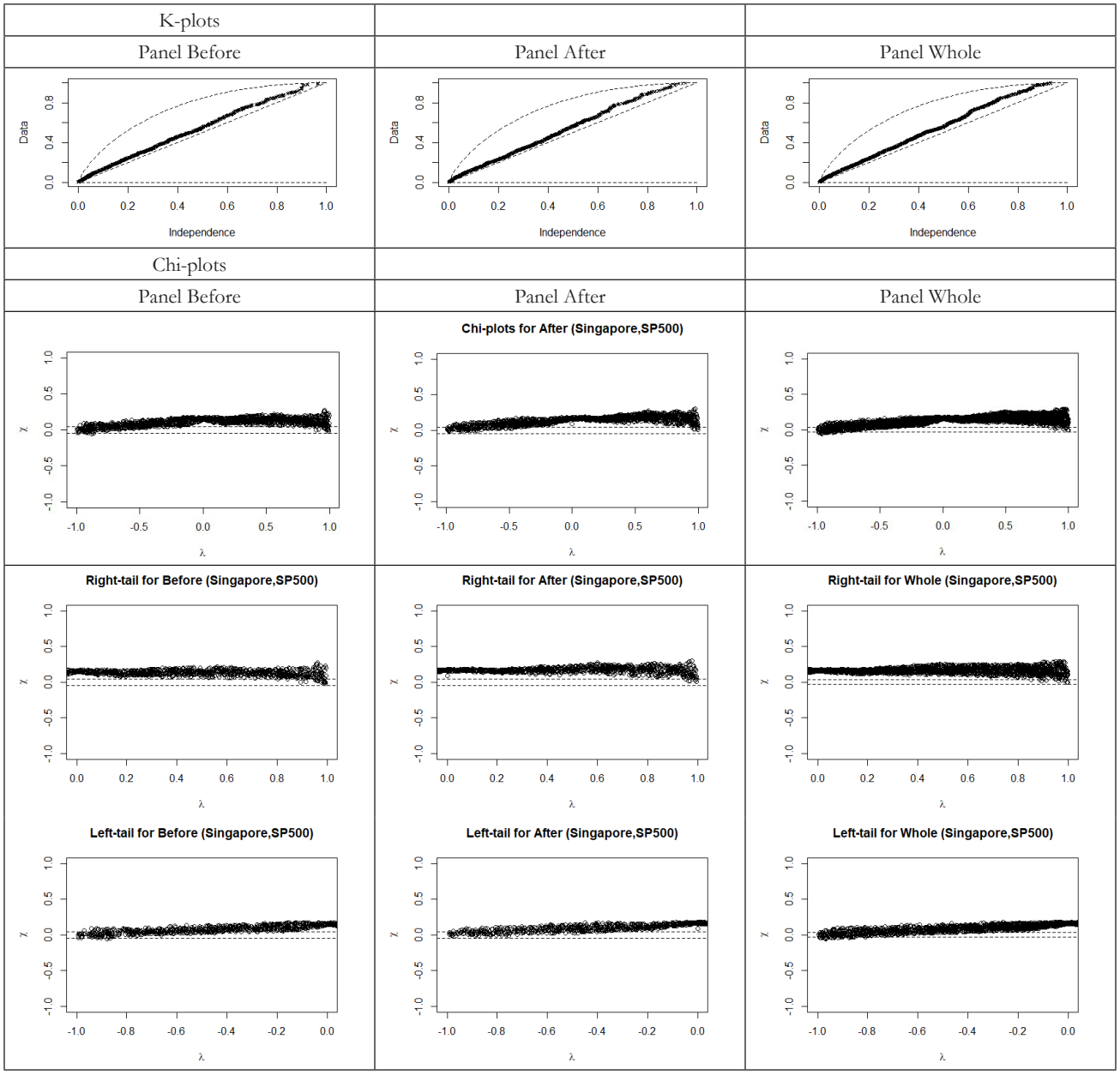

Figure 4: The Singapore and US stock markets from August 2000 to December 2016.

Figure 4 shows the non-parametric estimation for the interrelationship of the Singapore and US equity markets. The K-plots show a tail-dependence structure between the two equity markets in the pre-crisis, post-crisis and even the whole period because the points are not linearly distributed along the 45-degree line of the graph. Similarly, the Chi-plots analysis demonstrates the existence of a right-tail dependence structure between a group of the US and the Singapore in the pre-crisis and post-crisis periods due to the distribution of Chi-plots for the right tail at all stages are almost out of the two control lines. Chi-plots for the whole period also indicate that there exists a right-tail dependence between the two stock markets because the Chi-plots for the right tail are outside the two limit lines (+/- 0.05).

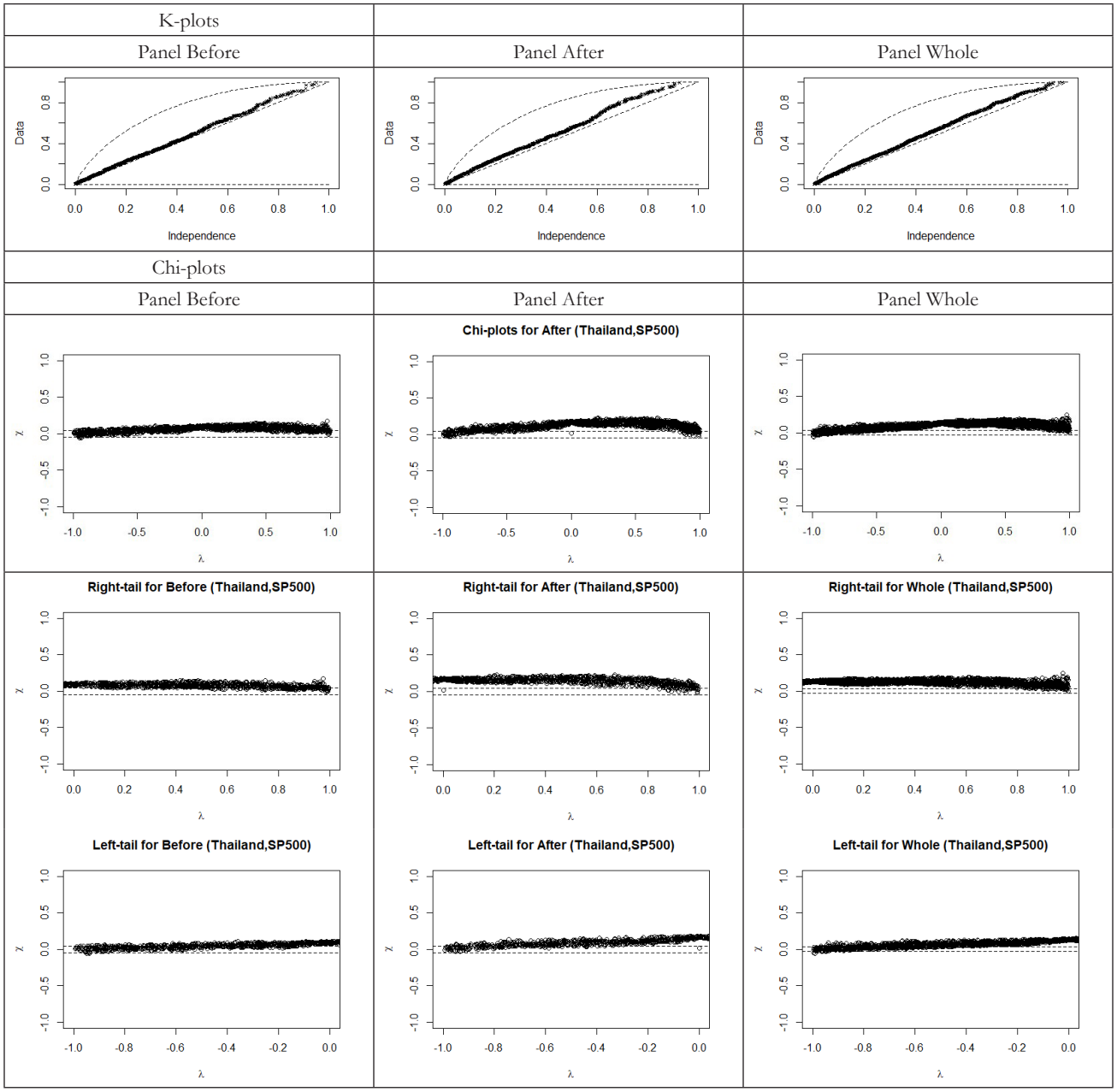

Figure 5: The Thailand and US stock markets from August 2000 to December 2016

Figure 5 includes the K-plots and Chi-plots for the dependence between the Thai and US stock markets. K-plots show a tail-dependence structure between the two stock markets in the pre-crisis, post-crisis and even the whole period because the points are not linearly distributed along the 45-degree line of the graph at the tail end of both graphs. K-plots of the whole period also indicate that there is a tail-dependence structure between the two equity markets. Similarly, in the pre-crisis period, Chi-plots for the left tail show that the points were distributed outside the two control lines, indicating that between the U.S. and Singapore stock markets have a left-tail dependence structure at this stage. However, in the post-crisis period, there is a right-tail dependence structure between the two markets because the Chi-plots for the right tail at this stage have many points distributed outside the two control lines. The Chi-plots of the period also points out that between the two markets there is a right-tail dependence structure. This result is similar to K-plots' findings.

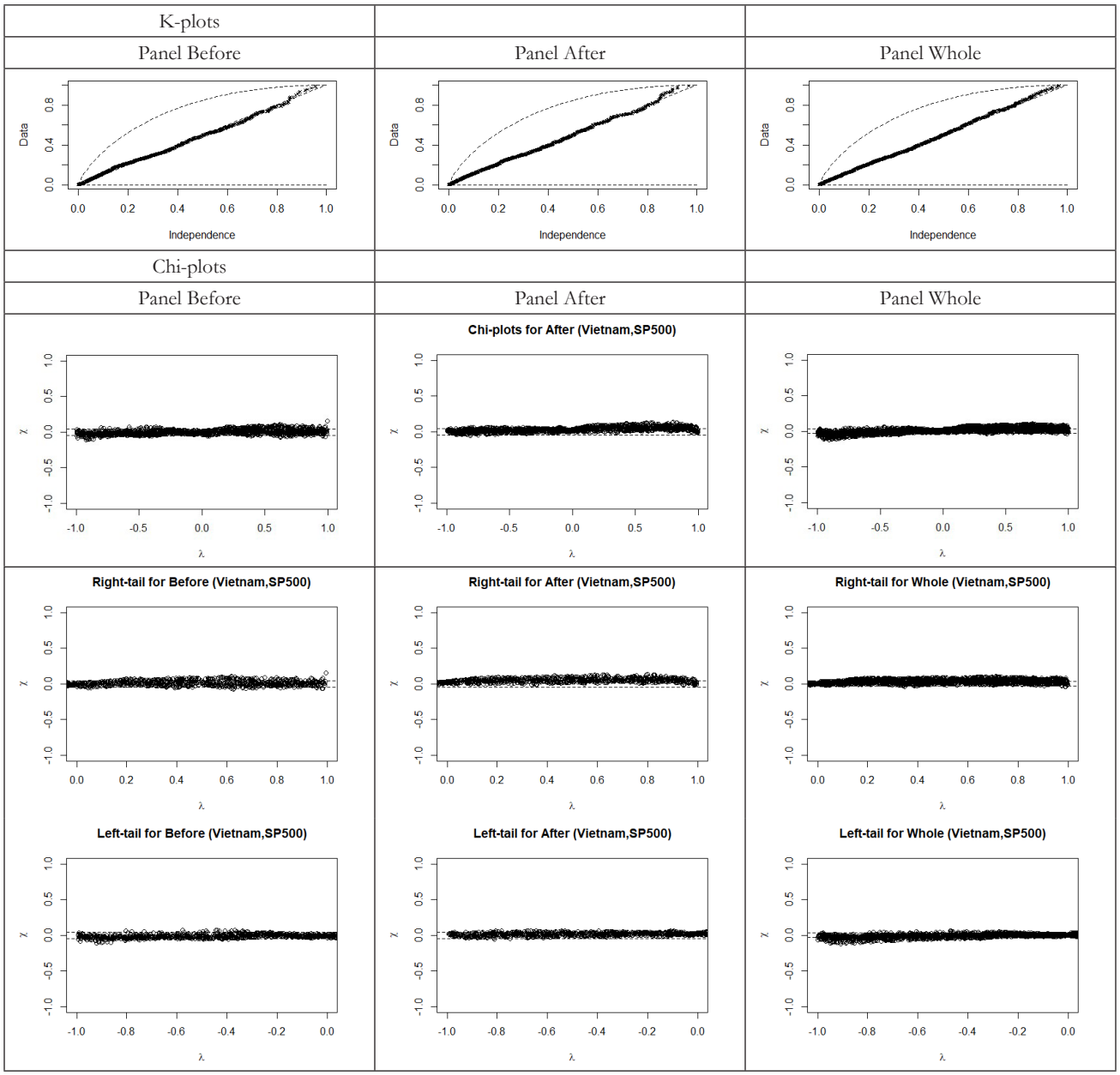

Figure 6: The Vietnam and US stock markets from August 2000 to December 2016

The findings when analyzing the interrelationship between a pair of the US and Vietnamese securities market are presented in Figure 6. The K-plots analysis shows that there is no tail-dependence structure between the two countries before 2007 and in the whole dataset because the points lie almost linearly along the 45-degree line. However, before the crisis period, the K-plots indicate that between the two markets there is a tail-dependence structure since the points do not lie along the 45-degree line at the tail end of the graph. Similarly, there is no shape of depending structure on tail between the two equity markets after 2007 because the two plotted lines in Chi-plots for the left and right-tail are almost within the two control lines. In addition, in the before period as well as in the whole period, between the two stock markets, there is a left-tail dependence since many points of the Chi-plots for the left tail at this stage lie outside the two control lines.

4.2. The Copulas analysis

In the following part, the results of the three Copulas cousins, namely Clayton, Gumbel and Normal, will be presented, and the results will be used to analyze the contagion of the US crisis to the equity markets in the six ASEAN nations (Malaysia, Philippines, Singapore, Indonesia, Thailand and Vietnam) from August 2000 to December 2016. The Copulas are selected at each stage based on the value of the corresponding Loglikelihood (the Copulas cousins with the largest Loglikelihood at each stage). The following table shows the results of the Copulas parameter estimation divided into three phases: Before, After, and Whole.

Table 2
The estimated parameters for countries' stock markets with US stock market by Copulas approach

Countries	*Period*	*Data*	*Clayton*	*Gumbel*	*Normal*
Indonesia	Before	Param	0.1466	1.052	0.09352
		Loglikelihood	13.74	5.83	6.57
	After	Param	0.2071	1.121	0.175
		Loglikelihood	22.16	32.03	23.72
	Whole	Param	0.1894	1.099	0.1464
		Loglikelihood	46.17	47.48	34.61
Malaysia	Before	Param	0.1303	1.051	0.07649
		Loglikelihood	11.05	5.973	30.45
	After	Param	0.2616	1.144	0.2045
		Loglikelihood	26.69	41.63	32.56
	Whole	Param	0.1841	1.096	0.1326
		Loglikelihood	41.23	44.28	28.32
Phillipines	Before	Param	0.08339	1.026	0.04973
		Loglikelihood	4.931	1.872	1.851
	After	Param	0.1426	1.075	0.1182
		Loglikelihood	10.92	14.07	10.73
	Whole	Param	0.1106	1.05	0.07423
		Loglikelihood	17.66	14.46	8.825

(*Contd...*)

Countries	*Period*	*Data*	*Clayton*	*Gumbel*	*Normal*
Singapore	Before	Param	0.338	1.165	40.73
		Loglikelihood	47.06	46.9	0.2301
	After	Param	0.4306	1.226	0.2947
		Loglikelihood	69.42	78.6	69.32
	Whole	Param	0.404	1.21	0.2755
		Loglikelihood	141.6	149.8	223.2
Thailand	Before	Param	0.1914	1.082	0.1354
		Loglikelihood	18.62	13.67	13.85
	After	Param	0.3861	1.184	0.2517
		Loglikelihood	41.54	53.54	49.94
	Whole	Param	0.3038	1.142	0.206
		Loglikelihood	79.69	75.08	69.25
Vietnam	Before	Param	0.04321	1.012	0.006415
		Loglikelihood	1.351	0.6297	2.107
	After	Param	0.1084	1.053	0.08174
		Loglikelihood	7.783	7.326	5.108
	Whole	Param	0.07479	1.032	0.02869
		Loglikelihood	8.639	7.47	1.315

Source: The authors.

Generally, the Clayton is picked as the most appropriate copulas to represent the dependence of the entire stock market, in pre-crisis, post-crisis as well as the whole period. Of the parameter values selected at each stage, the Clayton Copulas account for 44.4% (the selected parameter values are highlighted). The Gumbel Copulas take 38.89% of the selected parameter values, the remaining Normal Copulas, which represent the dependence of stock market pairs only make up 16.71%.

The Clayton Copulas are chosen to be the best match to show the relationship between the Indonesia and the United States stock market, indicating that before the US subprime mortgage crisis, the Indonesian and US markets reveal a left-tail dependence structure. In particular, the two stock markets tend to crash together rather than boom together. The estimated results, however, show that there has been a dependency structural change between these two markets before the crisis period and more specifically the Gumbel Copulas are believed to be the fittest to demonstrate it. After the crisis, the two markets tend to crash together rather than boom together. Furthermore, Gumbel Copulas are chosen as the best fit to depict the dependence structure between the two markets in the whole period. Thus, the contagion of the US crisis to Indonesia is almost non-existent in the post-crisis period, suggesting that investors in the United States can minimize the risk of portfolio investment in the post-crisis period by investing in the Indonesian stock market.

In contrast to the Indonesian market, before the crisis period there is no tail-dependence between the Malaysian and US stock markets, which means the links the two markets at this stage are extremely weak. A sharp drop in the US stock market will not affect the Malaysian stock market. This explains why the Normal Copulas are chosen as the best fit to depict the dependence structure between the two markets in the pre-crisis period. In after the crisis period, the appearance of the dependency structure was identified,

and Gumbel Copulas are chosen as the best Copulas tool to demonstrate the dependence structure between the Malaysian and US stock markets, revealing a right-tail dependence between the two stock markets. This result also indicates that when the US stock market booms, the Malaysian market is more likely to boom together than the case of falling or other cases. Thus, the fact that the Clayton Copulas and Gumbel Copulas are respectively chosen to be fittest to depict the dependence structure between the two stock markets in the pre, post crisis and in the whole period, presents an important implication. There is no evidence of the contagion of the US of the crisis on the Malaysian stock market in the pre as well as post-crisis. Therefore, investors can minimize their investment portfolio risk by investing in the Malaysian stock market instead of the United States'.

The results show that between the Philippines and the US stock market appeared the change of dependence structure. The most compelling reason is, in the pre-crisis stage, the Clayton Copulas are chosen to represent the interrelationship, whereas Gumbel Copulas are chosen as the appropriate representative for the dependence structure between the two markets in the post-crisis period. In closer analysis, in the pre-crisis period, the stock markets of the Philippines and the United States report a left-tail dependence structure, which means that the two markets are likely to crash at this stage higher than other cases. However, this dependence is quite weak with a parameter of 0.08339. In the post-crisis period, the fact that Gumbel Copulas are chosen to represent the dependence structure proves that after the crisis, a sharp fall in the yields of the US stock market (crisis) has almost no impact on the Philippines stock market. In contrast, the likelihood that the rate of return of both markets will increase at this stage is quite high. In addition, the Clayton Copulas are chosen to represent the interrelationship between the two markets in the whole period.

Similarly, in the pre-crisis period, the Clayton Copulas are chosen as suitable to depict the left-tail dependence between the US and Thai stock markets. A sharp decline in the rate of return of the US stock market will lead to a sharp fall in Thai market yields at this stage, which is the empirical evidence of the influence of the US subprime mortgage crisis on the Thai stock market in the pre-crisis period. In addition, according to the estimation, there has been a change in the interrelationship between the two markets in the post-crisis period. The Gumbel Copulas are chosen to represent the dependence between the rate of return of the two markets at this stage, which reports the existence of a tail dependence in right side between the two equity markets and the possibility that the two markets are to rise together is very high during this period. However, in the whole period, the Clayton Copulas are chosen as the best fit to represent the dependence structure between the two securities markets of the two nations.

Unlike other stock markets in the ASEAN region, before the US subprime crisis, there is no appearance of tail dependence between the US and Vietnam's stock markets because the Normal Copulas are chosen as the most suitable to represent the dependence structure between the two markets at this stage. A sharp fall in US market returns has little impact on Vietnam's stock market, as the parameter index is relatively low, at 0.00642, indicating a weak relationship between the two markets. In other words, there is no evidence of the contagion effect on Vietnam stock market in the pre-crisis period. In the post-crisis period, there is a change in the dependence structure between the two markets and the Clayton Copulas are chosen as suitable to describe the interrelationship, which could be said to be evidence of contagion effect of the crisis on the Vietnam stock market. The possibility that the two markets fall together in this period is quite high with a coefficient of 0.1084. Similarly, the Clayton Copulas are also chosen as suitable to represent the dependence structure in the whole period.

Like most of the stock markets, the dependence structure experiences a change between the Singapore and US stock markets in the pre and post crisis period. Before the crisis there is a left-tail dependence between the two stock markets and it is quite high with a parameter of 0.338. In other words, a sharp decline in US profitability during this period would lead to a sharp decline in the Singapore stock market's return on equity, which reports the contagion effect of the mortgage crisis on the Singapore stock market at this stage. In the post-crisis period, Gumbel Copulas are chosen to represent the dependence structure between the two stock markets, reflecting the right-tail dependence between the two markets. At this stage, the probability that the two markets crash together is higher than other cases. However, in the whole period, Normal Copulas are chosen as suitable to represent the dependence structure between the two markets.

In summary, in the pre-crisis period Clayton Copulas are chosen as the most suitable description for the dependence structure of Indonesia, Philippines, Singapore, Thailand (4/6 ASEAN countries being researched). There is evidence of the contagion effect of the US mortgage crisis on most of the ASEAN countries in the pre-crisis period. In addition, Vietnam and Malaysia are not affected by the crisis at this stage, as there are no tail-dependence structures between the two countries with the United States. Interestingly, there has been a change in all countries' dependence structure in the post-crisis period. All five countries (except Vietnam) have a right-tail dependence structure at this stage, which suggests that the possibility of booming together of the five countries with the United States in the post-crisis period is extremely high compared to the rest. Only in Vietnam is there evidence of the contagion effect of the US crisis in this period, with Clayton Copulas being chosen as the best fit to depict the dependence structure between Vietnam and the United States markets.

5. CONCLUSION AND REMARKS

Once again, the authors employ the dataset with both non-parametric and parametric approaches in the period from August 2000 to December 2016. The typical non-parametric methodologies are Chi-plots and Kendall-plots. Besides, we also use three different Copulas families namely Normal, Gumbel and Clayton to estimate the contagion risk to ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, Vietnam and Thailand) in the stock market for two periods (pre-and-post financial crisis). To be more precise, Indonesia, Philippines and Thailand also have the left-tail dependence, which means having spillover risk from the US stock market. Meanwhile, there is no evidence showing that Vietnam and Malaysia have contagion risk with the biggest market in this period. In contrast, after financial crisis time, both methods demonstrate that Vietnam has incurred the contagion risk with the US. This result is not completely shown in any previous publications. Interestingly, only Vietnam suffers the contagion risk after financial crisis from the US market. This proves that Vietnam is overconfident to face the financial crisis because it has not influenced on Vietnam. However, Vietnam does not have sufficient strategies to deal with the phenomenon. Thus, after financial crisis, they suffered much more than the previous period. From the results, we suggest that the US investors could minimize losses in their portfolios by diversifying into non-influence countries. However, this is also a lesson for policy makers to evaluate their solutions in the crisis period, which helps them revise their actions in monetary and fiscal policies.

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