# A Non-Parametric Extreme-Value-Theory Analysis of Asian Stock Market Linkages, 1995 - 2008

Thomas B. Fomby

Narongchai Thitinanpong

Department of Economics

Southern Methodist University

Dallas, Texas

U.S.A.

February 2009

**Abstract**

This paper uses non-parametric Extreme-Value-Theory techniques discussed in Hartmann, Straetmans, and de Vries (2001) to investigate the stock market linkages between a set of Asian economies over the period 1995 – 2008. This span of the data covers the period of the Thai Bhat crisis of 1997 as well as the recent U.S. mortgage-based crisis of 2008. Probabilities of extreme returns for each country are calculated as well as the probabilities of co-crashes and crash-booms among the various pairs of the sample Asian countries. We find that the 1997-crisis-affected countries (Thailand, Malaysia, Indonesia, Philippines, and Korea) have higher probabilities of extreme returns than the non-crisis affected countries (Japan, Hong Kong, China, and Taiwan). In addition we find that the 1997-crisis affected countries have higher probabilities of co-crashes than the non-crisis-affected countries. Among the countries examined, China appears to be the least likely to have a co-crash with another country that is in crisis. When considering the Japanese stock market as a potential safe haven for investors in the 1997-crisis-affected countries we find that in no cases does it appear that Japan can serve as a safe haven for such investors.

# 1. Introduction

In 1997, the Asian currency crisis originating in Thailand had a contagion effect among the other economies in the region. Indeed, they all faced regime shifts in exchange rate, stock market crashes and private investment slumps. In addition, in the latter part of 2008 the Asian economies were more or less similarly affected by the mortgage-backed crisis that began in the U.S. As Edison, Luangaram and Miller (2000) have noted, stock markets can be leading indicators for crises in the real sectors of economies. Thus this study aims to empirically investigate stock market linkages among the Asian economies for the purpose of coming to better understand how the countries of Asia are financially linked and thus invariably economically linked.

This study employs the non-parametric Extreme-Value-Theory (EVT) methods found in Hartmann, Straetmans, and de Vries (2001).[1] Their methods are used to analyze weekly stock market returns from 1995 – 2008 in the stock markets of Thailand, Malaysia, Indonesia, Philippines, and Korea, hereafter designated as the 1997-crisis-affected countries, and the stock markets of Japan, Hong Kong, China, and Taiwan designated as the non-crisis countries.[2] For all of the Asian countries examined here we calculate tail probabilities (i.e. the probabilities of booms and busts) vis-à-vis the semi-parametric probability estimator of de Hann, et. al. (1994). After calculating non-parametric bivariate tail probabilities, we compute the probabilities of co-crashes and the

[1] We are very grateful to Professor Straetmans for sharing with us the Gauss code used in his 2001 co-authored paper with Professors Hartmann and de Vries.
[2] Hong Kong is a special administrative region of China. For simplicity we refer to Hong Kong as a country rather than referring to it as a special administrative region.

probabilities of crash-booms between country pairs that allow us to gauge the sensitivities of the stock markets of the Asian countries with each other.

To the empirical results, there could be a stock market crash every 10 - 14 years in most 1997-crisis-affected economies namely, Thailand, Malaysia, Indonesia and Korea, except for the Philippines where a crash could happen once every 20 years or so. For the others not harshly hit by the 1997 Asian crisis, Hong Kong, China, Taiwan and Japan would take somewhat longer times for a crash to appear.

With respect to the co-crashes, the stock markets in the 1997-crisis-affected economies are highly correlated with one another. Hong Kong also has the high possibility of co-crash with the 1997-crisis-affected economies. Japan and Taiwan seem to have high connection with each other. However, China does not have high linkages to the other regional economies.

To the consideration of crash-booms, we consider the hypothesis that in the time of crisis, Japan could serve as a safe-haven for investors in the stock markets of the 1997-crisis-affected economies. However, the results here indicate that Japan's stock market generally does not serve as a safe-haven for these countries.

The rest of this paper is organized as follows: The next section briefly describes the data we use and its sources. Section 3 describes the empirical methodologies used while Section 4 presents the empirical results. Section 5 conducts a sensitivity analysis of the empirical results while conclusions are given in Section 6.

# 2. Data

The local-currency stock-market price indexes for the Asian economies of China, Indonesia, Japan, Hong Kong, Malaysia, Philippines, Korea, Taiwan and Thailand are compiled from the Bloomberg database, ranging from 1995 to 2008. These price indexes are not corrected for dividends. The log returns are calculated on a weekly basis to avoid timing differences among the stock exchanges. In this regard the weekly returns for each stock market are calculated from the daily price index as weekly log first-differences from Friday to Friday.

# 3. Methodology

This paper follows the non-parametric EVT methods in Hartmann, Straetmans and de Vries (2001) to estimate the linkages among the Asian stock markets. It allows us to capture the dependence structure of the data distributions without having to specify specific parametric distributions for individual country stock returns or their joint distributions. This section provides a general outline of the methodology used. For more details the reader can consult Hartmann, Straetmans and de Vries (2001).

### 3.1 An Extreme Linkage Indicator

Suppose we are interested in calculating the expected number of markets that crash given that at least one market has crashed. Let $X$ and $Y$ be random returns for two different financial markets. Also, let $x$ and $y$ be the corresponding cutoff values such that values of $X$ and $Y$ above these values indicate a boom. Let $\kappa$ stand for the number of markets with extreme returns. Then, the extreme linkage indicator is the conditional expectation, $E[\kappa \mid \kappa \geq 1]$, where

$$E[\kappa \mid \kappa \geq 1] = \frac{P\{X > x\} + P\{Y > y\}}{1 - P\{X \leq x \cap Y \leq y\}} = \frac{P\{X > x\} + P\{Y > y\}}{P\{X > x \cup Y > y\}} = \frac{P_1 + P_2}{P_{12}}$$

$$= P\{\kappa = 2 \mid \kappa \geq 1\} + 1 \quad . \tag{3.1}$$

Then in terms of co-booms, the expected number of booms given the existence of at least one boom is equal to 1 plus the conditional probability that both markets boom given that at least one market booms. When constructing an extreme linkage indicator for co-crashes, one can apply the above formula to the negative of the sample returns. Later in this paper we will be reporting extreme linkage indicators for crash-booms between Japan and 1997 crisis-affected countries like Thailand. In this case to apply the formula of (3.1), the negative of the returns of Thailand are compared with the non-negated returns of Japan.

Hartmann, Straetmans and de Vries (2001) further applied the upper quantile functions for $X$ and $Y$ together with the stable tail dependence function (STDF), $l(.,.)$, introduced by Huang (1992). Then equation (3.1) becomes

$$E[\kappa \mid \kappa \geq 1] = \frac{P_1 + P_2}{P_{12}} \approx \frac{P_1 + P_2}{l(P_1, P_2)} \quad . \tag{3.2}$$

Simply interpreted, if both markets are completely dependent, a crash in one market coincides with a crash in the other. In this case the extreme linkage indicator is equal to two. If both markets are completely independent, a crash in one market does not condition the probability of a crash in the other and the indicator is equal to one.

### 3.2 The Estimation Steps for the Extreme Linkage Indicator

To estimate the extreme linkage indicator in equation (3.2), the first thing to do is calculate $P_1$ and $P_2$, the univariate excess probabilities for each financial market.[3] The estimation for these probabilities exploits the fact that the distributions of financial asset returns typically have heavy tails. From the semi-parametric probability estimator by de

[3] Hereafter we will refer to any tail probabilities of interest as “excess” probabilities as is so often done in the literature.

Haan et al. (1994), the univariate excess probability can be estimated by the following equation.

$$\hat{P}_q = \frac{m}{n}\left(\frac{X_{n-m,n}}{q}\right)^{\alpha} \tag{3.3}$$

where $\hat{P}_q$ = the univariate excess probability, $X_{n-m,n}$ = the tail cut-off point or (n-m)'th ascending order statistic, n = the sample size, q = the quantile value, and $\alpha$ = the tail index. The approximation for the tail index ($\alpha$) follows the non-parametric estimator of Hill (1975), namely,

$$\hat{\gamma} = \frac{1}{\hat{\alpha}} = \frac{1}{m}\sum_{j=0}^{m-1}\ln\left(\frac{X_{n-j,n}}{X_{n-m,n}}\right) \quad . \tag{3.4}$$

From equation (3.4), the value of Hill's estimator is conditional on the parameter m. An accepted way of finding an optimal value for m is to plot the different values of Hill's estimator as a function of m and then choose the value of m, say $\hat{m}$, where the Hill estimate stabilizes. One then simply reciprocates the chosen Hill estimate $\hat{\gamma}$ to get the estimate of the tail index, say $\hat{\alpha}$. Given $\hat{m}$ and $\hat{\alpha}$ it is straightforward to get $\hat{P}_q$ using equation (3.3). Therefore, given specific quantile values, the estimates for the univariate excess probabilities of each market $(P_1, P_2)$ can be obtained.

Next we need to estimate the bivariate excess probability, $P_{12}$, which is approximately equal to the STDF evaluated at $(P_1, P_2)$, that is, $l(P_1, P_2)$. Although the STDF can be parametrically estimated as in Longin and Solnik (2000), Hartmann, Straetmans and de Vries (2001) use a non-parametric estimation method based on the higher order statistics of the $X$ and $Y$ returns. The empirical estimate for the STDF at $(P_1, P_2)$ can be obtained from the following equation.

$$\hat{l}\left(\hat{P}_1, \hat{P}_2\right) \approx \frac{1}{k}\sum_{i=1}^{n} I\left\{X_i > X_{n-\left[k\hat{P}_1\right],n} or Y_i > Y_{n-\left[k\hat{P}_2\right],n}\right\} \tag{3.5}$$

where $[x]$ = the integer part of $x$, and k is a nuisance parameter in the STDF that we need to find much like the nuisance parameter m we found in equation (3.4). Hartmann, Straetmans and de Vries (2001) applied Huang (1992)'s polar transform for the empirical STDF in equation (3.5). Then, it becomes

$$\hat{P}_{12} \approx \hat{r}\hat{l}\left(\cos\hat{\theta}, \sin\hat{\theta}\right) = \frac{1}{k}\hat{r}\sum_{i=1}^{n} I\left(X_i > X_{n-\left[k\cos\hat{\theta}\right],n} or Y_i > Y_{n-\left[k\sin\hat{\theta}\right],n}\right) \tag{3.6}$$

where $\hat{\theta} = \arctan\left(\frac{\hat{P}_2}{\hat{P}_1}\right)$ and $\hat{r} = \sqrt{\hat{P}_1^2 + \hat{P}_2^2}$ . The value of k that is chosen is the value that stabilizes the estimate $\hat{P}_{12}$.

In summary, using the estimators from equations (3.3) – (3.6), we can obtain an estimate of the extreme linkage estimator of equation (3.2). Let an estimate of the extreme linkage estimator be denoted by E. Then, as noted before, the closer E is to 2, the more dependent the excess returns are. In contrast, as E approaches 1 the excess returns become independent.

### 3.3 Hypothesis Testing of the Equality of Two Tail Indices

A test that we present below is of the equality between two Hill's estimators or, equivalently two tail indices. This in essence allows one to compare the thickness of the left tail with the right tail of a distribution of returns. Under the null hypothesis of the equality of two tail indices in a given univariate distribution, the following T-statistic has a standard normal distribution.

$$T_{12} = \frac{\hat{\gamma}_1(m_1) - \hat{\gamma}_2(m_2)}{\sigma[\hat{\gamma}_1(m_1) - \hat{\gamma}_2(m_2)]}$$

$$= \frac{\hat{\gamma}_1(m_1) - \hat{\gamma}_2(m_2)}{\sqrt{\hat{\sigma}^2(\gamma_1) + \hat{\sigma}^2(\gamma_2) - 2\,\hat{\text{cov}}(\hat{\gamma}_1, \hat{\gamma}_2)}} \quad . \tag{3.7}$$

Indeed, $\hat{\sigma}^2(\hat{\gamma})$ is approximately equal to $\frac{\hat{\gamma}^2}{m}$. Moreover, there is no covariance between the left-tail and right-tail Hill's estimators.

Secondly, suppose that we would like to test for a significant asymptotic dependency between two stock market return distributions. In this case, there are two interesting types of asymptotic dependency: co-crash and crash-boom. The co-crash between two stock markets could indicate the contagion effect between two economies. In contrast, the crash-boom could stand for a situation where a booming stock market is an alternative place for investors to invest who currently are invested in the crash market. Peng (1999) proposed the tail dependence coefficient $\eta$ to measure this asymptotic dependency. The coefficient is estimable through the following equation.

$$\hat{\eta} = \frac{\ln 2}{\ln\left[4 - \hat{l}(2,2)\right] - \ln\left[2 - \hat{l}(1,1)\right]} \tag{3.8}$$

Indeed, this coefficient is equal to 1 when the asymptotic dependency exists, and, is less than 1 otherwise. Then, the corresponding hypothesis test is one-sided. Under the null hypothesis of co-dependency the following W-statistic is distributed as a standard normal random variable.

$$W = \frac{\hat{\eta} - 1}{\sigma[\hat{\eta}]} \tag{3.9}$$

Peng (1999) shows that the asymptotic standard error, $\sigma[\hat{\eta}]$, is estimable from the STDF and its derivative.

The last hypothesis that we test here is of the equality of the probability of co-crashes and crash-booms or if one dominates the other. Hartmann, Straetmans and de Vries (2001) suggest the following Z-statistic for this test.

$$Z = \frac{\hat{l}_{CC}(k_1) - \hat{l}_{CB}(k_2)}{\sigma\left[\hat{l}_{CC}(k_1) - \hat{l}_{CB}(k_2)\right]} \quad . \tag{3.10}$$

The term $\hat{l}_{CC}(k_1)$ denotes the excess probability of a co-crash while the term $\hat{l}_{CB}(k_2)$ denotes the excess probability of a crash-boom. The standard error $\sigma[\hat{l}_{CC}(k_1) - \hat{l}_{CB}(k_2)]$ can be obtained by the bootstrap method. Under the null hypothesis of the equality of these probabilities, the Z-statistic has a standard normal distribution. This test can, of course, be applied to any specific pair of stock markets of interest.

# 4. Empirical Results

In this section we examine the relationship between selected Asian stock market returns using the methods and tests discussed in the previous section. Let us divide the sample economies into two groups. The first group was severely hit by the 1997 Asian crisis and consists of Thailand, Malaysia, Indonesia, Philippines and Korea. We call this group "the 1997-crisis-affected economies". Indeed, they faced stock market crashes and huge currency devaluations. Some of them had to ask the International Monetary Fund (IMF) for financial aid programs. From figure 1, their weekly stock market return reached the very low level, ranging from -15 % to -20 % during the period of 1997 - 1999. The second group, the non-crisis countries, consists of Japan, Hong Kong, China and Taiwan, which suffered to a lesser degree from the crisis. Their lowest weekly stock market returns during 1997 – 1999 ranged approximately from -10 % to -20 % with less frequency than the first group. However, in 2008, all economies seemed to have the same problem of a crash resulting from the financial sector crisis in the U.S. especially for Thailand, Indonesia, Korea and Japan with new lowest weekly return records.

Table 1 shows that the weekly return data from all economies have approximately zero mean, except for Thailand with a little lower mean of -1.5 %. At the 10% level, there is significant skewness in each of the series, all series having negative skewness except for Malaysia and China. Kurtosis for each the series is significantly positive. Comprehensively, all of the series are non-normal as the Jacque-Bera test for normality is strong rejected in each case. Given excess kurtosis in these series, the distributions of these returns series have sharper peaks and both longer and fatter tails than the normal distribution. Thus the non-parametric approach adopted here has much to recommend it.

The left tail index ($\alpha_L$) in all economies except for China and Taiwan is lower than the corresponding right tail index ($\alpha_R$) indicating that in all economies except China and Taiwan, the left tails are fatter than the right tails. But still the differences in the tails of the various distributions are not statistically significant except for Japan. See the T-Stat column of Table 1. Fortunately, whatever the weekly return distribution seems to be, the empirical methods of Hartmann, Straetmans and De Vries (2001) are still applicable because no distributional assumption needed.

### 4.1 Probabilities for a Single Extreme Return

Table 2 presents the univariate excess probabilities for several quantiles. The probabilities reported in this table are in the form of annual probabilities. That is, the weekly probabilities of excess returns are converted to annual probabilities by multiplying the weekly probabilities by 52. Thus far, most researchers have paid attention to the left tail or the crash side. For example, the probability that Thailand's stock market will shrink by more than 25 % within a week sometime during the period of a year is 0.094. Alternatively interpreted, that stock market will lose more than 25 % within a week once in every 10 (1/0.094) years. With the same explanation, all 1997-crisis-affected economies would have a stock market crash in every 10 to 14 years, except for the Philippines where a crash might be expected every 20 years. This result could be consistent with the two actual crises, the 1997 Asian crisis and the 2008 U.S. crisis. During each of these crises, the stock market in the said economies did shrink by around 20 to 25 %. Moreover, the time duration between those crises is about 11 years.

For the non-crisis group of economies, the probabilities of a stock market crash are on average lower than that in the 1997-crisis-affected ones. With the same explanation above, a stock market crash would happen once every 20 years in China and Hong Kong, 58 years in Taiwan and somewhat longer in Japan. Indeed, the univariate excess probability estimates for Japan are approximately equal to those reported in Hartmann, Straetmans and de Vries (2001) even though they used a slightly different time period.

**4.2 The Co-Crashes between Asian Stock Markets**

In this section we quantify the probabilities of stock market co-crashes in the sample economies. The extreme linkage indicator (E) in equation (3.1) becomes $\frac{P\{X < x\} + P\{Y < y\}}{P\{X < x \cup Y < y\}}$. For Table 3, -25 % is used as a threshold value to define a crash. Indeed, it could stand for a crash when compared with the maximum loss in weekly returns from the sample retained in Table 1. The expected number of crashes, E, given at least one crash has occurred in one of the countries is reported in the third column. The greater the number is, the greater the co-dependency of crashes between the denoted country pair. Co-dependencies involving the Philippines, Malaysia, and Hong Kong are among the highest (Philippines-Hong Kong = 1.345; Malaysia-Philippines = 1.301; Indonesia-Philippines = 1.298; Korea-Hong Kong = 1.263; and Malaysia-Hong Kong = 1.262). China is the least connected with the other eight economies. Indeed, its E values range from 1.01 to 1.15.

Another way to view these crash co-dependencies is as follows. Take, for example, the E value of 1.129 for the co-crash between Thailand and Malaysia. Therefore, of 8 (1/0.129) crashes occurring among these countries, one occurrence is likely to yield a co-crash.

Also we can see that the 1997-crisis-affected economies have a co-crash relationship with one another in higher degrees than with Japan, China and Taiwan. The corresponding E values among the crisis-affected economies range from 1.10 to 1.30. There must be a crash 4 to 10 times in one of these economies to make the other country in the pair face a crash. Hong Kong is the only one in the second group of economies that has high linkages with the 1997-crisis-affected economies with E values ranging from 1.12 to 1.34.

In the fourth column of Table 3 we see that the estimates for the tail dependent coefficient ($\eta$) are approximately equal to one. The corresponding W-statistics have small absolute values, and thus the null hypothesis of asymptotic dependency or high probabilities of co-crashes among all of the pairs of countries cannot be rejected.

### 4.3 The Crash-Boom between the 1997-Crisis-Affected Economies and Japan: Does Japan Offer a Safe Haven?

In this section we test if Japan could be an alternative place for the investors from the 1997-crisis-affected economies when the latter is facing a crash. As generally perceived, Japan is one of the most global of financial centers. Indeed, given the methods examined here it is easy to quantify the crash-boom relationship between the crisis-affected economies and Japan. The extreme linkage indicator (E) in equation (3.1) becomes $\frac{P\{X < x\} + P\{Y > y\}}{P\{X < x \cup Y > y\}}$. In Table 4 the cut-off value of 25 % is used to define a boom in Japan while a cut-off value of -25 % for the crisis-affected countries is used to define a crash. The estimated tail dependent coefficients ($\eta$) are approximately equal to one, confirming the possibility of a crash-boom relationship between the crisis-affected countries and Japan but they are all statistically insignificant. Moreover, the estimates of E are generally low, ranging from 1.01 to 1.02. These estimates of crash-boom dependencies are quite a bit lower than those for co-crashes.

The Z-statistics in Table 4 are used to test the dominance between co-crashes and crash-booms among the country pairs. Indeed, for Thailand-Japan, Indonesia-Japan and Philippines-Japan, the statistics have a big negative value, and reject the null hypothesis of equality between those two relationships. These big negative values indicate the predominance of co-crashes over crash-booms. From equation (3.10), the STDFs (joint probabilities as in $P_{12}$) for crash-booms are significantly higher than for co-crashes. Therefore, from equation (3.2), the E dependency measures for crash-booms are significantly lower than for co-crashes. Then, the co-crash dominates the crash-boom in these three cases. For Malaysia-Japan and Korea-Japan, the statistics do not reject the null hypothesis of equality. In total, these results suggest that Japan's stock market historically has not bee a safe haven for investors in the 1997-crisis-affected economies.

# 5. Sensitivity Analysis

In this section we change the threshold values for a crash and a boom from -25 % and 25 % to -20 % and 20 % and conduct a sensitivity analysis of the results derived in the co-crash analysis of Table 3 and the Crash-Boom analysis of Table 4. The corresponding results are shown in table 5 and table 6. There seems to be virtually no difference in conclusions offered in Table 3 as compared to Table 5 as it relates to co-crashes in these countries. There is, however, a very slight difference in the crash-boom results regarding the Z-statistics. Indeed, there are two pairs, Indonesia-Japan and Korea-Japan, which have a big negative value for that statistics. For the other pairs, the statistics is not statistically significant. Then, a statement that Japan's stock market does not significantly play a role for alternative investments for investors in the 1997-crisis-affected economies is still applicable. Thus, the robustness of the results presented in Tables 3 and 4 are pretty robust to the choice of boom and bust definitions.

# 6. Conclusions

This paper studies the stock market linkages in the Asian economies by applying the non-parametric EVT methods from Hartmann, Straetmans and De Vries (2001). It analyzes the weekly stock market returns in the 1997-crisis-affected economies namely, Thailand, Malaysia, Indonesia, Philippines and Korea together with Japan, Hong Kong, China and Taiwan from 1995 to 2008. The empirical results reveal that there is significant potential for co-crashes among regional economies. However, China does not seem to have high linkages to the others. Moreover, for the crash-boom, Japan's stock market does not seem to offer a safe haven for investors in the 1997-crisis-affected economies when these economies are facing a crisis.

For future research we plan to partition the data used here into two parts – a Thai Bhat crisis part incorporating data before and after 1997 and a second part involving the several months leading up to and including the latest financial crisis originating in the U.S. mortgage market. In doing so we will be able to gauge to what extent the two crises give rise to similar conclusions concerning the propensities for co-crashes among these Asian countries and the role that Japan might have played as a safe haven in the first period as compared to the second period.

Secondly, additional research might pursue the relationships between the stock markets and the corresponding bond markets of these countries to come to understand the extent to which these countries bond markets can provide safe havens for stock markets within and across countries. Unfortunately, unlike in Hartmann, Straetmans and De Vries (2001) and their study of the G-5 countries, the bond market data for the above Asian countries are much less plentiful. For example, in Thailand, the time series for the government bond's gross price index is available only from 1999 to now, which offers a much shorter time span than the time span used for the analysis in this paper.

# References


Bae, K.-H., Karolyi, A., Stulz, R., 2003, "A New Approach to Measuring Financial Contagion". *Review of Financial Studies*, 16, 717-763.

Boyer, B., Gibson, M. and M. Loreton, 1997, "Pitfalls in tests for changes in correlation", *International Discussion Paper*, no. 5 -97, Board of Governors of Federal Reserve System, December.

Burnside, C., Eichenbaum, M. and Rebelo, S., 2001, "Prospective Deficits and the Asian Currency Crisis", *the Journal of Political Economy*, Vol. 109, No. 6, pp. 1155-1197

Calvo, Sarah, and Carmen M. Reinhart, 1996, "Capital flows to Latin America: Is there evidence of contagion effects?" in Guillermo A. Calvo, Morris Goldstein, and Eduard Hochreiter, eds.: Private Capital Flows to Emerging Markets After the Mexican Crisis (Institute for Inter-national Economics, Washington, DC).

Chen, Zhiwu and Knez, Peter J., 1995, "Measurement of Market Integration and Arbitrage" *Review of Financial Studies* 8-2, 287-325.

Danielsson, J., and C. de Vries, 2000, "Value-at-Risk and Extreme Return", working paper, London School of Economics.

de Haan, L., Jansen, D.W., Koedijk, K. and C.G. de Vries, 1994, "Safety first portfolio selection, extreme value theory and long run asset risks", in J. Galambos ed., Proceedings from a Conference on Extreme Value Theory and Application, Kluwer Press, 471 – 487.

Edison , Hali J., Luangaram, P. and Miller, M., 2000, "Asset Bubbles, Leverage and 'Lifeboats': Elements of the East Asian Crisis", *the Economic Journal*, Vol. 110, No. 460, pp. 309-334

Edwards, Sebastian, 1998, "Interest rate volatility, capital controls, and contagion", Working Paper 6756, NBER.

Ehrmann, M., Fratzscher, M. and Rigobon, R., 2005, "Stocks, Bonds, Money Markets and Exchange Rates: Measuring International Financial Transmission", Working Paper 11166, NBER

Fischer, Stanley, 1998, "The Asian crisis: A view from the IMF", *IMF Survey*, Washington, D.C., vol. 27, no. 2 (January).

Forbes, K.J. and R. Rigobon, 2002, "No Contagion, Only Interdependence: Measuring Stock Market Co-Movements", *the Journal of Finance* 57 (5): 2223-2261.

Flood, Robert P., and Garber, Peter M., 1984, “Collapsing Exchange-Rate Regimes: Some Linear Examples”, *Journal of International Economics*, 17, 1-13.

Flood, R. P., and Rose, A. K., 2003, “Financial Integration: a New Methodology and an Illustration”, Working Paper 9880, NBER.

Glassman, J., 2001, “Economic Crisis in Asia: The Case of Thailand”, *Economic Geography*, Vol. 77, No. 2, pp. 122-147

Hamao, Yasushi, Ronald W. Masulis, and Victor K. Ng, 1990, “Correlations in price changes and volatility across international stock markets”, *the Review of Financial Studies,* 3, 281-307.

Hartmann, P., S. Straetmans, and C. de Vries, 2001, “Asset Market Linkages in Crisis Periods”, working paper No.71, European Central Bank.

Hill, B. M., 1975, “A simple general approach to inference about the tail of a distribution”*, the Annal of Statistics,* 3, 1163-1173.

Huang, Xin, 1992, “Statistics of bivariate extreme values”, Timbergen Institute Research Series, Ph.D. thesis no. 22, Erasmus University Rotterdam.

King, M., Sentana, E.,Wadhwani, S., 1994, “Volatility and links between national stock Markets”, *Econometrica*, 62, 901–934.

King, Mervyn A., and Sushil Wadhwani, 1990, “Transmission of volatility between stock mar-kets”*, Review of Financial Studies,* 3, 5-33.

Krugman, Paul, 1979, “A Model of Balance-of-Payments Crises”, *Journal of Money, Credit and Banking*, 11, 311-25.

Krugman, Paul, 1998, “What happened to Asia”, *Chulalongkorn Journal of Economics*, vol. 10, no. 1, pp. 69-87.

Lee, Sang B., and Kwang Jung Kim, 1993, “Does the October 1987 crash strengthen the co-movements among national stock markets?”, *Review of Financial Economics,* 3, 89-102.

Longin, F. M., 1996, “The Asymptotic Distribution of Extreme Stock Market Return”, *Journal of Business,* 69, 383-408.

Longin, Francois M., and Bruno Solnik, 1995, “Is the correlation in international equity return constant: 1960-1990?”, *Journal of International Money and Finance*, 14, 3-26.

Longin, Francois, and Bruno Solnik, 2001, “Extreme Correlation of International Equity Markets,” *Journal of Finance*, 56, 649 – 676.

Normandin, Michel, 2004, “Canadian and U.S. Financial Markets: Testing the International Integration Hypothesis under Time-Varying Conditional Volatility”, *The Canadian Journal of Economics / Revue canadienne d'Economique*, Vol. 37, No. 4, pp. 1021-1041

Obstfeld, Maurice, 1986, “Rational and Self-Fulfilling Balance-of-Payments Crises”, *American Economics Reviews*, 76, 72-81.

Obstfeld, Maurice, 1996, “Models of Currency Crises with Self-Fulfilling Features”, *European Econ. Rev*, 40, 1037-47.

Peng, L., 1999, “Estimation of the coefficient of tail dependence in bivariate extreme.” *Statistics & Probability Letters*, 43, 399-409.

Sachs, Jeffrey D., Tornell, Aaron, and Velasco, Andres, 1996, “Financial Crises in Emerging Markets: The Lessons from 1995”, Brookings Papers Econ. Activity, no. 1, pp. 147-98.

**Figure 1: The Asian Stock Markets' Weekly Rate of Return**

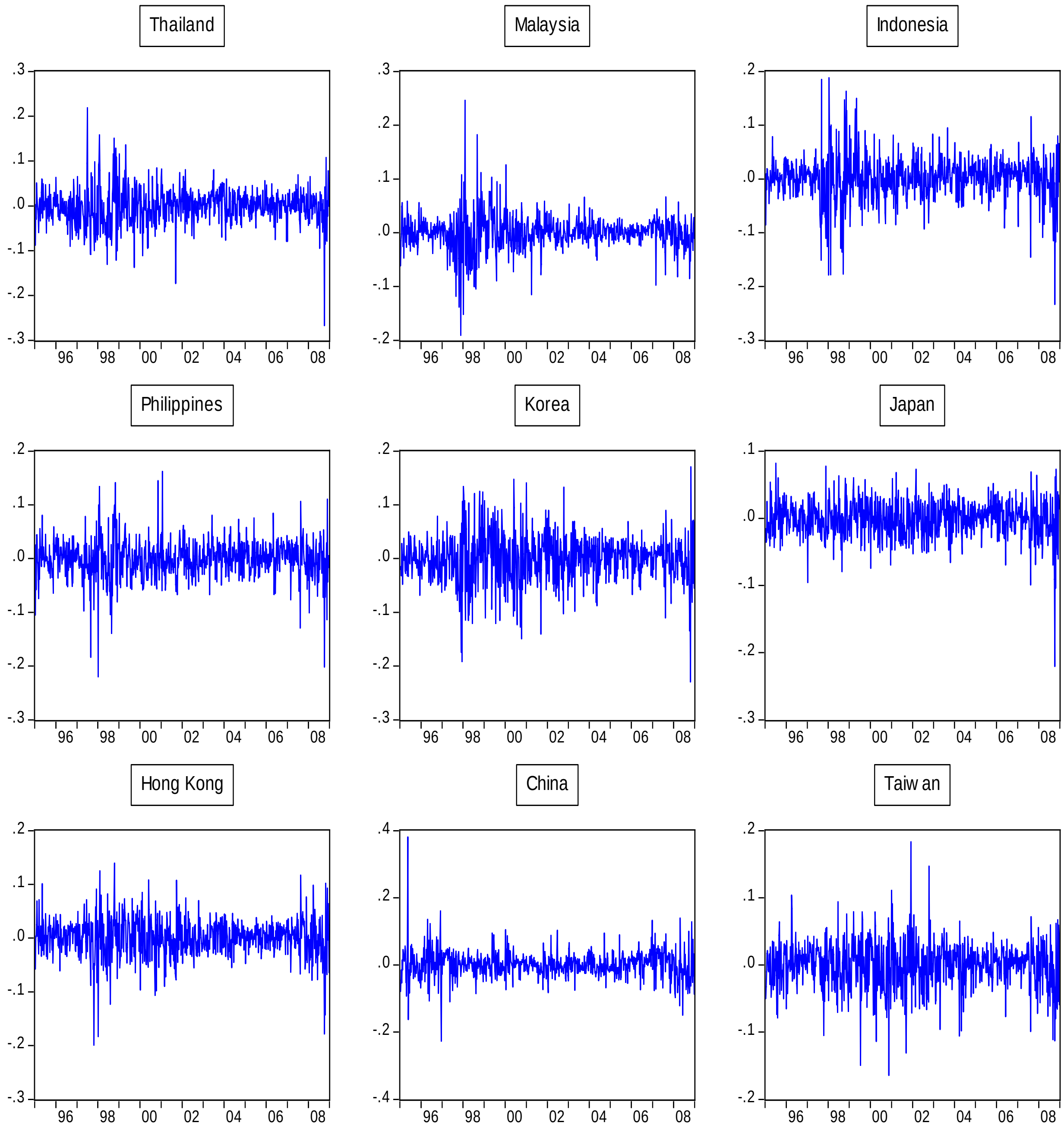

**Table 1: Descriptive Statistics and Tail Indices**

| | Mean | Max | Min | Skew. | Kurt. | JB | $m_L$ | $m_R$ | $\alpha_L$ | $\alpha_R$ | T-Stat |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Thailand** | -1.531 | 21.838 | -26.661 | -0.167 (0.065) | 7.176 (0.000) | 533.322 (0.000) | 75 | 35 | 2.443 | 2.925 | 0.902 (0.367) |
| **Malaysia** | -0.013 | 24.578 | -19.026 | 0.175 (0.053) | 11.459 (0.000) | 2177.380 (0.000) | 40 | 35 | 2.256 | 2.319 | 0.118 (0.406) |
| **Indonesia** | 0.140 | 18.803 | -23.297 | -0.396 (0.000) | 7.337 (0.000) | 590.660 (0.000) | 30 | 10 | 2.593 | 3.053 | 0.463 (0.643) |
| **Philippines** | -0.053 | 16.184 | -21.985 | -0.495 (0.000) | 7.908 (0.000) | 761.717 (0.000) | 25 | 15 | 2.736 | 3.424 | 0.698 (0.485) |
| **Korea** | 0.016 | 17.031 | -22.928 | -0.314 (0.000) | 5.283 (0.000) | 170.492 (0.000) | 40 | 30 | 2.562 | 3.072 | 0.736 (0.461) |
| **Japan** | -0.081 | 8.177 | -22.018 | -0.817 (0.000) | 8.084 (0.000) | 866.364 (0.000) | 65 | 10 | 3.130 | 7.527 | 3.233 (0.001) |
| **Hong Kong** | 0.084 | 13.916 | -19.921 | -0.518 (0.000) | 6.487 (0.000) | 402.114 (0.000) | 5 | 15 | 2.343 | 3.795 | 0.805 (0.420) |
| **China** | 0.144 | 38.070 | -22.629 | 0.907 (0.000) | 15.268 (0.000) | 4672.77 (0.000) | 40 | 30 | 2.734 | 2.591 | -0.261 (0.794) |
| **Taiwan** | -0.061 | 18.318 | -16.408 | -0.241 (0.007) | 5.320 (0.000) | 170.650 (0.000) | 20 | 25 | 3.518 | 3.034 | -0.563 (0.573) |

Notes: T-Statistic has the standard normal distribution.
The number in parenthesis is the p-value.

**Table 2: The Excess Probabilities for Weekly Stock-Market Return**
**(probabilities based on a yearly time-horizon)**

| | -15% | -20% | -25% | 15% | 20% | 25% |
|---|---|---|---|---|---|---|
| **Thailand** | 0.328 | 0.162 | 0.094 | 0.190 | 0.082 | 0.043 |
| **Malaysia** | 0.223 | 0.116 | 0.070 | 0.161 | 0.083 | 0.049 |
| **Indonesia** | 0.327 | 0.155 | 0.086 | 0.201 | 0.084 | 0.042 |
| **Philippines** | 0.176 | 0.080 | 0.043 | 0.103 | 0.038 | 0.018 |
| **Korea** | 0.358 | 0.171 | 0.096 | 0.247 | 0.102 | 0.051 |
| **Japan** | 0.055 | 0.022 | 0.011 | 7.365 e-004 | 8.447 e-005 | 1.575 e-005 |
| **Hong Kong** | 0.158 | 0.080 | 0.047 | 0.075 | 0.025 | 0.010 |
| **China** | 0.201 | 0.091 | 0.049 | 0.259 | 0.122 | 0.068 |
| **Taiwan** | 0.106 | 0.038 | 0.017 | 0.091 | 0.038 | 0.019 |

**Table 3: The Co-Crash in the Asian Stock Markets (probabilities based on a yearly time-horizon)**

| | k | Bivar. Prob. | E | $\eta$ | W-Stat | p-val. |
|---|---|---|---|---|---|---|
| **Thailand-Malaysia** | 25 | 0.145 | 1.129 | 1.075 | 0.102 | 0.540 |
| **Thailand-Indonesia** | 35 | 0.150 | 1.206 | 1.079 | 0.098 | 0.539 |
| **Thailand-Philippines** | 30 | 0.114 | 1.207 | 1.015 | 0.019 | 0.507 |
| **Thailand-Korea** | 35 | 0.166 | 1.150 | 1.126 | 0.153 | 0.561 |
| **Thailand-Japan** | 50 | 0.098 | 1.069 | 1.104 | 0.143 | 0.557 |
| **Thailand-Hong Kong** | 40 | 0.121 | 1.169 | 1.067 | 0.129 | 0.551 |
| **Thailand-China** | 35 | 0.136 | 1.051 | 1.011 | 0.021 | 0.508 |
| **Thailand-Taiwan** | 25 | 0.103 | 1.081 | 1.107 | 0.189 | 0.575 |
| **Malaysia–Indonesia** | 30 | 0.126 | 1.241 | 1.029 | 0.039 | 0.515 |
| **Malaysia–Philippines** | 35 | 0.087 | 1.301 | 0.950 | -0.066 | 0.473 |
| **Malaysia–Korea** | 35 | 0.143 | 1.164 | 1.066 | 0.088 | 0.535 |
| **Malaysia–Japan** | 35 | 0.075 | 1.083 | 1.048 | 0.076 | 0.530 |
| **Malaysia-Hong Kong** | 50 | 0.093 | 1.262 | 0.973 | -0.032 | 0.481 |
| **Malaysia–China** | 35 | 0.111 | 1.084 | 0.967 | -0.055 | 0.477 |
| **Malaysia–Taiwan** | 40 | 0.080 | 1.102 | 1.127 | 0.199 | 0.579 |
| **Indonesia–Philippines** | 30 | 0.100 | 1.298 | 0.971 | -0.035 | 0.485 |
| **Indonesia–Korea** | 20 | 0.107 | 1.220 | 1.021 | 0.029 | 0.511 |
| **Indonesia–Japan** | 50 | 0.089 | 1.098 | 1.062 | 0.093 | 0.537 |
| **Indonesia-Hong Kong** | 40 | 0.114 | 1.181 | 0.989 | -0.015 | 0.493 |
| **Indonesia–China** | 35 | 0.134 | 1.016 | 1.046 | 0.094 | 0.537 |
| **Indonesia–Taiwan** | 40 | 0.097 | 1.072 | 1.102 | 0.137 | 0.554 |

Notes: (-25%, -25%) is the cut-off point for the stock-market crash in the paired countries.
W-Statistic has the normal distribution.
* and ** mean that the null hypothesis is rejected at the 10 % and 5 % significance levels, respectively.

**Table 3: The Co-Crash in the Asian Stock Markets (cont.)**
**(probabilities based on a yearly time-horizon)**

| | K | Bivar. Prob. | E | $\eta$ | W-Stat | p-val. |
|---|---|---|---|---|---|---|
| **Philippines–Korea** | 40 | 0.127 | 1.101 | 1.043 | 0.065 | 0.526 |
| **Philippines–Japan** | 40 | 0.048 | 1.133 | 1.043 | 0.065 | 0.526 |
| **Philippines-Hong Kong** | 40 | 0.068 | 1.345 | 0.946 | -0.062 | 0.474 |
| **Philippines–China** | 40 | 0.081 | 1.151 | 0.990 | -0.016 | 0.493 |
| **Philippines–Taiwan** | 40 | 0.055 | 1.108 | 1.081 | 0.117 | 0.546 |
| **Korea–Japan** | 40 | 0.097 | 1.109 | 0.978 | -0.028 | 0.488 |
| **Korea–Hong Kong** | 50 | 0.114 | 1.263 | 0.982 | -0.021 | 0.491 |
| **Korea–China** | 50 | 0.141 | 1.035 | 1.049 | 0.098 | 0.539 |
| **Korea–Taiwan** | 40 | 0.108 | 1.057 | 1.033 | 0.048 | 0.519 |
| **Japan-Hong Kong** | 50 | 0.051 | 1.156 | 1.027 | 0.037 | 0.514 |
| **Japan–China** | 55 | 0.055 | 1.096 | 1.014 | 0.026 | 0.510 |
| **Japan–Taiwan** | 50 | 0.024 | 1.190 | 0.991 | -0.011 | 0.495 |
| **Hong Kong–China** | 55 | 0.087 | 1.110 | 1.070 | 0.120 | 0.547 |
| **Hong Kong–Taiwan** | 45 | 0.057 | 1.133 | 1.000 | 0.000 | 0.500 |
| **China–Taiwan** | 50 | 0.061 | 1.101 | 1.041 | 0.137 | 0.554 |

Notes: (-25%, -25%) is the cut-off point for the stock-market crash in the paired countries.
W-Statistic has the normal distribution.
* and ** mean that the null hypothesis is rejected at 10 % and 5 % significance levels, respectively.

**Table 4: The Crash-Boom between the 1997-Crisis-Affected Economies and Japan (probabilities based on a yearly time-horizon)**

| | K | Bivar. Prob. | E | $\eta$ | W-Stat | p-val. (W-Stat) | Z-Stat | p-val. (Z-Stat) |
|---|---|---|---|---|---|---|---|---|
| **Thailand–Japan** | 40 | 0.091 | 1.025 | 1.004 | 0.041 | 0.516 | -2.635** | 0.008 |
| **Malaysia–Japan** | 45 | 0.069 | 1.022 | 1.052 | 0.246 | 0.597 | 0.345 | 0.730 |
| **Indonesia–Japan** | 50 | 0.085 | 1.020 | 1.053 | 0.179 | 0.571 | -2.237** | 0.025 |
| **Philippines–Japan** | 55 | 0.042 | 1.019 | 1.049 | 0.161 | 0.564 | -1.827* | 0.067 |
| **Korea–Japan** | 55 | 0.095 | 1.018 | 1.006 | 0.024 | 0.509 | -0.187 | 0.851 |

Notes: (-25%, 25%) is the cut-off point for the stock-market crash and boom in the paired countries.
W-Statistic has the normal distribution.
Z-Statistic has the standard normal distribution.
* and ** mean that the null hypothesis is rejected at 10 % and 5 % significance levels, respectively.

**Table 5: The Sensitivity Analysis for the Co-Crash in the Asian Stock Markets (probabilities based on a yearly time-horizon)**

| | K | Bivar. Prob. | E | $\eta$ | W-Stat | p-val. |
|---|---|---|---|---|---|---|
| **Thailand-Malaysia** | 40 | 0.240 | 1.163 | 1.034 | 0.046 | 0.518 |
| **Thailand-Indonesia** | 40 | 0.269 | 1.178 | 1.058 | 0.071 | 0.528 |
| **Thailand-Philippines** | 30 | 0.199 | 1.217 | 1.015 | 0.019 | 0.507 |
| **Thailand-Korea** | 30 | 0.275 | 1.211 | 1.111 | 0.132 | 0.552 |
| **Thailand-Japan** | 45 | 0.171 | 1.080 | 1.081 | 0.108 | 0.543 |
| **Thailand-Hong Kong** | 30 | 0.211 | 1.149 | 1.095 | 0.124 | 0.549 |
| **Thailand-China** | 30 | 0.242 | 1.047 | 1.013 | 0.026 | 0.510 |
| **Thailand-Taiwan** | 30 | 0.183 | 1.095 | 1.074 | 0.111 | 0.544 |
| **Malaysia–Indonesia** | 35 | 0.227 | 1.195 | 1.012 | 0.017 | 0.507 |
| **Malaysia–Philippines** | 35 | 0.153 | 1.280 | 0.950 | -0.066 | 0.473 |
| **Malaysia–Korea** | 25 | 0.265 | 1.085 | 1.094 | 0.124 | 0.549 |
| **Malaysia–Japan** | 35 | 0.125 | 1.109 | 1.048 | 0.076 | 0.530 |
| **Malaysia-Hong Kong** | 35 | 0.162 | 1.217 | 0.975 | -0.034 | 0.486 |
| **Malaysia–China** | 55 | 0.189 | 1.103 | 1.052 | 0.104 | 0.541 |
| **Malaysia–Taiwan** | 40 | 0.138 | 1.123 | 1.127 | 0.199 | 0.579 |
| **Indonesia–Philippines** | 35 | 0.184 | 1.274 | 1.000 | 0.000 | 0.500 |
| **Indonesia–Korea** | 35 | 0.284 | 1.149 | 1.024 | 0.036 | 0.514 |
| **Indonesia–Japan** | 60 | 0.164 | 1.080 | 1.051 | 0.077 | 0.530 |
| **Indonesia-Hong Kong** | 40 | 0.201 | 1.173 | 0.989 | -0.018 | 0.493 |
| **Indonesia–China** | 40 | 0.229 | 1.074 | 1.030 | 0.057 | 0.321 |
| **Indonesia–Taiwan** | 35 | 0.178 | 1.088 | 1.089 | 0.146 | 0.558 |

Notes: (-20%, -20%) is the cut-off point for the stock-market crash in the paired countries.
W-Statistic has the normal distribution.
* and ** mean that the null hypothesis is rejected at 10 % and 5 % significance levels respectively.

**Table 5: The Sensitivity Analysis for the Co-Crash in the Asian Stock Markets (cont.)**
**(probabilities based on a yearly time-horizon)**

| | K | Bivar. Prob. | E | $\eta$ | W-Stat | p-val. |
|---|---|---|---|---|---|---|
| **Philippines–Korea** | 35 | 0.227 | 1.107 | 1.024 | 0.036 | 0.514 |
| **Philippines–Japan** | 45 | 0.092 | 1.111 | 1.069 | 0.105 | 0.542 |
| **Philippines-Hong Kong** | 65 | 0.129 | 1.242 | 1.014 | 0.017 | 0.506 |
| **Philippines–China** | 35 | 0.153 | 1.122 | 0.977 | -0.038 | 0.484 |
| **Philippines–Taiwan** | 50 | 0.105 | 1.131 | 1.062 | 0.089 | 0.535 |
| **Korea–Japan** | 40 | 0.177 | 1.095 | 0.978 | -0.028 | 0.488 |
| **Korea-Hong Kong** | 50 | 0.201 | 1.255 | 0.982 | -0.022 | 0.491 |
| **Korea–China** | 30 | 0.259 | 1.014 | 1.067 | 0.184 | 0.573 |
| **Korea–Taiwan** | 35 | 0.196 | 1.073 | 1.024 | 0.635 | 0.514 |
| **Japan-Hong Kong** | 55 | 0.088 | 1.169 | 1.033 | 0.045 | 0.518 |
| **Japan–China** | 50 | 0.102 | 1.111 | 1.024 | 0.044 | 0.517 |
| **Japan–Taiwan** | 65 | 0.052 | 1.170 | 1.048 | 0.070 | 0.527 |
| **Hong Kong–China** | 35 | 0.160 | 1.073 | 1.011 | 0.019 | 0.507 |
| **Hong Kong–Taiwan** | 50 | 0.104 | 1.150 | 1.008 | 0.012 | 0.504 |
| **China–Taiwan** | 40 | 0.116 | 1.115 | 1.098 | 0.183 | 0.572 |

Notes: (-20%, -20%) is the cut-off point for the stock-market crash in the paired countries.
W-Statistic has the normal distribution.
* and ** mean that the null hypothesis is rejected at 10 % and 5 % significance levels, respectively.

**Table 6: The Sensitivity Analysis for the Crash-Boom between the 1997-Crisis-Affected Economies and Japan (probabilities based on a yearly time-horizon)**

| | K | Bivar. Prob. | E | $\eta$ | W-Stat | p-val. (W-Stat) | Z-Stat | p-val. (Z-Stat) |
|---|---|---|---|---|---|---|---|---|
| **Thailand–Japan** | 30 | 0.157 | 1.035 | 0.987 | -0.046 | 0.481 | 0.000 | 1.000 |
| **Malaysia–Japan** | 45 | 0.114 | 1.023 | 1.052 | 0.246 | 0.597 | 1.584 | 0.113 |
| **Indonesia–Japan** | 40 | 0.151 | 1.026 | 1.009 | 0.028 | 0.511 | -2.991** | 0.002 |
| **Philippines–Japan** | 50 | 0.078 | 1.021 | 1.046 | 0.160 | 0.563 | -0.534 | 0.593 |
| **Korea–Japan** | 40 | 0.167 | 1.026 | 1.000 | 0.000 | 0.500 | -2.281** | 0.022 |

Notes: (-20%, 20%) is the cut-off point for the stock-market crash and boom in the paired countries.
W-Statistic has the normal distribution.
Z-Statistic has the standard normal distribution.
* and ** mean that the null hypothesis is rejected at 10 % and 5 % significance levels, respectively.