

# THE RELATIONSHIP BETWEEN ASIA PACIFIC MARKETS DURING THE FINANCIAL CRISIS: VAR-GRANGER CAUSALITY ANALYSIS

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## ABSTRACT

**Introduction/Main Objectives:** This study investigates the relationships between equity markets during the Asian financial crisis and the subprime mortgage crisis in Asia-Pacific. **Background Problems:** The advantages of market integration are under scrutiny in the midst of global financial crises, which have many implications for international asset pricing and regulators to develop strategies to protect economies. During the crises, the equity markets responded with different patterns, and it is important to understand in more detail the market relations during each crisis, especially for the less and more integrated markets. **Novelty:** We provide in-depth analysis to compare the market relationships during two extremely different financial crises originating from less integrated markets (i.e., emerging ones) and more integrated markets (i.e., developed ones), based on the prices which give a direct measurement and clear interpretation. This research provides a significant contribution by showing new findings in the form of a comparison of market relations during two extremely different crises in the Asia-Pacific region. **Research Methods:** This study employs time-series data from economic territories based on the Morgan Stanley Capital International (MSCI) Asia-Pacific classification and the United States. We conducted analysis using the vector autoregressive, Granger causality test, and impulse response, to point out the market relationships during the crises or turmoil periods. **Finding/Results:** The results show that the Asian financial crisis affected the emerging markets more and this indicates the unidirectional causality relationships among them. Meanwhile, the subprime mortgage crisis affected all the markets, but more indicated the bidirectional relationships, especially the developed markets. **Conclusion:** Although these two financial crises were global in nature, the effects on the region were different. The origin of the shock and the level of market integration affected the market relationships differently during the crises.

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## INTRODUCTION

Liberalization and globalization have led to changes that have brought domestic markets closer to the global market. In this case, the markets are more integrated especially in emerging markets. The removal of trade barriers and capital controls has led to rapid developments in the international trade in commodities, services, and financial assets, so the world's economic and financial systems are increasingly integrated. Several previous studies on increased market integration show inconclusive results (see, Bekaert & Harvey, 2003; Berger & Pukthuanthong, 2012; Carrieri et al., 2007; Kose et al., 2009; Pukthuanthong & Roll, 2009). Increased market integration has an opposite function; although integration has advantages, it also has several drawbacks. The advantages of an integrated market are under scrutiny especially when global financial crises occur because highly interconnected markets will accelerate and propagate shocks across markets. Countries which are more globally integrated will be more vulnerable to shocks, due to high interconnectivity among markets which may well lead to the spread of a crisis into global markets (Berger & Pukthuanthong, 2012; Pukthuanthong & Roll, 2009). However, Bekaert et al. (2014) examined the globalization hypothesis which holds that crises hit hardest those economies that are highly integrated globally through trade and financial linkages, but they failed to find strong evidence in favor of the hypothesis. These studies have shown inconclusive results regarding levels of integration and global financial crisis. It can be seen, over time, that several global financial crises occurred with originating shocks not only from more integrated markets (i.e. developed markets) but also from less integrated markets (i.e. emerging markets) which affected both markets. Therefore, it's important to understand in more

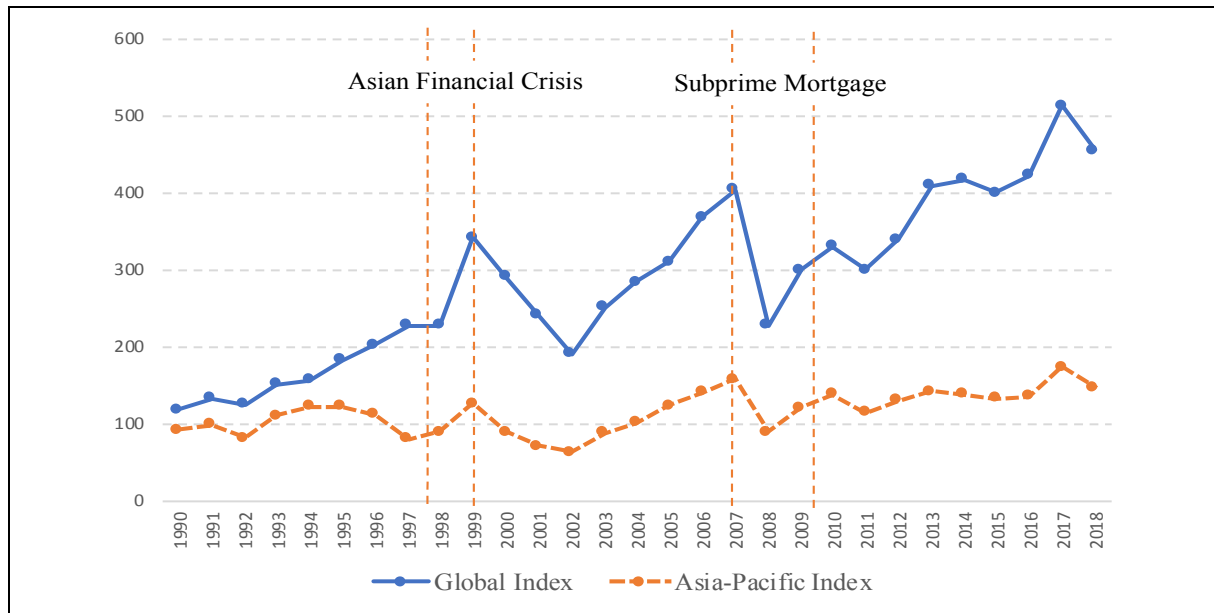
detail how the market relationships work during crises especially in the context of the two different financial crises that originated from a less integrated market (in the case of the Asian financial crisis) and a more integrated market (in the case of the subprime mortgage crisis)?

Our main interest lies in the Asian financial crisis of 1997 to 1998 and the subprime mortgage crisis of 2007 to 2009, which were two major global financial crises that hit countries in Asia-Pacific, which is a region with rapid economic development that had 74% of the world market's capitalization in 2017<sup>1</sup>. These two crises were different in nature; one originated from an emerging market in the region and the other from a developed market that was more integrated globally. In the case of the integrated market (i.e., developed market), it's important to compare it to the shock from the less integrated market (i.e., emerging market). Therefore, we have tried to compare the relationships among equity markets in the cases of two different financial crises to understand how the shocks from the less integrated market (the Asian financial crisis) and from the more integrated market (the subprime mortgage crisis) were transmitted to the global market.

Figure 1 shows the price movement of the global and regional markets from 1990 to 2018; it exhibits an upward trend, even though it has some declines at certain periods. It shows that the Asian financial crisis and the subprime mortgage crisis had different effects on the price movement of markets, which were expected to have uniform responses from similar shocks of a global financial crisis under a market integration framework. This difference indicated that these two crises had different characteristics, especially in the transmission of shocks and the relationships among equity markets during the

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<sup>1</sup> Source: data.worldbank.org, September 7<sup>th</sup> 2019

**Figure 1.** Movements of Global and Regional Market Indices

Note: this graph represents the price movement of the global and regional markets using the MSCI World Index and Asia-Pacific Index. Source: Thomson Reuters, plotted by the author.

crisis periods. This has many implications for international asset pricing and investment as well as for regulators to develop strategies of economic protection.

This study contributes to the growing amount of literature on global financial crises, especially on the differences between market relations during global financial crises in both less integrated and more integrated markets where shocks originate from both. It's important for practitioners and regulators to understand the propagation of shocks during crises and the relationships among equity markets in the two very different financial crises, especially in the case of an integrated market framework. We used the vector autoregressive (VAR), Granger causality tests, and impulse response, based on the price of equity markets which gave a direct measurement and provided an easy and clear interpretation (Volosovych, 2011). In addition, the performance of country's equity market has a strong relationship with its economic performance, so the usage of the equity market is expected to show the economic relationship

(e.g., Akbari et al., 2020; Claessens et al., 2011; Paramati et al., 2016; Setiawan, 2012).

The rest of this article is organized as follows. Section 2 presents some reviews about market integration, global financial crises, and the contagion effect. Section 3 introduces the model and empirical methodology. Section 4 presents the data and discusses the major empirical results, and the concluding remarks are in Section 5.

## LITERATURE REVIEW

Market integration is related to the fact that there has been an increase in trade and financial activity on international markets, which has strengthened the co-movement among countries' domestic markets. Capital mobility and free trade have driven the globalization process, which has led to increased market integration. Most evidence for increased market integration shows some direct and indirect implications. The direct implications are that more integrated markets should lead to a lower cost of capital, increased investment opportunities, increased

savings, and enhanced economic growth through the international risk sharing (Bekaert & Harvey, 2003; Carrieri et al., 2007). The indirect implications are the expected encouragement of the development of domestic markets, improved corporate and public governance, leading to efficiency among domestic firms that are subject to international competition, and discipline on macroeconomic policies (Kose et al., 2009)

The advantages of the integrated market are under scrutiny because the markets that are integrated more globally will be more vulnerable to shocks, due to the high interconnectivity among its members which may well lead to spread the shocks to global markets (Berger & Pukthuanthong, 2012; Pukthuanthong & Roll, 2009). When one examines the Asian financial crisis and the subprime mortgage crisis, the first crisis originated from the emerging market and began with the depreciation of the currencies in the Asia region and then spread globally. This crisis was an economic crisis that had a broad impact on macroeconomic stability. The second crisis originated from the largest and most influential economy and later it spread across global markets. This crisis was a chain reaction of credit risk inherent in derivative financial instruments, triggered by the liquidity crisis in the United States (US) banking system which later spread to global markets.

Global financial crises that hit several countries can occur simultaneously due to interdependence between markets—or the contagion effect—from one market to another, but the distinction between interdependence and contagion is tenuous because all of them are part of the transmission mechanism whose distinctions are model-dependent (Rigobón, 2019). One aspect of the debate about contagion is the disagreement about its exact definition (see, Bekaert et al., 2005; Forbes & Rigobon, 2001). Forbes and Rigobon (2001) argued that there is

no consensus on exactly what constitutes contagion or how it should be defined. The term contagion in the equity market usually refers to the consideration that markets move closely together, or serially, during crisis periods. Bekaert et al. (2005) defined contagion as an excess correlation in which the correlation is above the expected return from the economic fundamentals. However, there is also disagreement regarding the definition of economic fundamentals which might differ across countries and the mechanisms that associate them to the correlation of asset returns.

Paas and Kuusk (2012), as quoted by Singh and Singh (2017), explained the three definitions of transmission. The first definition is the broadest one and it considers contagion to be the transmission of shocks across countries or a spillover effect across countries where the fundamental relationship is a channel of transmission. The second definition has a limitation that only includes the transmission of shocks that is outside the fundamental relationships. This definition is often referred to as an excess correlation, which is a correlation that is not influenced by fundamental factors and common shocks. Herding behavior is usually considered to be the cause of a correlation that exceeds the expected correlation. The third definition has the most restrictive definition and it says that transmission occurs not only when there is the transmission of shocks to another country but the transmission is stronger during a crisis than during a tranquil period. This definition proposed by Forbes and Rigobon (2001) was called shift-contagion which did not include a constant high correlation during the crisis period. This condition was not defined as contagion but interdependence between markets. Candelon and Tokpavi (2016) introduced a kernel-based nonparametric inferential procedure to analyze spillovers during the crisis in

Europe and to distinguish contagion from interdependence effects.

Rigobon (2019) explained that the theories related to the transmission of shocks among markets had viewpoints that could be divided into fundamental, financial, and coordinating. The fundamental view of contagion explains the propagation of shocks across countries by appealing to real channels. The financial view concentrates on constraints and inefficiencies in banking sectors and international equity markets. The coordinating viewpoint studies the behavior of investors and policy makers, and coordination problems as the explanation behind contagion.

## METHOD, DATA, AND ANALYSIS

### 1. Samples and Data

The samples in this study are from the economic territories based on the Morgan Stanley Capital International (MSCI) for Asia-Pacific classification, and consists of a) developed markets: Australia (AUS), Hong Kong (HKG), Japan (JPN), New Zealand (NZL), Singapore (SGP); b) emerging markets: China (CHN), India (IND), Indonesia (IDN), South Korea (KOR), Malaysia (MYS), Pakistan (PAK), the Philippines (PHL), Taiwan (TWN), and Thailand (THA). This study also includes the United States of America (US), although it is not an official MSCI Asia-Pacific classification, but the country where the subprime mortgage crisis was originated which is one of the issues in this study. It's also a developed country with the world's largest economy and has the longest tradition of free capital mobility.

We use daily data of the domestic markets' indices in their local currency from Thomson Reuters for the periods from 1997 to 1998 (the Asian financial crisis), and 2007 to 2009 (the subprime mortgage crisis). To mitigate the effect of time zone differences in the daily data, one-

day lag was adjusted for the US. The domestic markets' indices were adjusted to a common currency, the US dollar (USD), by multiplying them with local currency per USD value exchange rate. Our analysis will concentrate on the price and return in USD which is the investor's perspective, such as is the practice in international financial studies in order to avoid exchange rate disruptions and maintain comparability between countries (Goetzmann et al., 2005; Pukthuanthong & Roll, 2009). It also refers to Stulz (1981) who stated that in an integrated capital market, assets in different markets will have the same returns when measured in a common currency. These two crises are treated as the same in terms of methodology with the objective of comparing them directly in the context of market integration framework.

### 2. Research Methodology

Some previous studies have been taken into consideration to define the period of the global financial crises. For the Asian financial crisis, we define the start as being when the market in Hong Kong crashed in October 1997, and the end of this crisis period is defined as being in December 1998. We define the beginning of the subprime mortgage crisis as being when the initial fall of the stock market occurred, due to a liquidity crisis, in August 2007, and the end of this crisis period is determined to be during June 2009 based on data from the National Bureau of Economic Research (NBER)<sup>2</sup>, which considers

<sup>2</sup> The NBER is the widely accepted arbiter of recessions and recoveries in the United States business cycle. The periods maintain by NBER's Business Cycle Dating Committee which determines when peaks and troughs occur in economic activity and it examines and compares the behavior of various measures of broad activity: real GDP measured on the product and income sides, economy-wide employment, and real income. The committee also may consider indicators that do not cover the entire economy, such as real sales and the Federal Reserve's index of industrial production. The committee announcement on June 2009 as business cycle trough/end

that date to be the end of the recession in the US (see, Lehkonen, 2015).

The equity market index is a non-stationary data series by its nature, so a study using this data needs to use a non-stationary model, such as the cointegration or vector error correction model (VECM). We can use a stationary data series by converting them into market returns, which is equivalent to the first difference of market price in the natural logarithm. The market returns are a stationary data series by their nature, so we can use a stationary model such as the autoregressive or vector autoregressive model (VAR). This study uses the natural logarithm of the price at time  $t$  as endogenous variables,  $Y_t = \ln(P_t)$ , so if we use the first difference of  $Y_t$  or  $\partial(Y_t)$ , it means the market return.

The first step is to ensure the stationarity of the data series which is tested using unit root tests. The second step is to test a long-run relationship or an equilibrium relationship which is tested using Johansen's cointegration, which develops a multivariate approach for testing cointegration among non-stationary data series (Johansen, 1991, 1995). Based on these tests, we determine the usage of the VAR or VECM. If the data series is known to be  $I(1)$  with no cointegration, then we use a procedure where we estimate first order differenced VAR, and the VECM if it's known with cointegration. The third step is to test the stability of models that would be tested using the inverse roots of AR/MA polynomial. We used the VAR model formed in the matrix equation as follows:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \dots + \beta_n Y_{t-n} + \varepsilon_t \quad (1)$$

where  $Y_t, Y_{t-1}, Y_{t-n}, \beta_0$ , and  $\varepsilon_t$  are vectors

$$\begin{aligned} 15 \times 1 \text{ of } Y_t &= \begin{bmatrix} Y_{1t} \\ Y_{2t} \\ \vdots \\ Y_{nt} \end{bmatrix}, Y_{t-1} = \begin{bmatrix} Y_{1t-1} \\ Y_{2t-1} \\ \vdots \\ Y_{nt-1} \end{bmatrix}, \\ Y_{t-n} &= \begin{bmatrix} Y_{1t-n} \\ Y_{2t-n} \\ \vdots \\ Y_{nt-n} \end{bmatrix}, \beta_0 = \begin{bmatrix} \beta_{10} \\ \beta_{20} \\ \vdots \\ \beta_{n0} \end{bmatrix}, \\ \varepsilon_t &= \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{nt} \end{bmatrix}; \beta_1 \text{ and } \beta_n \text{ are matrices} \end{aligned}$$

15x15 as follows:

$$\begin{aligned} \beta_1 &= \begin{bmatrix} \beta[1]_{11} & \beta[2]_{11} & \dots & \beta[n]_{11} \\ \beta[1]_{21} & \beta[2]_{21} & \dots & \beta[n]_{21} \\ \vdots & \vdots & & \vdots \\ \beta[1]_{n1} & \beta[2]_{n1} & \dots & \beta[n]_{n1} \end{bmatrix} \\ \beta_n &= \begin{bmatrix} \beta[1]_{1n} & \beta[2]_{1n} & \dots & \beta[n]_{1n} \\ \beta[1]_{2n} & \beta[2]_{2n} & \dots & \beta[n]_{2n} \\ \vdots & \vdots & & \vdots \\ \beta[1]_{nn} & \beta[2]_{nn} & \dots & \beta[n]_{nn} \end{bmatrix} \end{aligned}$$

This model consists of the endogenous variables as much as the samples of fifteen countries for  $n=1$  to 15, that could be set in individual equation for each country as follows:

$$\begin{aligned} Y_{1t} &= \beta_{10} + \beta[1]_{11}Y_{1t-1} + \beta[2]_{11}Y_{2t-1} + \dots \\ &\quad + \beta[n]_{11}Y_{nt-1} + \dots \\ &\quad + \beta[1]_{1n}Y_{1t-n} + \beta[2]_{1n}Y_{2t-n} \\ &\quad + \dots + \beta[n]_{1n}Y_{nt-n} + \varepsilon_{1t} \\ &\quad \vdots \\ &\quad \vdots \\ &\quad \vdots \\ Y_{nt} &= \beta_{n0} + \beta[1]_{n1}Y_{1t-1} + \beta[2]_{n1}Y_{2t-1} + \dots \\ &\quad + \beta[n]_{n1}Y_{nt-1} + \dots \\ &\quad + \beta[1]_{nn}Y_{1t-n} + \beta[2]_{nn}Y_{2t-n} \\ &\quad + \dots + \beta[n]_{nn}Y_{nt-n} + \varepsilon_{nt} \end{aligned}$$

The VAR is a natural generalization of univariate autoregressive models that was popularized by Christopher A. Sims (1980). One

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of last recession based on several monthly indicators and consideration which is described at:  
<https://www.nber.org/news/business-cycle-dating-committee-announcement-september-20-2010>.

of the main problems with the VAR is how to interpret the coefficient because the VAR is a-theoretical; therefore, we use the Granger causality and impulse response analysis. We perform the Granger causality test to examine the effect of equity markets' past values during the global financial crises using the Wald tests on the coefficients from the VAR model estimation. According to Granger (1969), variable X is said to Granger cause the variable Y if the past value of X could better predict Y after controlling for the past value of Y, or equivalently, if the coefficients on the lagged value of X are statistically significant. The stability of models is important especially for the Granger causality test. The presence of instabilities may lead to incorrect VAR-based statistical inference that must be adjusted as did Rossi and Wang (2019). This test is determined into three types: unidirectional, bidirectional, or none of the causal relationships exist.

During crisis periods, the volatility tended to increase which caused an increasing correlation but it was not necessarily indicative of contagion (Bekaert et al., 2014; Forbes & Rigobon, 2001). In a regional context, It is also consistent with the general empirical evidence by Wan et al. (2016) where the correlation between regional markets tends to increase significantly during financial turbulence. Forbes and Rigobon (2001) have stated that there is no consensus on exactly what constitutes contagion or how it should be defined. They used the term "shift-contagion" as the significant increase of cross-market co-movement after a shock. If two countries are closely linked through economic fundamentals, then a crisis in one country will be expected to have a strong impact on the other. This transmission is not defined as a contagion but more as an interdependence between market. Bekaert et al. (2014) defined contagion as an excess correlation, over and above what one

would expect from the economic fundamental. If the market correlation does not increase significantly after the shock but still has a high level of market correlation, this situation is defined as interdependence. We conclude that during a crisis period in a high correlation, a shock is transmitted in two ways through the contagion or interdependence due to closely linked markets. Hence, we use these terms in the context of a short-run dynamic co-movement during a high correlation period. This helps to point out the causality relationship among markets during a crisis period in terms of unidirectional causality relationships from one market to another and the bidirectional causality which is also termed as a feedback relationship. Under the efficient market hypothesis (EMH), if markets are efficient, it's expected that all information will be absorbed simultaneously in various markets. Consequently, there should be no lead-lag movement relationships among various markets and vice versa (X. Wang, 2015).

We also use the impulse response analysis to trace out the speed of adjustment or how long it took for the equity markets to be re-established following a one standard deviation shock from one of them (see, Chua et al., 2012; Shu et al., 2018). The Granger causality and impulse response have implications for market inefficiency. If the markets are efficient and there are no non-synchronous trading effects, it should be expected with the contemporaneous relationships. The efficient market theory states that equity prices will reflect what information it contains, so the flow of information between different markets leads to the correlation between the markets.

## RESULT AND DISCUSSION

### 1. Summary Statistics

The summary statistics are reported in Tables 1 and 2 for the total available data of each sample

during the Asian financial crisis and the subprime mortgage crisis. Table 1 reports the averages of equity market returns to be between -0.224% and 0.061% with standard deviations between 1.187% and 6.576%. The averages of the developed and emerging markets are -0.047% and -0.076% with standard deviations of 1.960% and 3.418%. The emerging markets had greater volatility but lower returns which means the risk and return trade-off was not applied. It shows that during the Asian financial crisis, the emerging markets suffered more and had higher risk than the developed markets. Most markets in the Asia region were more affected by the negative returns, except China's market which had the positive return of 0.023% and the smallest standard deviation of 1.292% which suggests that China's market applied a relative strict capital access system to prevent the negative impact of cross-border risk transmission on its market. This result is in line with Baek and Jun (2011), Wang and Liu (2016) where during Asian financial crisis, China's market did not suffer from currency crisis that was mostly due to the small portion of the Its market that was open to foreign investors.

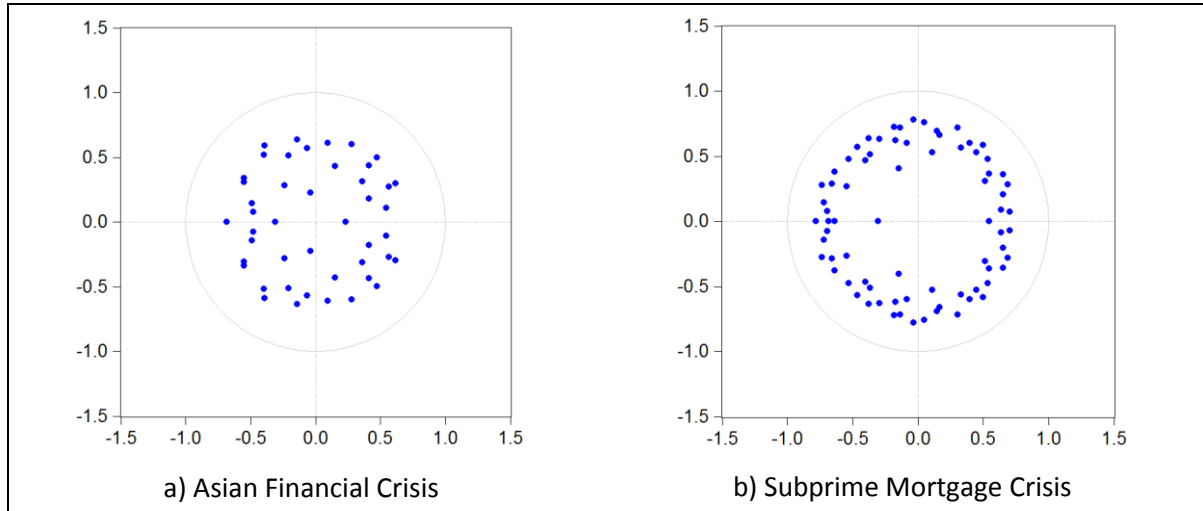
Table 2 reports the averages of equity market returns to be between -0.172% and -0.007% with standard deviations between 1.439% and 3.199%. The averages of the developed and emerging market are -0.062% and -0.061% with standard deviations of 2.307% and 2.273%. It shows that during the subprime mortgage crisis, both the markets were affected by this crisis with the negative equity returns; but, the developed markets suffered more and had slightly higher risk than the emerging markets. Generally, this shows that the Asian financial crisis and the subprime mortgage crisis had different effects on the equity markets. The first crisis originated from the emerging market of Thailand and affected the emerging markets harder than the

developed markets. Meanwhile, the second crisis originated from the developed market of the US and affected both of the markets. This result is consistent with Ahmad et al. (2012) indicated that the Asian financial crisis was more disturbing event than the subprime mortgage crisis in Asia-Pacific region.

## 2. Relationship Between Markets During the Crises

To estimate using the VAR, we performed the preliminary test that is described in Appendix C. The first step of the analysis is the stationarity of data series. A unit root test shows that the null hypothesis of the unit root at level cannot be rejected for all the data series, but the null hypothesis of the unit root for the first difference can be rejected. It shows that the data series of  $Y_t$  is non-stationary at level, but stationary in their first difference or  $I(1)$ . The second step is the long-run relationship test for all the data series. Johansen's cointegration test results show there to be no cointegrations for both the Asian financial crisis and the subprime mortgage crisis. Based on these tests, the data series is  $I(1)$  and no long-run relationship, so we require the stationarity of data series in the first difference of  $Y_t$ , which means the return and the VAR are applied. This model is employed with a lag length of 3 and 5 to be optimum lags for the first and second crises from the VAR lag order selection criteria that are presented in Appendix D. The third step is the stability test of the models. The presence of instabilities may lead to incorrect VAR-based statistical inference especially for the Granger causality test. Therefore, the traditional Granger causality test cannot be used, but the presence of instability must be considered as did Rossi and Wang (2019). Figure 2 represents the stability test of VAR models using the inverse roots of an AR characteristic polynomial. It shows that all the roots lie



**Figure 2.** Inverse Roots of AR Characteristic Polynomial

inside the unit circle, which is an indication that the VAR models are stable or stationary.

The results from the VAR estimation are analyzed using the Granger causality tests to investigate a short-run dynamic co-movement among the markets during the Asian financial crisis and the subprime mortgage crisis, as reported in Tables 3 and 4. They show the Chi-square and significance levels of the Wald tests for each pair of markets that represent the short-run linkages and their causal direction.

Table 3 reports the causality relationships during the Asian financial crisis, which shows the unidirectional and bidirectional causality of 37 and 8 relationships. The bidirectional causality relationships between two markets during this crisis consist of HKG-USA, HKG-AUS, NZL-HKG, SGP-HKG, CHN-NZL, CHN-SGP, MYS-JPN, and PHL-SGP. Hong Kong and Singapore have higher bidirectional causality of 4 and 3 relationships, which represents a nexus of the equity markets' linkages during this crisis. This result is in line with Wang and Liu (2016) that Singapore and Hong Kong were the most influential market in Asia during the Asia financial crisis. Meanwhile, the unidirectional causality of 37 relationships represents one-way causa-

lity from one market to another during this crisis. The emerging markets have a higher number of causality relationships (28) than the developed markets (25) with the unidirectional and bidirectional causality of 24 and 4 relationships, respectively. It shows that during the Asian financial crisis, the emerging markets are more affected by the unidirectional causality relationships from one market to another, and the nexus of linkages at Hong Kong and Singapore.

Australia and China's markets have many significant coefficients of 9 and 8 that indicates a lead-lag effect in which the delay returns of these two markets can explain the return of most of the markets. These markets also have a bidirectional causality relationship to the nexus of linkages of Hong Kong and Singapore in this period. It shows that Australia-Hong Kong and China-Singapore have feedback relations which are important in the shock transmission during the Asian financial crisis.

The Asian financial crisis, which originated from Thailand, spread to other markets which indicates the one-way causality mechanism especially in the emerging markets, even though the developed markets also had a lot of two-way

causality relationships. From a financial point of view, the reason for the propagation of shocks is the imperfection in the financial system through the financial institutions' network. This crisis began with the devaluation of the Thai baht as its economic crisis grew worse and this had a broad impact on macroeconomic stability and caused an increase in market risk. The capital asset pricing model (CAPM) developed by Sharpe (1964), Lintner (1965), and Mossin (1966) explained that market risk was related positively to asset return. An increase in market risk leads to an increase in asset prices to compensate this additional risk to its assets (see, Figure 1 during the Asian financial crisis). This study is consistent with Hubbansyah and Husodo (2018) that the financial sector was the leading regional transmitter of shock to the real and financial sector across countries during the Asian financial crisis.

Table 4 reports the causality relationship during the subprime mortgage crisis, which has the unidirectional and bidirectional causality of 40 and 11 relationships. The bidirectional causality relationships between two markets during this crisis consist of HKG-USA, JPN-AUS, SGP-HKG, SGP-JPN, CHN-JPN, CHN-NZL, MYS-JPN, MYS-NZL, PHL-NZL, THA-JPN, and TWN-MYS. Japan has the highest bidirectional causality with 5 relationships, which represents a nexus of the equity markets' linkages during this crisis. This result is supported by Wang and Liu (2016) finding that Japan is the most vulnerable market during the

crisis. Meanwhile, the unidirectional causality of 40 relationships represents one-way causality from one market to others during this crisis. The US has the highest unidirectional causality with 7 relationships that indicates a lead-lag effect in which the delay returns of these markets can explain the return of the US market, even though it has a feedback relationship with Hong Kong. The developed markets have 33 causality relationships with the unidirectional and bidirectional causality of 19 and 14 relationships, which are higher than the emerging markets with 29 causality relationships. It shows that, during this crisis, the markets are more affected, especially the developed markets with the bidirectional causality relationships, and the nexus of linkages is Japan. Although the emerging markets have an increase in the bidirectional causality relationships among their markets, the unidirectional causality relationships, however, still dominate during this crisis.

Japan's and Malaysia's markets had many significant coefficients of 13 and 11 and this indicates a lead-lag effect, the delay in returns of these two markets which can explain the return of most of the markets. Japan's market, as the nexus in this period, granger caused to another of 13 markets and also had feedback relations with the bidirectional causality to Australia, Singapore, China, Malaysia, and Thailand. This shows that Japan's market was the most important market in the shock transmission during the subprime mortgage crisis.





**Table 3.** Chi-square of VAR Granger Causality/Block Exogeneity Wald Tests during the Asian Financial Crisis

	Dependent Variables														
	Developed Markets							Emerging Markets							
	USA	AUS	HKG	JPN	NZL	SGP	CHN	IDN	IND	KOR	MYS	PAK	PHL	THA	TWN
USA	7.21 *	6.29 *	3.92	13.55 ***	2.00	1.45	5.442	4.86	2.36	5.22	3.78	3.893	0.695	1.14	
AUS	3.44	12.43 **	1.11	15.20 ***	6.65 *	3.25	3.734	1.67	9.04 **	12.19 ***	6.61 *	13.34 ***	10.12 **	10.32 **	
HKG	23.20 ***	32.46 ***	5.62	34.10 ***	15.88 ***	2.61	1.502	0.95	2.36	2.53	5.33	1.96	6.99 *	19.09 ***	
JPN	4.69	4.73	0.58	4.90	6.76 *	0.09	4.461	6.24	7.52 *	10.26 **	1.91	0.37	2.92	2.74	
NZL	2.87	5.16	9.58 **	1.44	3.21	13.61 ***	0.877	1.41	0.71	5.38	6.05	1.88	1.77	3.44	
SGP	2.16	3.69	7.03 *	1.28	4.16	7.57 *	5.579	2.84	1.57	3.16	0.72	6.851 *	10.97 **	2.09	
CHN	14.63 ***	5.46	9.87 **	6.09	9.46 **	15.46 ***	5.301	3.39	2.84	8.73 **	8.94 **	4.01	6.30 *	11.60 ***	
IDN	0.88	0.73	2.79	3.39	1.98	7.61 *	2.19	1.56	1.03	0.61	1.85	16.10 ***	2.30	5.08	
IND	2.17	5.13	6.25	3.63	2.81	4.20	6.05	0.406	2.91	1.86	1.02	1.34	3.15	4.67	
KOR	4.93	1.08	4.81	2.88	6.42 *	6.15	1.13	12.60 ***	0.85	12.79 ***	0.98	8.73	15.58 ***	3.45	
MYS	7.33 *	1.57	0.66	7.65 *	1.76	2.32	1.52	6.73 *	6.70 *	2.42	3.27	2.31	3.07	8.42 **	
PAK	3.89	3.76	3.29	4.00	6.43 *	6.13	3.17	3.674	1.125	1.43	3.27	1.71	1.16	1.73	
PHL	2.21	5.64	6.24	1.27	7.18 *	9.12 **	6.25	5.293	3.369	8.45 **	1.74	0.34	2.32	0.23	
THA	2.71	2.89	1.04	0.51	9.19 *	3.11	2.98	5.215	3.025	3.04	0.71	0.83	1.74	9.02 **	
TWN	0.82	1.86	5.78	5.17	1.03	5.78	1.29	2.260	0.055	5.15	2.95	9.82 **	3.25	2.54	

Note: \*, \*\*, and \*\*\* denote statistical significance at 10%, 5%, and 1% levels.

**Table 4.** Chi-square of VAR Granger Causality/Block Exogeneity Wald Tests during the Subprime Mortgage Crisis

	Dependent Variables													
	Developed Markets							Emerging Markets						
	USA	AUS	HKG	JPN	NZL	SGP	CHN	IDN	IND	KOR	MYS	PAK	PHL	THA
USA	6.81	14.25 **	5.74	1.56	6.18	5.62	2.15	8.75	4.09	2.14	5.19	17.99 ***	1.13	1.26
AUS	64.74 ***	2.58	29.33 ***	1.91	1.13	1.51	4.95	3.33	1.10	1.78	4.95	4.24	5.12	4.25
HKG	10.33 *	22.31 ***	5.58	6.91	9.34 *	3.28	13.13 *	1.86	5.02	0.61	8.44	3.11	5.06	2.12
JPN	56.03 ***	26.96 ***	48.73 **	12.73 **	23.87 ***	11.64 **	15.89 ***	14.39 **	42.69 ***	14.16 **	5.91	21.54 ***	13.38 **	22.62 ***
NZL	40.42 ***	6.57	13.38 **	9.00	2.60	10.93 *	7.93	2.41	7.95	9.36 *	1.21	30.64 ***	9.88 *	5.78
SGP	4.22	13.18 **	19.18 ***	11.29 **	6.15	2.12	6.56	3.20	9.15	2.33	1.16	7.26	9.83 *	6.72
CHN	11.27 **	20.03 ***	8.91	11.77 **	5.52	3.45	14.05 **	10.57 *	4.77	16.06 ***	7.24	7.17	7.17	5.81
IDN	10.72 *	12.84 **	4.64	5.38	8.06	8.19	6.54	2.42	7.78	7.96	16.01 ***	14.61 **	2.27	2.27
IND	6.47	4.06	4.20	4.85	2.61	3.04	4.45	6.93	6.93	8.30	4.34	7.73	9.04	6.41
KOR	15.5 ***	3.45	10.82 *	5.98	7.06	6.84	19.81 ***	5.62	1.31	8.78	10.98 *	13.15 **	2.02	2.02
MYS	12.98 **	21.41 ***	17.29 ***	16.05 ***	14.65 **	18.76 ***	7.38	20.32 ***	4.23	19.48 ***	3.28	10.93 *	18.93 ***	19.56 ***
PAK	6.33	1.70	4.08	3.56	2.88	1.47	3.92	2.34	0.93	0.22	1.61	1.06	3.71	3.71
PHL	3.78	6.04	2.51	5.70	10.93 *	6.28	1.36	4.50	6.89	4.27	5.19	2.42	2.19	2.19
THA	9.66 *	2.47	6.68	16.11 ***	3.14	1.75	2.00	7.22	5.96	5.43	3.83	3.50	2.49	2.49
TWN	3.39	15.03 **	4.86	4.12	6.90	7.03	3.60	7.24	1.94	12.02 **	5.56	3.82	3.70	3.70

Note: \*, \*\*, and \*\*\* denote statistical significance at 10%, 5%, and 1% levels.

The subprime mortgage crisis that originated in the US spread to other markets which indicated the two-way causality mechanism especially in the developed markets. This crisis is more influenced by risk perceptions; companies that previously had good ratings (e.g., Lehman Brothers, and American International Group/AIG) entered bankruptcy. There was a shifting in investors' perceptions about market risks. This crisis caused a correction in the perception of market risks that adjusted to the decrease in asset prices, especially in early periods of the crisis (see, Figure 1 during the subprime mortgage crisis). Hubbansyah & Husodo (2018) discovered a more complicated configuration of spillover during the subprime mortgage crisis in which the financial sector was not the only transmitter of shock; but it had also been accompanied by the real sector that also adjusted to the decrease in some real asset price such as the bursting of property price (Anggun Andini & Falianty, 2022).

Tables 3 and 4 show that the Asian financial crisis and the subprime mortgage crisis were different in terms of the causality relationships of the markets. Generally, the developed markets had more bidirectional causality relationships of markets, whereas the emerging markets had more unidirectional ones. The developed markets had bidirectional causality relationships during the first and second crisis comprising 12 and 14 relationships which were higher than the emerging markets which had 4 and 8 relationships. However, the emerging markets were still more indicative of the one-way causality relationships for both the crises with the unidirectional causality of 24 and 21 relationships.

### 3. Dynamic Responses of Each Markets During the Crises

For additional insight from the previous test, we use the dynamic responses of each equity market

to innovation from Thailand and the US market using the estimated VAR system that reported in Tables 5 and 6. To simplify the interpretation of these tables, the impulse response is also figured in time paths of the normalized impulse responses of the equity markets that are presented in Appendices A and B. This study concentrates on a shock from Thailand's market for the Asian financial crisis and one from the US market for the subprime mortgage crisis, which were the origins of the crises. Table 5 shows that during the Asian financial crisis, the innovation from Thailand was more rapidly transmitted to the emerging markets with, on average, the significant response being on day 2, compared to the developed markets, where it was on day 3; and, on average, the first response in the emerging markets was greater than in the developed markets. Taiwan's market responded to this shock most dramatically on day 1 and then this rapidly tapered off until day 4. Indonesia and South Korea's markets had the longest responses from day 2 until 9, while Japan's market had the shortest response from day 2 until 4. Generally, the emerging markets responded to the shock more rapidly with longer and larger responses than the developed markets. It shows that any information that originated from Thailand's market had a subsequent positive impact on most of the emerging markets which were faster and larger than the developed markets. The emerging markets also adjusted this impact longer than the developed markets.

Table 6 shows that during the subprime mortgage crisis, the innovation in the US was rapidly transmitted to all the markets on day 1, but the first response in the developed markets was larger than the emerging markets. The US response to its own shock was initially negative until day 3, but most markets had the negative response initially from day 5 until the end of the period. Japan's market has the shortest response

until day 4, while the most of adjustments to this shock were completed, on average, on day 7. This shows that any information originating from the US market had a subsequent positive impact on all markets on the first response of day 1, and most markets still had a positive impact until day 4. Most markets adjusted for this impact in, on average, 7 days except Japan's market which was significantly shorter in just 4 days.

According to the efficient market hypothesis (EMH), all markets had a lead-lag effect during the subprime mortgage crisis which means inefficient. However, the response of markets during the subprime mortgage crisis was faster than during the Asian financial crisis, which suggests that the markets are more efficient for both the developed and emerging markets over time in line with an increase of market integration. The markets generally responded to the shock with a high degree of efficiency which minimized the benefit from the lead-lag effect. Furthermore, the information that was relevant to the subprime mortgage crisis from the US was more publicly available and easy for other markets to access, which minimized the asymmetry of information and increased market efficiency.

## **CONCLUSION AND SUGGESTION**

Market integration has been one of the most important phenomena and fields of study in international finance over the last four decades, especially in emerging markets. However, the advantages of market integration are under scrutiny in the midst of global financial crises. Some previous studies also have inconclusive results regarding the levels of integration and the crises. Our main concern is to understand global financial crises in more detail, especially the

differences in market relations during two extremely different crises in the Asia-Pacific region that originated from a less integrated market (the Asian financial crisis) and from a more integrated market (the subprime mortgage crisis).

The result shows that, during the crises, the more integrated, developed markets exhibited more bidirectional causality relationships than the less integrated, emerging ones. The Asian financial crisis affected the emerging markets more which indicated the unidirectional causality relationships among the emerging markets which are less bidirectional with the nexus of linkages at Hong Kong and Singapore. The emerging markets also had a faster and larger response to the shock and longer adjustment than the developed markets. Meanwhile, the subprime mortgage crisis affected all the markets which indicated the bidirectional relationships among them especially the developed markets with the nexus of linkages at Japan. During this crisis, any information that originated from the US market had a subsequent positive impact on all markets on the first day, but the developed markets had a greater response than the emerging markets. The emerging markets were also affected during this crisis which indicated an increase in the bidirectional causality relationships among the markets but the unidirectional causality was still the dominant relationship. The leading and lagging, in terms of the causality relationships, depended on the market from where information originated and the level of market integration. If the lead-lag effect existed, the markets were not efficient with regard to information with varying time adjustments, therefore the predictability of market returns was possible to predict.



Table 5. Impulse Responses to the Unit Shock in Thailand's Market

Period	Impulse Responses in														
	Developed Markets					Emerging Markets									
	USA	AUS	HKG	JPN	NZL	SGP	CHN	IDN	IND	KOR	MYS	PAK	PHL	THA	TWN
1	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000	0,02352	0,00240
2	-0,00035	-0,00035	0,00020	-0,00017	-0,00100	-0,00194	-0,00099	0,00153	0,00024	0,00487	0,00099	-0,00044	0,00182	-0,00231	0,00108
3	0,00101	0,00121	0,00070	0,00042	0,00194	0,00075	0,00021	-0,00619	0,00098	-0,00015	0,00237	-0,00187	0,00015	0,00088	0,00055
4	-0,00102	-0,00109	-0,00111	-0,00062	-0,00189	0,00090	-0,00075	0,00394	-0,00113	-0,00362	0,00136	-0,00104	0,00065	0,00086	-0,00189
5	0,00011	0,00079	0,00205	0,00033	0,00118	0,00097	0,00072	-0,00125	0,00041	-0,00163	0,00073	0,00150	0,00139	0,00055	-0,00011
6	0,00008	0,00013	-0,00108	0,00039	-0,00003	0,00030	0,00003	0,00187	0,00009	0,00002	0,00157	0,00007	0,00018	-0,00056	0,00039
7	-0,00008	0,00011	-0,00018	0,00005	0,00025	-0,00028	0,00004	-0,00222	-0,00001	0,00061	-0,00096	0,00041	-0,00006	-0,00034	0,00012
8	0,00029	0,00009	0,00047	-0,00002	0,00015	0,00036	0,00000	-0,00004	0,00003	0,00071	0,00041	0,00000	-0,00051	0,00025	0,00046
9	-0,00008	-0,00021	-0,00030	-0,00011	-0,00013	-0,00042	0,00017	-0,00051	0,00018	0,00051	-0,00026	-0,00006	0,00000	0,00006	-0,00014
10	-0,00006	-0,00007	-0,00012	-0,00002	-0,00012	-0,00005	-0,00001	0,00006	-0,00003	-0,00036	-0,00018	-0,00024	-0,00030	-0,00007	-0,00014

Cholesky Ordering: USA AUS HKG JPN NZL SGP CHN IDN IND KOR MYS PAK PHL THA TWN

Table 6. Impulse Responses to the Unit Shock in the United States' Market

Period	Impulse Responses in														
	Developed Markets					Emerging Markets									
	USA	AUS	HKG	JPN	NZL	SGP	CHN	IDN	IND	KOR	MYS	PAK	PHL	THA	TWN
1	0,01442	0,00819	0,00731	0,00783	0,00494	0,00688	0,00169	0,00526	0,00730	0,00796	0,00328	0,00111	0,00677	0,00401	0,00506
2	-0,00305	-0,00136	0,00049	-0,00052	-0,00030	0,00051	0,00036	0,00133	0,00308	-0,00145	0,00004	0,00193	-0,00128	0,00070	0,00000
3	-0,00043	0,00355	0,00415	0,00058	0,00023	0,00156	0,00137	0,00151	0,00170	0,00230	0,00112	-0,00038	0,00114	0,00094	0,00155
4	0,00089	-0,00076	-0,00046	0,00095	0,00061	-0,00094	0,00150	0,00053	0,00016	-0,00054	0,00050	0,00025	0,00098	0,00074	-0,00019
5	-0,00112	-0,00082	-0,00128	-0,00019	-0,00101	-0,00025	-0,00038	0,00122	-0,00108	0,00171	-0,00026	-0,00060	0,00016	-0,00028	-0,00067
6	-0,00041	-0,00016	0,00013	-0,00018	0,00102	0,00033	0,00148	-0,00039	0,00213	-0,00038	0,00070	0,00109	-0,00016	0,00060	-0,00048
7	0,00087	0,00005	-0,00058	-0,00032	-0,00014	-0,00056	0,00000	-0,00035	-0,00119	-0,00086	-0,00012	-0,00034	0,00057	-0,00013	-0,00008
8	-0,00019	0,00018	0,00011	0,00027	0,00005	-0,00011	0,00013	-0,00021	-0,00054	-0,00007	-0,00015	-0,00014	-0,00046	-0,00021	-0,00003
9	-0,00027	-0,00054	-0,00022	-0,00019	-0,00055	-0,00014	0,00022	-0,00048	0,00007	-0,00015	-0,00007	-0,00055	-0,00002	-0,00018	-0,00011
10	-0,00015	-0,00053	-0,00032	-0,00026	-0,00016	-0,00011	-0,00027	0,00014	-0,00011	-0,00040	0,00002	-0,00013	-0,00046	-0,00013	-0,00030

Cholesky Ordering: USA AUS HKG JPN NZL SGP CHN IDN KOR MYS PAK PHL THA TWN

Most of the previous studies have stated that market integration is time-varying and generally takes several years with occasional reversals (M. E. H. Arouri et al., 2012; Bekaert & Harvey, 1995; Carrieri et al., 2007; Pukthuanthong & Roll, 2009). These findings relate to the market integration in which the more integrated, developed markets are in line with the market relations in bidirectional causality relationships among members during crises periods. In the case of emerging markets, Arouri et al. (2013) studied them in certain regions and suggested that the emerging market regions had become less segmented because liberalization had caused them to have increased exposure to global factors. The increasing integration of the emerging markets is in line with the increasing market relationships in the bidirectional relationship from the Asian financial crisis to the subprime mortgage crisis. Although these two financial crises were global in nature, the origins of the shocks and level of market integration affecting the market relations were different during these crises.

This study provides empirically significant implications for investors, especially in the midst of increasing causality relationships across the market due to the increasing correlation of international assets. This findings suggest that investors should be careful with regard to the increasing of market relations especially the bidirectional causality relationships among markets that lead to the strengthening of the correlation of international assets, causing the benefit of diversification to tend to decline. This argument is well known based on the modern portfolio theory, which relies on the seminal work of Harry Markowitz (1952). From the regulator's perspective, this study provides information on the differences between the relationships among markets that are less and more integrated, so they can possibly enact

appropriate policies to protect their markets in future crises.

This study has limitations in terms of its sample during the crisis periods of the Asian financial crisis and the subprime mortgage crisis; so, we could not analyze more comprehensively the relationships in the markets before and after these crises. The VAR also had several limitations which depend on the theory behind the causality relationships during the crises. Future studies could explore using more samples and deeper theories to support the relationships between markets during crises.

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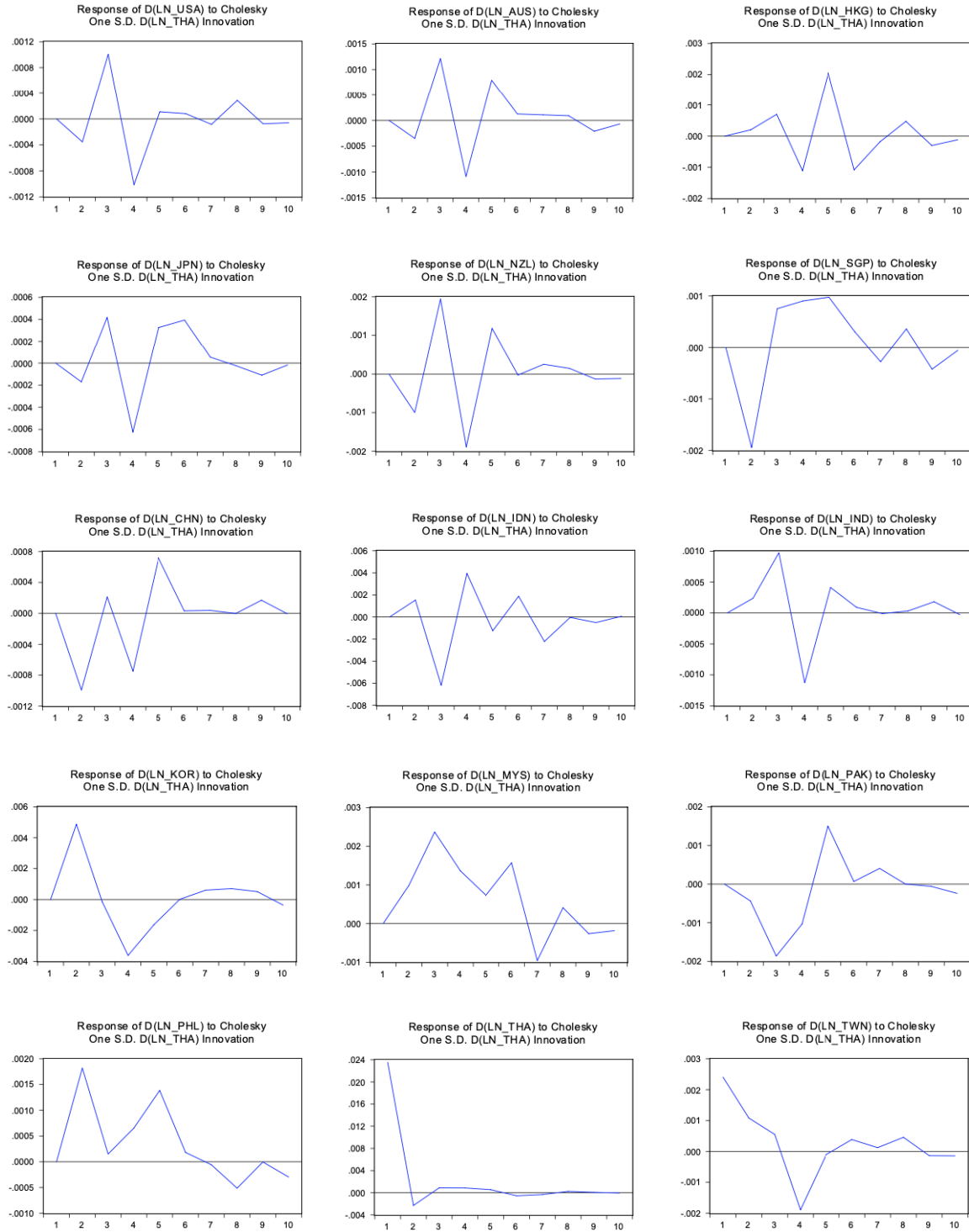
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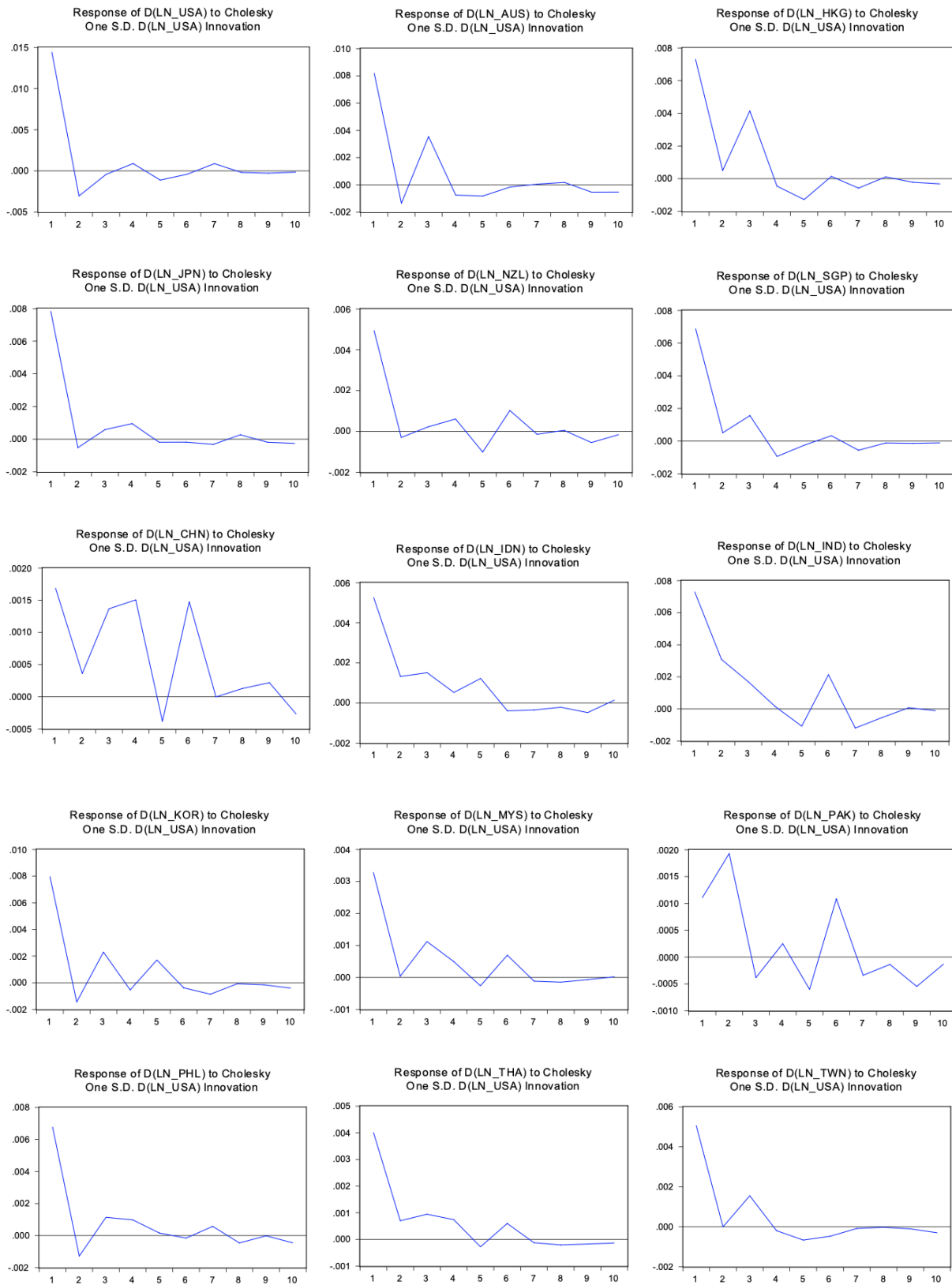
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APPENDICES

Appendix A: Graph of Impulse Responses to the Unit Shock in the Thailand's Equity Market



**Appendix B: Graph of Impulse Responses to the Unit Shock in the United States' Equity Market**



**Appendix C: Preliminary Tests to Determine the Usage of VAR or VECM**

To determine the usage of the vector autoregressive model (VAR) or vector error correction model (VECM), the first step is to ensure the stationarity of the data series using a unit root test. The estimation results of the unit root test are presented in Tables C1 and C2. They show that the null hypothesis of unit root at-level cannot be rejected; but the null hypothesis for the first difference can be rejected. It means that the data series of  $Y_t$  were non-stationary at-level, and stationary in their first difference or  $I(1)$ .

**Table C1.** Summary of Group Unit Root Test during The Asian Financial Crisis

Method	At-Level			First Difference			Cross-sections
	Statistic	Prob.*	Obs	Statistic	Prob.*	Obs	
Null: Unit root (assumes common unit root process)							
Levin, Lin & Chu t	0.68690	0.7539	4885	-94.8962	0.0000	4872	15
Breitung t-stat	1.24703	0.8938	4870	-50.6504	0.0000	4857	15
Null: Unit root (assumes individual unit root process)							
Im, Pesaran and Shin W-stat	1.78491	0.9629	4885	-66.9002	0.0000	4872	15
ADF - Fisher Chi-square	14.2862	0.9932	4885	2044.36	0.0000	4872	15
PP - Fisher Chi-square	13.7082	0.9952	4890	2214.22	0.0000	4875	15

Note: \* Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

**Table C2.** Summary of Group Unit Root Test during the Subprime Mortgage Crisis

Method	At-Level			First Difference			Cross-sections
	Statistic	Prob.*	Obs	Statistic	Prob.*	Obs	
Null: Unit root (assumes common unit root process)							
Levin, Lin & Chu t	3.17118	0.9992	7477	-134.363	0.0000	7466	15
Breitung t-stat	3.00160	0.9987	7462	-66.091	0.0000	7451	15
Null: Unit root (assumes individual unit root process)							
Im, Pesaran and Shin W-stat	4.82165	1.0000	7477	-87.0211	0.0000	7466	15
ADF - Fisher Chi-square	4.14965	1.0000	7477	3006.85	0.0000	7466	15
PP - Fisher Chi-square	5.16231	1.0000	7485	3234.50	0.0000	7470	15

Note: \* Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

The second step is to test the long-run relationship or an equilibrium relationship among the markets using the Johansen's cointegration test that develops multivariate approach for testing cointegration among non-stationary data series. The estimation results of this test are presented in Tables C3 and C4.



**Table C3.** Estimation Results of Johansen's Cointegration Test during the Asian Financial Crisis

Hypothesized No. of CE(s)	Eigen-value	Unrestricted Cointegration Rank Test (Trace)			Unrestricted Cointegration Rank Test (Maximum Eigenvalue)		
		Trace Statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.267581	545.4292	NA	NA	101.2056	NA	NA
At most 1	0.240300	444.2236	NA	NA	89.32011	NA	NA
At most 2	0.172682	354.9035	NA	NA	61.60884	NA	NA
At most 3	0.151535	293.2947	348.9784	0.8023	53.40611	77.38180	0.9202
At most 4	0.131152	239.8886	298.1594	0.8888	45.69072	71.33542	0.9678
At most 5	0.121131	194.1978	251.2650	0.9258	41.96377	65.30016	0.9441
At most 6	0.098314	152.2341	208.4374	0.9602	33.63391	59.24000	0.9878
At most 7	0.088755	118.6002	169.5991	0.9648	30.20671	53.18784	0.9733
At most 8	0.071974	88.39345	134.6780	0.9732	24.27620	47.07897	0.9856
At most 9	0.059749	64.11725	103.8473	0.9709	20.02281	40.95680	0.9811
At most 10	0.044710	44.09444	76.97277	0.9642	14.86558	34.80587	0.9880
At most 11	0.028972	29.22886	54.07904	0.9289	9.555055	28.58808	0.9960
At most 12	0.025551	19.67381	35.19275	0.7469	8.411905	22.29962	0.9351
At most 13	0.021071	11.26190	20.26184	0.5171	6.921401	15.89210	0.6791
At most 14	0.013267	4.340500	9.164546	0.3638	4.340500	9.164546	0.3638

Note: \*\* MacKinnon-Haug-Michelis (1999) p-values. Trend assumption: No deterministic trend (restricted constant). Lags interval (in first differences): 1 to 1 based on the Akaike information criterion.

**Table C4.** Estimation Results of Johansen's Cointegration Test during the Subprime Mortgage Crisis

Hypothesized No. of CE(s)	Eigen-value	Unrestricted Cointegration Rank Test (Trace)			Unrestricted Cointegration Rank Test (Maximum Eigenvalue)		
		Trace Statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.157578	549.9680	NA	NA	85.22253	NA	NA
At most 1	0.140445	464.7455	NA	NA	75.21604	NA	NA
At most 2	0.131604	389.5294	NA	NA	70.13028	NA	NA
At most 3	0.107304	319.3991	348.9784	0.3576	56.41392	77.38180	0.8238
At most 4	0.095903	262.9852	298.1594	0.5085	50.10671	71.33542	0.8609
At most 5	0.087322	212.8785	251.2650	0.6408	45.41170	65.30016	0.8375
At most 6	0.072356	167.4668	208.4374	0.7700	37.32812	59.24000	0.9329
At most 7	0.061689	130.1387	169.5991	0.8239	31.64606	53.18784	0.9479
At most 8	0.053680	98.49264	134.6780	0.8499	27.42153	47.07897	0.9276
At most 9	0.038616	71.07110	103.8473	0.8772	19.57279	40.95680	0.9861
At most 10	0.033113	51.49831	76.97277	0.8090	16.73591	34.80587	0.9564
At most 11	0.029443	34.76240	54.07904	0.7339	14.85296	28.58808	0.8266
At most 12	0.025551	19.67381	35.19275	0.7469	8.411905	22.29962	0.9351
At most 13	0.021071	11.26190	20.26184	0.5171	6.921401	15.89210	0.6791
At most 14	0.013267	4.340500	9.164546	0.3638	4.340500	9.164546	0.3638

Note: \*\* MacKinnon-Haug-Michelis (1999) p-values. Trend assumption: No deterministic trend (restricted constant). Lags interval (in first differences): 1 to 2 based on the Akaike information criterion.

Tables C3 and C4 show that there are no cointegrations for both during the Asian financial crisis and the subprime mortgage crisis. We determine to use the VAR because the data series are  $I(1)$  and no long-run relationship. Hence, we require the stationarity of data series using first difference of  $Y_t$ , which mean the returns.

**Appendix D: VAR Lag Order Selection Criteria****Table D1.** Estimation Results of VAR Lag Order Selection Criteria during the Asian Financial Crisis

Lag	LogL	LR	FPE	AIC	SC	HQ
0	11567.40	NA	9.09e-51*	-72.65661*	-72.47915*	-72.58573*
1	11786.46	416.0812	9.45e-51	-72.61927	-69.77998	-71.48524
2	11952.10	298.9820	1.38e-50	-72.24592	-66.74481	-70.04874
3	12128.39	301.5672*	1.92e-50	-71.93953	-63.77659	-68.6792
4	12272.65	233.1904	3.33e-50	-71.43179	-60.60702	-67.10831
5	12441.90	257.5928	5.06e-50	-71.08113	-57.59453	-65.6945
6	12589.57	210.8268	9.14e-50	-70.59479	-54.44636	-64.145
7	12768.03	237.9425	1.42e-49	-70.30207	-51.49181	-62.78913
8	12956.90	234.0054	2.20e-49	-70.07482	-48.60273	-61.49873

Note: \* indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

**Table D2.** Estimation Results of VAR Lag Order Selection Criteria during the Subprime Mortgage Crisis

Lag	LogL	LR	FPE	AIC	SC	HQ
0	19751.16	NA	3.97e-54	-80.3917	-80.26350*	-80.34135
1	20241.65	949.0083	1.35e-54*	-81.47311*	-79.4219	-80.66760*
2	20455.36	400.4381	1.41e-54	-81.42713	-77.45291	-79.86645
3	20588.31	240.9873	2.07e-54	-81.05218	-75.15494	-78.73632
4	20714.58	221.1722	3.13e-54	-80.65004	-72.82978	-77.57901
5	20877.47	275.3543*	4.10e-54	-80.39705	-70.65377	-76.57085
6	21027.82	244.9690	5.72e-54	-80.09297	-68.42669	-75.5116
7	21174.87	230.6047	8.16e-54	-79.77545	-66.18615	-74.43891
8	21347.43	260.0696	1.06e-53	-79.56184	-64.04953	-73.47013

Note: \* indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion