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INTEGRATION OF THE MAJOR EQUITY MARKETS IN EAST ASIA AROUND THE RECENT GLOBAL FINANCIAL CRISIS

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ABSTRACT

This study investigates the integration of the stock markets in the US, Japan, Hong Kong and Mainland China before, during and after the subprime crisis. The data included cover the time period from January 2004 to October 2013. Both the data in local currency and the data in the common currency of US dollar are analyzed in the study.

In this thesis, Johansen cointegration test, Granger causality test, the method of variance decomposition, and the newly proposed spillover indexes of Diebold and Yilmaz (2012) are utilized to study the cross-market connections of the four stock markets. The cointegration tests indicate that the financial crisis has temporarily strengthened the long-term linkages of the stock markets. The Granger causality tests show that the impact of the Asian stock markets on the US market during the crisis is larger than that of the pre-crisis period. The variance decomposition suggests that the interdependences of the selected stock markets are stronger during the crisis period and the increased inter-linkages of the markets do not sustain after the crisis. The spillover indexes further confirm that more intense cross-market spillovers occurred during the crisis period.

KEYWORDS: Stock market integration, Financial crisis, Variance decomposition, Spillover index.

1. INTRODUCTION

The ever-increasing real economic linkages and the gradual elimination of capital market restrictions across countries may have contributed to the integration of the international stock markets. Defined as the equalization of risk-adjusted expected returns in different stock markets, the notion of stock market integration became significant during the 1980s but the majority of the research on this topic has been conducted in recent years (Sharma and Seth 2012). One particular category of previous research concentrates on the effect of economic shocks, such as stock market crashes or financial crises, on the integration or connection of international stock markets (see e.g., Forbes and Rigobon 2002).

The purpose of this thesis is to investigate the degree of integration of four stock markets in East Asia before, during and after the 2008–2009 global financial crisis. The stock markets included are Shanghai stock market in Mainland China, Hong Kong stock market, Japanese stock market and US stock market. Four stock indexes representing each of those four stock markets will be used to study the interdependence among them. The index data both in the local currency and in the common currency of US dollar are analyzed. US, Mainland China and Japan are selected in the study because they are the three largest economies in the world; in addition to the fact that US is the country where the financial crisis started, it is undeniable that US economy has the greatest influence on the world economy and previous studies also indicate that US capital market has huge impact on other capital markets in the world. As a financial center in Asia and a special administrative region of China, Hong Kong is closely connected to Mainland China and US; therefore, equity market in Hong Kong is also included in the study.

Moreover, due to the dominant role of the US stock market, it is commonly considered to be the global factor in the international stock markets, and the Japanese and Hong Kong stock markets are widely accepted as the regional factors in the Asian stock markets. Hence, the current investigation of the stock markets in Mainland China, Hong Kong, Japan and US can also be treated as an examination of how the stock market in Mainland China is affected by the regional and global factors.

The study is important in threefold. Firstly, the economic implication of the existence of cointegration among some stock markets is that those markets have long-term equilibrium relationship and cannot drift far from this relationship and thus the effect of investment diversification into those stock markets would be limited. Therefore, knowing the cointegration relationship would guide the international investment strategy and gauge the potential benefit from such a strategy. Secondly, for the government policymakers, understanding the interconnections among the stock markets would help determine the policy impacts of one country or region on the other countries or regions. Thirdly, though extensive research has been conducted on the subject of international stock market integration, few studies have examined the characteristics of integration of the selected stock markets for the period after 2009. Given the consensus that equity market correlation and causality relationship is time-varying, such a study may shed light on the stock market linkages during different economic situations.

The study also has some possible contributions. First, both the data measured in local currency and the data denominated in a common currency of US dollar are employed in this thesis. Second, the study includes the newly proposed spillover indexes of Diebold and Yilmaz (2012) to examine the return transmissions across different stock markets. Third, although most of the previous literature suggests that financial crises enhance the stock market linkages, there still exists the question of whether a financial crisis permanently or temporarily changes the level of equity market integration (cf. Yang, Kolari and Min 2003 and Huyghebaert and Wang 2010). The current study on stock market integration around the subprime crisis may add some new evidence on this issue.

Regarding the impact of the recent global financial crisis on the correlations of the four equity markets included in the study, one general expectation is that the financial crisis may have increased the connections of the stock markets. Thus, the following hypothesis will be tested in the thesis:

H0: the subprime crisis did not strengthen the integration of the selected stock markets.
H1: the subprime crisis strengthened the integration of the selected stock markets.

The remainder of the study is structured as follows. Chapter 2 reviews some related literature. Chapter 3 presents the theoretical background. Chapter 4 describes the data. Chapter 5 provides the methods of the study. Chapter 6 reports the empirical results and Chapter 7 concludes the thesis.

2. LITERATURE REVIEW

To facilitate the review of the extensive research on this topic, previous literature will be divided into three categories: studies on equity markets of different regions, studies on emerging and developed equity markets and studies on the effects of financial crisis; the division may not be absolute and some of the studies could belong to more than one category.

2.1. Previous studies on equity markets of different regions

One group of previous research investigates the integration of the stock markets in Europe and U.S.. Fraser and Oyefeso (2005) analyze the integration of U.S., UK and European stock markets. Their study shows that there are eight cointegration vectors among the nine stock markets included in their analysis and hence a single common trend exists among those markets. Masood, Bellalah, Chaudhary, Mansour and Teulon (2010) study the cointegration relationship of three Baltic stock markets during the financial Tsunami. Their study indicates two cointegrating or long-term relationships among Baltic bench, Riga and Tallinn indices. More recently, Kenourgios and Samitas (2011) assess the integration among five Balkan emerging and four developed stock markets by the methods of cointegration tests and asymmetric generalized dynamic conditional correlation. They find that there is one cointegration relationship among the equity markets of those nine countries during the period 2000–2009. Investigating the equity market cointegration and causality among six major Balkan countries, Germany and U.S., Syriopoulos (2011) finds that equilibrium relationship exists between the Balkan and mature equity markets.

One category of previous research examines the connections of equity markets in one continent or around the world. For example, Chen, Firth and Rui (2002) document the equity market linkages among six Latin American countries during a period from 1995 to 2000. Their findings demonstrate that there may exist one long-run equilibrium relationship among those markets before 1999 but no evidence of such relationship is found after 1999. Aggarwal and Kyaw (2005) investigate the integration of the equity markets in U.S., Canada and Mexico before and after the adoption of NAFTA in 1993. Using data of different frequencies (daily, weekly and monthly), they report that integration and correlation among the three markets are stronger during the period after NAFTA was passed.

Another stream of previous studies focus on the linkages, cointegration or causality properties of the equity markets in Asia or among Asian and other developed countries. Huang, Yang and Hu (2000) assess the causality and cointegration among U.S., Mainland China, Hong Kong, Taiwan and Japan during the period from October 1 1992 to June 30 1997. Taking into account possible regime shifts, they find that cointegration and feedback exist between Shanghai and Shenzhen markets and that U.S. market Granger causes Hong Kong and Taiwan stock markets. Siklos and Ng (2001) examine the connection of equity markets in five Asia-Pacific regions, U.S. and Japan. Their findings support that those markets tend to be connected only after the occurrence of such shocks as the market crash in 1987 or the 1990 Gulf War. Their study also reveals that there exists one common trend among the seven markets investigated.

Zhu, Lu, Wang and Soofi (2004) study the cointegrating and causal relationship between Mainland China and Hong Kong stock markets from 1993 to 2001. They find that no long-term relationship exists between the two markets and there is one direction Granger causality between Shenzhen and Shanghai before 1994. After analyzing the linkages among the equity markets in Greater China Economic Area, U.S. and Japan, Cheng and Glascock (2005) conclude that there is no evidence of cointegration among those markets from January 1993 to August 2004. Yu, Fung and Tam (2010) apply six methods of measuring stock market integration to 10 equity markets in Asia. They find that cointegration among those equity markets is not strong and the integration process gained speed in 2007–2008 compared to the period from 2002 to 2006. Gupta and Guidi (2012) explore the equity market cointegration and comovement in India, Hong Kong, Singapore, U.S. and Japan. They find no supporting evidence of cointegration among those five stock markets and the correlations between the stock markets are higher during periods of crises, such as September 11 2001.

2.2. Previous studies on emerging and developed equity markets

Regarding the studies on emerging markets, Phylaktis and Ravazzolo (2005), for example, analyze the linkages between six emerging stock markets in Pacific-Basin, Japan and U.S. during the period from 1980 to 1998. Their study suggests that the included equity markets are not connected together during the two decades and the stock market in Japan shows larger influence on the Pacific Rim than the U.S. market. They also find that the Asian crisis may have limited effect on the integration of the stock markets under investigation. The study by Maneschiöld (2006) indicates that

Baltic equity markets are lowly integrated with the international equity markets. Examining a sample of 25 emerging stock markets, Chambet and Gibson (2008) find high level of segmentation among those markets. Cheng, Jahan-Parvar and Rothman (2010) consider the interdependence of the stock markets in the Middle East and North Africa. Their study suggests that the majority of those markets are segmented.

Some studies have also concentrated on the developed stock markets. For instance, Eun and Shim (1989) explore the transmission mechanism of the equity markets in nine major developed regions. They conclude that the interactions among these national stock indexes are significant. Bessler and Yang (2003) focus on the integration of nine developed stock markets. They detect the existence of one cointegrating relationship among those markets and the strong long-term influence of the U.S. stock markets on the other markets. D'ecclesia and Costantini (2006) examine the common trends and cycles among the stock markets in Japan, U.K., U.S. and Canada from 1978 to 2002. Their study suggests that a long-term equilibrium relationship exists among those stock markets. Pukthuanthong and Roll (2009) use an alternative method (adjusted R-square) to measure the global equity market integration. Their study shows that the integration level is lower for those countries that have more recent appearance in DataStream than those that have longer data availability in the database. The latter group of countries can be interpreted as the more developed countries and the former group is the less developed countries. Therefore, their study also suggests that the developed countries are more integrated.

Thus the overall result of previous studies on emerging and developed equity markets is that the developed markets tend to be more integrated than the emerging markets.

2.3. Previous studies on the effects of financial crisis

There is also another line of previous research that examines the effects of financial crisis on stock market interdependence. Sheng and Tu (2000) study the cointegration and causality relationship of 12 Asia-Pacific stock markets before and during the Asian financial crisis. They find no cointegration vectors among the stock markets in a group of nine Asian countries before the crisis but one cointegration relationship during the crisis, suggesting stronger integration of those stock markets during the crisis. They also report that there is no long-term equilibrium relationship among the stock markets of the North-East Asian countries and that the U.S. stock market has predicting power for some of the Asian equity markets. Developing a correlation measure that corrects for the effect of market volatility, Forbes and Rigobon (2002) find no significant increase in the stock market correlations during the 1987 U.S. stock market crash, 1994 Mexican devaluation and 1997 Asian crisis, according to which they conclude that no contagion exists. Instead, they find that the correlations are high for some markets in all periods (crisis and non-crisis periods), which they define as interdependence. However, the study by Chiang, Jeon and Li (2007) indicates that the correlations of the stock market returns increased during the Asian financial crisis. In addition, their study also demonstrates that in comparison to the period before the crisis, stock market correlations after the crisis are not statistically different, except for the correlation of Thailand and Korea and that of Thailand and Hong Kong.

Yang et al. (2003), investigating the integration and linkage of 11 Asian and U.S. stock markets around the Asian financial crisis, find that the interdependence of those stock markets becomes stronger during the crisis and the strengthened linkages sustain after the crisis.

Comparing the interconnections among the stock markets in five European countries and U.S. before and after the 1998 Russian financial crisis, Yang, Hsiao, Li and Wang (2006) find that the connections among those markets are stronger after the crisis. Cheung, Fung and Tsai (2010) examine the linkages and credit risk spillover effect among the global equity markets before and during the 2007–2009 financial crisis. The general conclusion of their study is that inter-linkages among the equity markets are stronger during the crisis and the effect of a shock from the U.S. stock market or from TED (a measure of credit risk) on the other stock markets is larger during the crisis.

Huyghebaert and Wang (2010) explore the interrelationships of seven East Asian stock markets and S&P500 around the Asian financial crisis. In line with Sheng and Tu (2000), their study reveals that no cointegration exists among the stock markets in the East Asian regions before the crisis but those markets show behavior of cointegration during the crisis. However, they also report that the nature of cointegration tends to be temporary–cointegration disappears after the crisis. They also find that U.S. stock market has great impact on the Asian markets in all periods except for the stock markets in Mainland China.

Nikkinen, Piljak and Äijö (2012) test for the dynamics of inter-linkages among the developed European stock markets and the stock markets in three Baltic countries for a time period that covers the 2008–2009 financial crisis. Their study shows that although the Baltic stock markets are loosely connected before the crisis, the financial crisis has significantly enhanced the connections and increased the influence of the developed European stock markets on the Baltic stock markets.

In general, while most of the previous studies suggest that financial crises increase the stock market linkages, there are no unanimous conclusions concerning the level of the equity market interdependence after a financial crisis in comparison with the degree of integration before the crisis.

3. THEORETICAL BACKGROUND

This chapter introduces some theoretical background related to the study. Since this thesis studies the integration of the international stock markets, the definition of integration and cointegration and the intrinsic value of stocks would be described first. Other theories, including portfolio diversification, equity market integration and financial contagion, will also be presented.

3.1. Statistical definition of integration and cointegration of financial time series

Many financial time series data show the property of stationarity. For example, short term and long term interest rates of government bonds tend to move together and never drift too much away from each other; this makes the difference between long term and short term interest rates wander around an average level, which indicates that the difference series is stationary. Stationarity here refers to covariance/weak stationarity, the definition of which is shown below. For a time series x_t (t=1,2,...,T), it is covariance stationary if it satisfies

(i) $E(x_t)=\mu$, where μ is a constant independent of t (t=1,2,...,T);

(ii) $var(x_t)=\sigma^2$, where σ^2 is a constant independent of t (t=1,2,...,T);

(iii) $cov(x_t, x_{t-k})=\gamma_k$, where k is a constant and γ_k is a function of k and is independent of t (t=1,2,...,T).

Engle and Granger (1987) define integration and cointegration in the following way. For a vector $\mathbf{x}_t = (x_{1t}, x_{2t} \ldots, x_{mt})'$, if each component series of $\mathbf{x}_t$ becomes stationary only after differencing *d* times, $\mathbf{x}_t$ is then called integrated with order *d*, denoted as *I(d)*; each component of $\mathbf{x}_t$ is also *I(d)*. If there exists a non-zero constant vector β such that $\beta'\mathbf{x}_t$ is *I*(*d*-*b*), the components of $\mathbf{x}_t$ are then cointegrated with order *d*,*b* (*b*>0), denoted as *CI(d,b)*; β is called the cointegration vector.

This definition can be illustrated by an example of the walks of a drunk and his dog. Both the drunk and his dog walk randomly or their individual walk is *I*(1). But their difference is always confined to be around a constant level and they never move too far away from each other; then this difference must be stationary or *I*(0). Hence the walks of the drunk and his dog are cointegrated, with order (1,1) or *CI*(1,1) and cointegration vector $(1,-1)'$. (Murray1994.)

3.2. Intrinsic value of stocks

The intrinsic value of a stock is the discounted value of all cash flows available to the owner of the stock. One way to estimate the intrinsic value is to use the dividend discount model:

(1) $$V_0 = \sum_{i=1}^{\infty} \frac{D_i}{(1+k)^i} ,$$

where V_0 is the intrinsic value, D_i is the expected dividend at time *i* and *k* is the risk-adjusted interest rate. In practice, it is commonly assumed that dividend grows at a constant rate; then the model, also referred to as the Gordon model, becomes $V_0 = \frac{D_0(1+g)}{k-g} = \frac{D_1}{k-g}$, where D_0 is the recent dividend and g is the dividend growth rate. (Bodie, Kane and Marcus 2009: 589–592.)

An extension of the constant-growth model is the two-stage (the first stage starts from 1 to *T*) dividend discount model: $V_0 = \frac{D_0(1+g_1)}{k-g_1}\left[1-(\frac{1+g_1}{1+k})^T\right] + \frac{D_0(1+g_1)^T(1+g_2)}{(k-g_2)(1+k)^T}$, with g_1 and g_2 being the dividend growth rate of the first and the second stage respectively.

3.3. Portfolio diversification

Markowitz (1952) presents the "expected returns–variance of returns" rule, which suggests that investors should favor portfolios with higher expected return and lower variance of return. In addition, he points out that a set of portfolios with efficient combination of expected return and variance of return, or the efficient frontier, can be constructed; investors can then choose the best portfolio from this set based on his or her preference. Since the original work of Markowitz, extensive research has been done on the subject of portfolio analysis, such as the extension of the model to multi-period and continuous time case, the development of single and multi-index models and the exploration of separation theorems and portfolio evaluation measures (Elton and Gruber 1997).

If returns for a group of assets are not perfectly correlated, investors can reduce the risk by diversifying the investments into those assets. For example, suppose an investor can invest in two assets: A and B. Since the correlation of the returns is not +1, during market downturns return from one asset, to some extent, offsets the return from the other, leading to a more stabilized overall return of the two assets. The following graph shows the possible expected return-standard deviation combinations obtainable from the two assets under three different assumptions of return correlation between A and B.

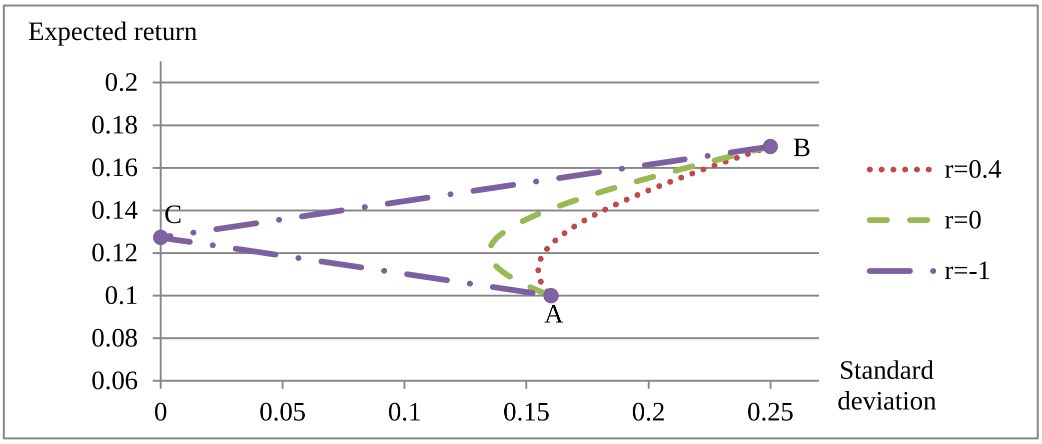

Figure 1. Possible combinations of expected return and standard deviation formed with assets A and B. (Source: Bodie et al. 2009: 201–203).

It can be noted from the graph that for a given level of risk, which is measured by standard deviation, a more desirable expected return can be obtained by buying both assets A and B in comparison to a single investment in A or B. One specific combination is point C, which gives higher expected return than A but has a standard deviation of zero. The graph also demonstrates that the smaller the correlation between A and B, the larger the benefit of diversification.

The gain of diversification is even larger when we extend our investments to the international capital markets where the asset returns are less correlated. The effect of diversifying globally can be illustrated by the figure below, which allows portfolio diversification among seven developed countries. As the capital allocation line has larger slope or Sharpe-ratio than any of the individual market, investors can achieve better risk-return combination by investing in foreign assets. It is worthwhile to point out that the figure only shows the potential gain by diversifying across the developed countries. Because the developing markets are less integrated with the international market, which is suggested by previous research shown in section 2.2, the benefits may be larger if the developing markets are also deemed to be part of the investment set.

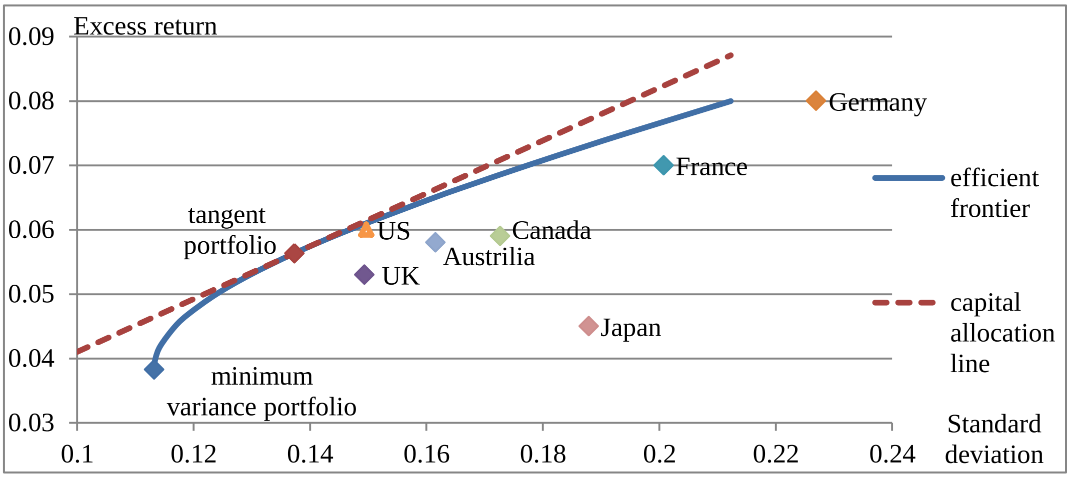

Figure 2. International portfolio diversification. (Source: Bodie et al. 2009: 231–236).

It is usually desirable to diversify the investments internationally even when the expected return of the foreign securities is lower than the expected return of the domestic securities. To make the international diversification profitable, the following condition needs to be satisfied for the expected return of the foreign securities:

$$(2)\bar{R}_F - R_f > (\bar{R}_D - R_f)(\frac{\sigma_F}{\sigma_D}\rho),$$

where $\overline{R}_F$ is the expected return of the foreign securities denominated in the domestic currency and σ_F is the corresponding standard deviation of the return. $\overline{R}_D, \sigma_D, R_f$ and ρ are respectively the expected return and standard deviation of the domestic securities, the risk-free rate and the return correlation coefficient between the foreign and domestic securities. Given the other five parameters, the minimum value required for the expected return of foreign securities can be derived. As ρ is usually much less than one and the standard deviations of the foreign and domestic securities are comparable, the term in the second parenthesis is generally less than one and thus the minimum value required for $\overline{R}_F$ is usually less than $\overline{R}_D$.(Elton, Gruber, Brown and Goetzmann 2011: 219–222.)

Numerous empirical studies on international diversification have been conducted. Grubel (1968) is the first to consider portfolio diversification in the international financial markets. He demonstrates the potential benefits of diversifying internationally. The study by Solnik (1995) shows that the risk level of the international portfolio could be 50% lower than that of the portfolio consisting of only the U.S. stocks. Both of the above studies approach the international diversification from the perspective of an American investor. The analysis by Driessen and Laeven (2007) explores the international diversification from the standpoint of a local investor. They find that investors can benefit from global diversification especially for those in the developing countries. Despite the evidence of substantial gains from international diversification, it should be noted that the development of information technology and the general trend of globalization may have decreased the potential benefits from investing abroad.

3.4. Equity market integration

According to Kearney and Lucey (2004), "*there are three basic approaches to defining the extent to which international financial markets are integrated. These fall into two broad categories–direct and indirect measures*".

3.4.1. Measures of equity market integration

In general, there is no commonly accepted method for measuring equity market integration (Pukthuanthong and Roll 2009). The survey conducted by Kearney and Lucey (2004) suggests that previous research has adopted three methods to assess equity market integration: by international CAPM, by examining the correlation or cointegration relationship of the stock markets or by using time-varying measures of integration.

One representative study that attempts to investigate the international stock market integration by international CAPM is the work of Bekaert and Harvey (1995). They notice that previous studies assume that equity markets are either fully segmented or fully integrated or partially segmented with the level of segmentation being constant through time. With the assumption that the market is perfectly segmented, expected return depends on the variance of the local market return; when the equity market is assumed to be completely integrated, expected return is determined by the covariance with the world market return; when the segmentation is assumed to be partial and constant over time, expected return of the market portfolio of ineligible equities

(equities that are ineligible to the restricted investors) is priced by the covariance with the world market return and the variance of the market portfolio (Errunza and Losq 1985). These three assumptions may not be realistic. To overcome this problem, Bekaert and Harvey (1995) propose a regime-switching model that allows the equity market segmentation to be partial and time-varying. By estimating the conditional likelihood of integration of a local equity market with the world capital market, they derive the evolving nature of integration.

In search of an alternative measure of market integration, Pukthuanthong and Roll (2009) support the use of the adjusted R-square from a multiple global factors model. The more recent research by Cheng et al. (2010) follows the same methodology of documenting equity market integration by international CAPM. They employed two methods. The first method is the static international CAPM model; whether an equity market is integrated with the world capital market is determined by examining the statistical significance of the estimated parameter for the world market return. Their second method is similar to the one used by Bekaert and Harvey (1995).

The second strand of research approaches the issue of equity market integration by analyzing the correlation or cointegration of the stock markets. For instance, Longin and Solnik (1995) examine the correlation coefficients of international equity market returns by multivariate GARCH model. In order to determine the constancy of the correlation coefficients, they test if the correlations are related to time, market volatility and some information variables. Other studies that use correlation analysis include Forbes and Rigobon (2002) and Chiang et al. (2007). On the other hand, some of the studies by cointegration analysis are also mentioned in the second chapter of this thesis (e.g., Sheng and Tu 2000, Chen et al. 2002, Huyghebaert and Wang 2010 and Gupta and Guidi 2012). It is also worth noting that some previous literature has suggested that simple correlation coefficient of the returns is not a good measure of integration due to the fact that it is biased when the volatility of the market return changes (Forbes and Rigobon 2002) and that it "can be small even when two countries are perfectly integrated" (Pukthuanthong and Roll 2009).

Just as pointed out by Kearney and Lucey (2004), the aforementioned two types of studies fail to take into account time variation in equity risk premium. The third category of studies addresses this issue by using time-varying measures of integration. Such studies include Fratzscher (2002) and Lucey and Aggarwal (2010).

3.4.2. Determinants and implications of equity market integration

Extensive studies on the factors that contribute to the equity market integration have been conducted. A variety of factors have been documented by previous empirical research, including economic, financial, geographical and cultural variables. Bekaert and Harvey (2000) show that emerging capital market liberalization could increase the equity market correlations. The research by Longin and Solnik (2001) indicates that equity market correlations increase in bearish markets. Flavin, Hurley and Rousseau (2002) discuss the influence of geographical variables on stock market correlation. They find that such geographical variables as the number of overlapping trading hours and sharing a common border can affect the market correlations. Johnson and Soenen (2003) study the stock market integration of eight American countries with United States. They conclude that higher share of trade with the U.S., lower bilateral exchange rate volatility and lower ratio of the U.S. stock market capitalization to the capitalization in the local country enhance market comovement. Bekaert, Harvey, Lundblad and Siegel (2007) argue that financial openness is also a contributing factor of market integration.

Trade openness and structure are also two important determinants as suggested by Chambet and Gibson (2008); countries with higher trade openness and lower trade diversification are more integrated. Quinn and Voth (2008) report that in comparison to economic fundamentals, capital account openness is a more important cause of global equity market correlations. More recently, Shi, Bilson, Powell and Wigg (2010) find that higher bilateral foreign direct investment could also lead to higher equity market integration. The study by Lucey and Zhang (2010) indicates that cultural distance can affect the stock market linkages; the smaller the cultural difference, the higher the linkages between two countries. Büttner and Hayo (2011) investigate the determinants of European equity market correlation and find that exchange risk, interest rate spreads, business cycles and market capitalization all have significant impact on the market integration.

Regarding the implications of equity market integration, the strengthening of stock market integration has three general consequences: decreasing the benefits of international portfolio diversification, enhancing the robustness of the individual economies and destabilizing the household savings rates. The first two implications could lead to higher economic growth while the effect of the last is undetermined. (Lucey and Aggarwal 2010.)

3.5. Financial contagion

There is no universal definition of contagion and the literature has proposed alternative definitions. The broad definition of contagion refers to the transmission of shocks from one country to another; this could happen during both stable and crisis periods. A more restrictive definition describes contagion as the transmission of shocks that cannot be explained by “fundamental link among the countries and common shocks”. Another more narrow meaning of contagion is defined as the stronger cross-country correlations during crisis period or after a shock. (World Bank 2013.)

Other definitions of contagion are presented by Pericoli and Sbracia (2003). They also define it as contagion if any of the following happens after the occurrence of a crisis in one country: 1) the likelihood of crisis in another country is significantly higher; 2) the high volatility of the asset prices spreads to other countries; 3) the transmission channel is strengthened (or weakened).

To account for the mechanisms of contagion, two types of effect, information effect and domino effect, have been discussed (Moser 2003). Due to information imperfections, market participants are unaware of the true status of an economy and thus tend to reevaluate it and take such actions as calling in loans after a crisis occurred in another country, even though the true condition of the economy has not changed. The other explanation – domino effect – is based on the observation that different economies are financially linked to each other, directly or indirectly. There are three scenarios: counterparty defaults, portfolio rebalancing due to liquidity constraints and portfolio rebalancing due to capital constraints. Counterparty defaults in one country could cause waves of counterparty defaults in other countries because of the cross-border debt holdings, spreading the crisis from one country to other countries. When investors incurred loss resulting from crisis in one market, they then have to sell the investment positions in other markets to increase liquidity. Besides liquidity requirement, they may also be constrained by the capital requirement, leading to decreased lending in the case of banks in other markets. (Moser 2003.)

In addition to the difficulty associated with the definition of contagion and the different explanations of the contagion mechanisms, previous studies examining the contagion effect during "crisis" times are inconclusive. For instance, according to World Bank's narrow definition of contagion, the examination by Forbes and Rigobon (2002) indicates no contagion during the 1997 Asian crisis. In contrast, Corsetti, Pericoli and Sbracia (2005), applying a single-factor model, confirm the occurrence of some contagion effect from the stock market in Hong Kong to five stock markets in Asia and Europe. Moreover, Chiang et al. (2007) adopt a dynamic conditional correlation model; they conclude that contagion exists during the 1997 Asian crisis.

3.6. Financial crisis transmission mechanisms

Using firm level data to study the transmission of East Asian and Russian crises, Forbes (2004) outlines five crisis transmission channels. *i*) The first channel is called product competitiveness; when the currency value of one country depreciates, the nominal price of its exported product would be relatively lower, affecting the price competitiveness of the products from other countries in the international markets. *ii*) The second transmission channel is referred to as the income effect; income effect occurs when the product demand in one country declines as a result of a crisis or shock, which leads to less export of other regions to this country. *iii*) The third channel through which crisis can be transmitted is the credit crunch; crisis in one country could significantly reduce the supply of credit in the international capital market and increase the financing cost of companies in other countries. *iv*) The fourth channel, forced-portfolio re-composition, describes the same mechanism as the one mentioned above: portfolio rebalancing due to liquidity constraints and portfolio rebalancing due to capital constraints. *v*) The fifth mechanism is the wake-up call effect, which is similar to information effect pointed out in the previous section. (Forbes 2004.)

The overall conclusion of Forbes (2004) is that trade channels (product competitiveness and income effect) were essential crisis transmission mechanisms and forced-portfolio re-composition effect also played a role in the transmission of those two crises, while the effect of credit crunch was less apparent. Rijckeghem and Weder (2001) compare trade channels with credit crunch/common lender effect, which is the effect when banks (common lenders) in a third country suffer large loss in the crisis country and thus have less funds available to the other countries, threatening the economic prospect of those countries. In contrast to Forbes (2004), they find that common lender/credit crunch effect may be a more important crisis transmission channel than trade linkages during the Mexican, Asian and Russian crises.

As for the studies relating to the 2007–2009 global financial crisis, Dooley and Hutchison (2009) suggest that emerging markets were, to some extent, unaffected by the U.S. subprime crisis from February 2007 to May 2008 (a decoupling process) but reacted strongly to the crisis after the “Lehman Day” (a recoupling process). Chudik and Fratzscher (2011) examine the role of two crisis spreading mechanisms: shocks to liquidity and “flight to safety”. Their study highlights that developed economies were mainly affected by the liquidity shocks while emerging economies were mostly influenced by the decline in risk appetite.

Cetorelli and Goldberg (2011) investigate how shocks to the loan supply of the global banks in the developed countries influence the emerging economies. They distinguish between three transmission channels: reduction of loan supply by the head offices of global banks to the emerging markets, reduction of loan supply by the local affiliates of the global banks to the emerging markets and reduction of loan supply by the emerging market banks due to the decreased funds obtainable from the international interbank borrowing. They uncover evidence of those three transmission channels. The more recent study by Cetorelli and Goldberg (2012) further supports this finding.

4. DATA

This chapter firstly briefly reviews the included stock markets and then describes the data used in the study.

4.1. Overview of the markets

To give an overall picture of the economic situations of the four markets, I plot the annual GDP growth rates for those countries in figure 3. From 2004 to 2007, the GDP growth in China was steadily accelerating while the economy in Hong Kong and US was gradually slowing down. On the other hand, the GDP growth in Japan during this period was oscillating. With the occurrence of the financial crisis in 2008, the economic situations of all the four regions deteriorated especially for Hong Kong, US and Japan, reaching the lowest level in 2009. Since 2009 the general economy has started to improve steadily.

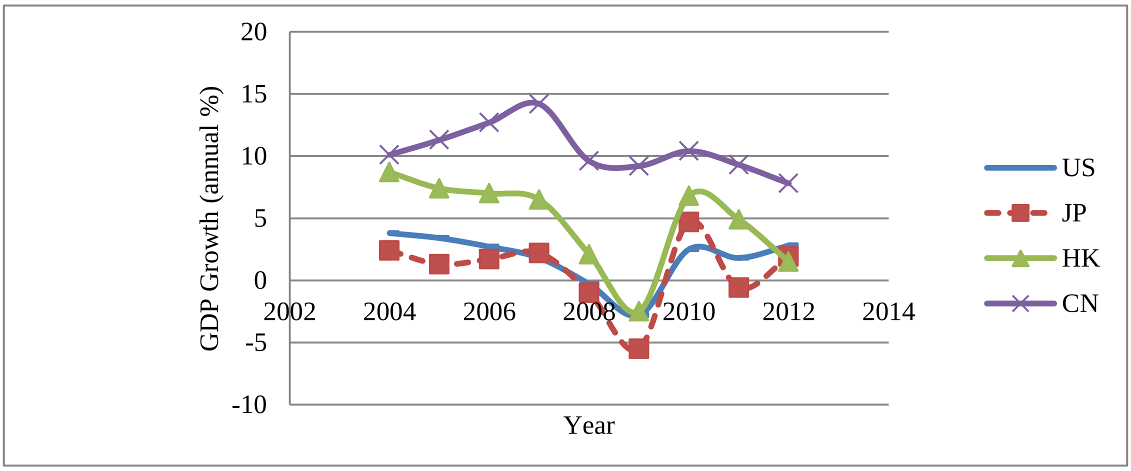

Figure 3. Annual GDP growth. (Source: World Bank).

To gain a more in-depth understanding of the selected stock markets, table 13 in the appendix provides a general description of the markets for the period from 2004 to 2012. Three dimensions of the markets are considered: number of listed domestic companies, market capitalization and stock trading activity. It can be seen from the table that market characteristics vary widely among different countries and across different years. In terms of the number of listed domestic companies, Mainland China and Hong Kong showed an upward trend for the entire period. The increase was evident for the Chinese market: the number of listed domestic companies almost doubled during the sampling period. In contrast, the number of listed domestic companies declined significantly for Japan in 2008 and 2012. In the U.S., the figure decreased from 5603 at the end of 2008 to 4401 at the end of 2009, the most dramatic decrease of the four regions and a reflection of the severe impact of the crisis on the U.S. stock market.

The second measurement of the stock markets, capitalization of the listed companies, dropped enormously around the crisis for all the four markets. The market capitalization of China was most volatile, which is partially because of the rise in the number of listed companies. As expected, US had dominant market capitalization among all the markets. When measured as a percentage of GDP, market capitalization of China and Japan was low while that of Hong Kong and US was high. This is true especially for the Hong Kong market, which had a market capitalization several times of its GDP. As for the stock trading activity, the total value of stocks traded as a percentage of GDP was relatively larger in the US and Hong Kong than in Japan and Mainland China and the trading was most active during the crisis period from 2007 to 2009 for all the four regions.

4.2. Sampling period and summary statistics of the data

The data are obtained from Datastream and consist of weekly stock price indexes for the time period from 1/7/2004 to 10/16/2013. Two sets of data are used in the study: one in local currency and one in common currency of US dollar. For the data measured in local currency, the price indexes included are S&P500 index for the U.S. stock market (US), Nikkei225 index for the Japanese market (JP), Hang Seng index for the Hong Kong stock market (HK), and Shanghai composite index for the Chinese stock market (CN).

For the data expressed in US dollars, the price indexes representing Japan, Hong Kong and Mainland China are the MSCI Japan, MSCI Hong Kong and MSCI China indexes in US dollars. Following studies that investigate the linkages of the international stock markets (e.g. Cheung et al. (2010) and Chudik & Fratzscher (2011)), weekly data are used to avoid the problem that the selected stock markets have nonsynchronous trading hours.

To examine the effect of the subprime crisis and following the study of Yang et al. (2003) who document the impact of the Asian financial crisis on the stock market integration in Asia, the full sample is divided into four subsamples as follows: pre-crisis period (1/7/2004–5/14/2008), crisis period (5/21/2008–7/1/2009), transition period (7/8/2009–12/28/2011) and stable period (1/4/2012–10/16/2013). The study by Dooley and Hutchison (2009) suggests that for the entire crisis period from February 2007 to February 2009, the emerging stock markets were decoupled from the impact of the U.S. financial crisis during the first phase from February 2007 to May 18 2008. Therefore, to capture the real effect of crisis transmission to the emerging Chinese stock market, the starting point of the crisis is defined as May 21 of 2008. As NBER defines June 2009 as the trough of the recent economic cycle, July 1 2009 is chosen as the endpoint of the crisis. Moreover, defining July 1 2009 as the end of the crisis can also avoid the confounding effect of the European debt crisis that began in late 2009.

There were signs of stability after 2011. For instance, by the end of 2011 real GDP of the U.S. has risen well above that of the pre-crisis period and its unemployment rate has decreased from the highest of 10% to about 8%. Similar improvements were also witnessed in Europe. Thus, I will also include the post 2011 time period. This time period could be treated as the post crisis period or a “stable” period as suggested by the stabilization of the real economic variables.

Figure 4 presents the development of the price indexes of the four markets. At the beginning of the sample period, the markets were either fluctuating (US and Japan) or decreasing (Hong Kong and China). All the four markets showed a general upward trend from the middle of 2005 to the middle of 2007. After that the markets started a declining process until the first quarter of 2009 when the markets began to increase. By the end of the sample period, all the markets except for the US were still below the pre-crisis level. It may be noted from the figure that although the financial crisis initiated from the US, the US market increased significantly after the crash, reaching a point higher than the pre-crisis level.

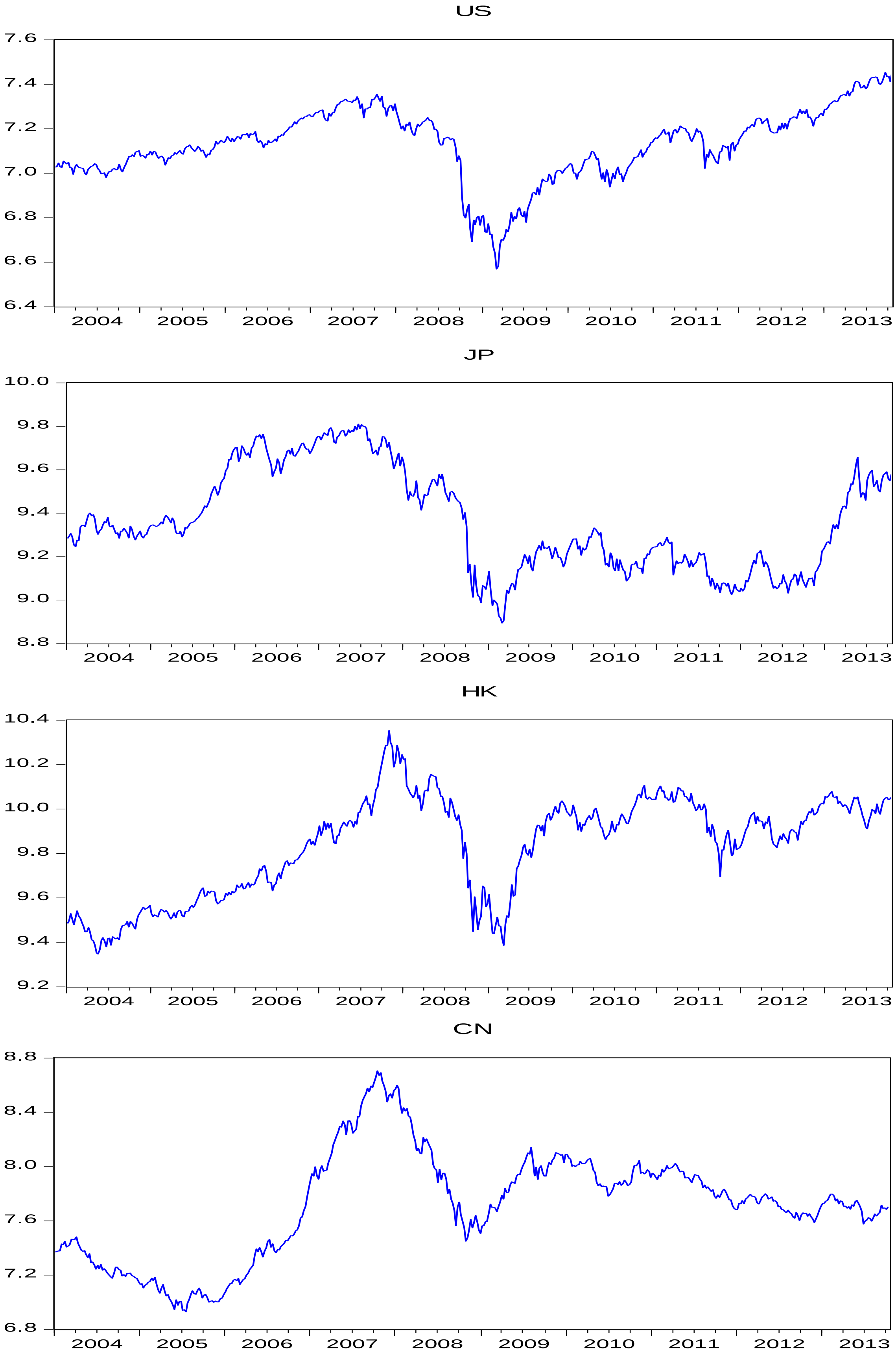

Figure 4. Time series of the indexes (local currency: natural logarithm of the index).

Table 1. Descriptive statistics of the returns (local currency).

	US	JP	HK	CN
Panel A: pre-crisis period				
Mean	0.10	0.12	0.29	0.37
Median	0.16	0.49	0.51	0.60
Maximum	4.00	6.30	6.96	11.91
Minimum	-6.25	-7.85	-12.17	-11.77
Std. Dev.	1.58	2.47	2.59	3.59
Observations	227.00	227.00	227.00	227.00
Panel B: crisis period				
Mean	-0.71	-0.58	-0.56	-0.28
Median	-0.27	-0.84	-0.64	-0.18
Maximum	9.64	14.79	15.56	13.90
Minimum	-16.45	-21.13	-15.48	-10.88
Std. Dev.	4.44	5.22	6.30	5.58
Observations	58.00	58.00	58.00	58.00
Panel C: transition period				
Mean	0.27	-0.09	0.03	-0.27
Median	0.52	0.20	0.28	-0.03
Maximum	7.07	7.06	12.04	8.18
Minimum	-11.74	-15.23	-10.59	-11.10
Std. Dev.	2.64	2.99	3.21	3.30
Observations	129.00	129.00	129.00	129.00
Panel D: stable period				
Mean	0.32	0.56	0.23	0.01
Median	0.30	0.79	0.38	0.04
Maximum	3.86	9.09	4.87	5.20
Minimum	-3.64	-9.60	-5.41	-9.38
Std. Dev.	1.62	3.25	2.29	2.40
Observations	93.00	93.00	93.00	93.00

Notes: the table provides the descriptive statistics of the returns which are calculated as 100 times the difference of the ln(price index).

Table 1 shows the descriptive statistics of the returns for each of the subsample period. The table indicates that the average returns for the pre-crisis period are all positive, ranging from 0.10% in the US to 0.37% in Mainland China. The mean returns during the crisis period, however, are all negative, indicating the large adverse effect of the financial crisis. The average returns during the stable period become positive. The sample average returns in the transition period are negative for Japan (-0.09%) and China (-0.27%), and positive for US (0.27%) and Hong Kong (0.03%).

In addition to reducing the level of the returns, the financial crisis has also increased the volatility of the returns represented by the standard deviation. Compared with the pre-crisis period, the standard deviations during the crisis period are much higher. For instance, before the financial crisis the standard deviation of the US market returns is 1.58% while the corresponding figure during the crisis period is 4.44%.

Table 2 below presents the return correlations for each of the sub-period. The table shows that the market correlations are stronger during the crisis than before the crisis, which suggests that the subprime crisis has led to higher market correlations. This is particularly true for the Chinese market. For example, the correlation between Japan and Mainland China has increased from 0.13 before the crisis to 0.33 during the crisis. Except for the Chinese market, the degree of market correlations in the stable period is more or less the same as the pre-crisis period. The stock market in Mainland China tends to be more closely correlated with the developed markets during the stable period than the pre-crisis period.

Therefore the initial analysis of the data seems to support that the subprime crisis only temporarily strengthened the market linkages. It should be pointed out that the data analyzed in this section are in the local currencies. For the common currency case, the results, shown in the appendix, are qualitatively similar.

Table 2. Correlation of the returns (local currency).

	US	JP	HK	CN
Panel A: pre-crisis period				
US	1.00			
JP	0.52***	1.00		
HK	0.56***	0.60***	1.00	
CN	0.11*	0.13*	0.27***	1.00
Panel B: crisis period				
US	1.00			
JP	0.65***	1.00		
HK	0.61***	0.84***	1.00	
CN	0.21	0.33***	0.50***	1.00
Panel C: transition period				
US	1.00			
JP	0.60***	1.00		
HK	0.67***	0.55***	1.00	
CN	0.45***	0.32***	0.55***	1.00
Panel D: stable period				
US	1.00			
JP	0.58***	1.00		
HK	0.60***	0.49***	1.00	
CN	0.29***	0.35***	0.45***	1.00

Notes: *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

5. METHODOLOGY

Previous research on international stock market integration employs a wide variety of methods such as vector auto-regression model, impulse response function and dynamic conditional correlation-GARCH model (see Sharma and Seth 2012). In this study Johansen cointegration test will be used to test the existence of cointegration among the four stock markets. Granger causality test would be adopted to examine if one stock market can help predict another stock market. Furthermore, the method of variance decomposition will be used to study the magnitude of impact each market exerts on other markets.

5.1. Random walk and unit root tests

Before investigating the cointegration of the stock indices, it is necessary to show that the indices are all integrated with the same order; or test has to be done to determine the number of unit roots in the price series.

One type of unit root process is the random walk, the characteristic equation of which has a root of one. For a time series y_t (t=1,2,...,T), if its current value is the sum of its previous value plus an error term that follows a white noise process, it is called a random walk. Obviously, random walk process is not stationary as its variance is t times the variance of the white noise error. Three test methods for unit root or stationarity are widely used in the empirical studies: augmented Dickey-Fuller test (ADF), Phillips-Perron test (PP) and KPSS test (for stationarity).

For the ADF test (Dickey and Fuller 1981), the following regression is run:

$$(3)\quad \Delta y_t = \alpha + \lambda t + \gamma y_{t-1} + \beta_1 \Delta y_{t-1} + ... + \beta_{p-1} \Delta y_{t-p+1} + \varepsilon_t ,$$

where p is the order and can be estimated by Akaike information criterion (AIC) or Schwarz-Bayesian information criterion (BIC).The test is then conducted on the t statistics of the coefficient of y_{t-1} by referring to tabulated critical values of the non-standard distribution for the t statistics. There are three versions of the ADF test and each has different critical values (Greene 2008: 751):

1) Random walk: $\alpha=0$ and $\lambda=0$;
2) Random walk with drift: $\lambda=0$;
3) Random walk with trend: no restriction on α and λ.

If all the betas in the above equation are set to zero, the resulting test is the Dickey-Fuller test. One advantage of ADF test over Dickey-Fuller test is that it allows for higher order autocorrelations of the error term (Greene 2008: 751).

5.2. Cointegration tests

Two approaches are commonly applied in the previous literature to test for the cointegration relations. The first approach is the Engle-Granger two-step procedure. The second method, Johansen cointegration test, is based on the likelihood ratio test. This section gives a general description of those two methods. However, because the Engle-Granger procedure only applies to the two variables case, only the results from the Johansen test are reported in the empirical section of the study.

5.2.1. Engle-Granger two-step procedure

Engle and Granger (1987) suggest a two-step method to test for the existence of cointegration between $I(1)$ series and estimate for the error correction model. The first step of their procedure is to run a linear regression (cointegrating regression) and then test for stationarity of the residuals. Among the seven methods they use to test for the stationarity, they recommend the augmented Dickey-Fuller test due to its high power and less sensitivity to the parameters in the null hypothesis. The second step of the procedure is based on the cointegration vector estimated in the first step and tries to estimate the error correction model in order to obtain both the long-term and short-term dynamics of the time series.

More specifically, suppose two time series x_{1t} and x_{2t} are shown to be $I(1)$ by the unit root test. The first step is to run the following regression:

$$(4) \quad x_{1t} = \beta_0 + \beta_1 x_{2t} + \varepsilon_t \ .$$

Stationarity of the residuals from the above equation is tested by the augmented Dickey-Fuller test. If the null hypothesis of unit root is rejected, then the residual, a linear combination of x_{1t} and x_{2t}, is stationary and thus x_{1t} and x_{2t} are cointegrated, indicating that a long-run relationship exists between the two series. The second step is to run the error correction model:

(5) $\Delta x_{1t} = \gamma_0 + \gamma_1 \Delta x_{2,t-1} + \gamma_2 e_{t-1} + \upsilon_t$,

where e_{t-1} is the residual from equation (4) and υ_t is the error term. In the error correction model, γ_1 measures the short-term effect of $x_{2,t-1}$ on x_{1t} while γ_2 measures the speed of adjustment to equilibrium for x_{1t} .

5.2.2. Johansen cointegration test

Engle and Granger procedure can only be used to test the case of one cointegration vector. For a system of more than two nonstationary series, there may exist more than one cointegration relationship. Therefore, a more general method is needed. Johansen (1988, 1991) proposes two likelihood ratio based cointegration tests to solve this problem, namely, the trace test and the maximum eigenvalue test.

Suppose a *p*th order vector autoregressive model (VAR(*p*)):

(6) $\mathbf{x}_t = \boldsymbol{\eta}_0 + \boldsymbol{\eta}_1 t + \Gamma_1 \mathbf{x}_{t-1} + ... + \Gamma_p \mathbf{x}_{t-p} + \boldsymbol{\varepsilon}_t \;\; (t = p+1, ..., T)$,

where $\mathbf{x}_t$ is an m-dimensional vector and is integrated of order one; $\boldsymbol{\eta}_0$ and $\boldsymbol{\eta}_1$ are m by 1 vector of constants; $\Gamma_1 ... \Gamma_p$ are m by m parameter matrices and $\boldsymbol{\varepsilon}_t$ is m-dimensional independent and identical Gaussian distribution. Johansen test is based on a vector error correction model (VECM), which can be derived from the above VAR model. First, subtract $\mathbf{x}_{t\text{-}1}$ from both sides of the equation; then replace $\mathbf{x}_{t\text{-}i}$ by $\Delta\mathbf{x}_{t\text{-}i}+\mathbf{x}_{t\text{-}i\text{-}1}$ for all i=1,2,...,p-1 ("I" in the equation below denotes the identity matrix).

$$
\begin{aligned}
(7)\quad \Delta\mathbf{x}_t &= \boldsymbol{\eta}_0+\boldsymbol{\eta}_1 t+(\Gamma_1\text{-I})\mathbf{x}_{t\text{-}1}+...+\Gamma_{\mathrm{p}}\mathbf{x}_{t\text{-}p}+\boldsymbol{\varepsilon}_t \\
&= \boldsymbol{\eta}_0+\boldsymbol{\eta}_1 t+(\Gamma_1\text{-I})(\Delta\mathbf{x}_{t\text{-}1}+\mathbf{x}_{t\text{-}2})+\Gamma_2\mathbf{x}_{t\text{-}2}+...+\Gamma_{\mathrm{p}}\mathbf{x}_{t\text{-}p}+\boldsymbol{\varepsilon}_t \\
&= \boldsymbol{\eta}_0+\boldsymbol{\eta}_1 t+(\Gamma_1\text{-I})\Delta\mathbf{x}_{t\text{-}1}+(\Gamma_1+\Gamma_2\text{-I})(\Delta\mathbf{x}_{t\text{-}2}+\mathbf{x}_{t\text{-}3})+\Gamma_3\mathbf{x}_{t\text{-}3}+...+\Gamma_p\mathbf{x}_{t\text{-}p}+\boldsymbol{\varepsilon}_t \\
&= \boldsymbol{\eta}_0+\boldsymbol{\eta}_1 t+(\Gamma_1\text{-I})\Delta\mathbf{x}_{t\text{-}1}+(\Gamma_1+\Gamma_2\text{-I})\Delta\mathbf{x}_{t\text{-}2}+(\Gamma_1+\Gamma_2+\Gamma_3\text{-I})\mathbf{x}_{t\text{-}3}+...+\Gamma_p\mathbf{x}_{t\text{-}p}+\boldsymbol{\varepsilon}_t \\
&\;... \\
&= \boldsymbol{\eta}_0+\boldsymbol{\eta}_1 t+(\Gamma_1\text{-I})\Delta\mathbf{x}_{t\text{-}1}+(\Gamma_1+\Gamma_2\text{-I})\Delta\mathbf{x}_{t\text{-}2}+...+(\Gamma_1+\Gamma_2+...+\Gamma_{p\text{-}1}\text{-I})\Delta\mathbf{x}_{t\text{-p+1}}+(\Gamma_1+\Gamma_2+...+\Gamma_p\text{-I})\mathbf{x}_{t\text{-}p}+\boldsymbol{\varepsilon}_t.
\end{aligned}
$$

By similar method, the following VECM can also be obtained from the VAR model.

$$
\begin{aligned}
(8)\quad \Delta\mathbf{x}_t &= \boldsymbol{\eta}_0+\boldsymbol{\eta}_1 t+(\Gamma_1+\Gamma_2+...+\Gamma_p\text{-I})\mathbf{x}_{t\text{-}1}+(\text{-}\Gamma_2\text{-}...\text{-}\Gamma_p)\Delta\mathbf{x}_{t\text{-}1}+...+(\text{-}\Gamma_{p\text{-}1}\text{-}\Gamma_p)\Delta\mathbf{x}_{t\text{-p+2}}+(\text{-}\Gamma_p)\Delta\mathbf{x}_{t\text{-}p\text{+}1}+\boldsymbol{\varepsilon}_t \\
&= \boldsymbol{\eta}\mathbf{D}_t+\Pi\mathbf{x}_{t\text{-}1}+\Pi_1\Delta\mathbf{x}_{t\text{-}1}+...+\Pi_{p\text{-}1}\Delta\mathbf{x}_{t\text{-}p\text{+}1}+\boldsymbol{\varepsilon}_t.
\end{aligned}
$$

Where $\boldsymbol{\eta}=(\boldsymbol{\eta}_0,\boldsymbol{\eta}_1)$, $\mathbf{D}_t=(1,t)'$, $\Pi = \Gamma_1+\Gamma_2+...+\Gamma_p\text{-I}$ and $\Pi_i=\text{-}\Gamma_{i+1}\text{-}...\text{-}\Gamma_p$ (i=1,...,p-1). In this thesis, the VECM model in equation (8) is illustrated. The test is about testing the rank of Π, which is the number of cointegration vectors. Since $0 \le \text{rank}(\Pi) \le m\text{-}1$ if $\mathbf{x}_t$ is $I(1)$, the following two cases need to be analyzed (Tsay 2005: 381):

i) rank(Π)=0 or there are no cointegrating relations between the component series of $\mathbf{x}_t$;

ii) $\text{rank}(\Pi)=r\ (1 \le r \le m\text{-}1)$. This is the case when there are r cointegration vectors.

To illustrate the test, the first step is to regress $\Delta\mathbf{x}_t$ on $\mathbf{D}_t, \Delta\mathbf{x}_{t\text{-}1} \ldots \Delta\mathbf{x}_{t\text{-}p+1}$. Denote the vector of residuals from this regression by $\boldsymbol{\omega}_t$. Then regress $\mathbf{x}_{t\text{-}1}$ on the same variables and denote the vector of residuals from this regression by $\hat{\mathbf{v}}_t$. Let $\hat{\lambda}_1 \ldots \hat{\lambda}_m$ be the square of the canonical correlations between $\boldsymbol{\omega}_t$ and $\hat{\mathbf{v}}_t$ ($\hat{\lambda}_1 \ge \hat{\lambda}_2 \ge \ldots \ge \hat{\lambda}_m$). The trace test statistics is $\text{LR}_{\text{trace}}(r_0)\text{=-(T-P)}\sum_{i=r_0+1}^{m} \ln(1\text{-}\hat{\lambda}_i)$ and it is used to test the hypothesis:

$$\text{H}_0\text{: rank}(\Pi) \le r_0 \quad \text{against H}_1\text{: rank}(\Pi)>r_0 \quad (0 \le r_0 \le m\text{-}1).$$

The maximum eigenvalue test statistics is $\text{LR}_{\max}(r_0)\text{=-(T-P)ln}(1\text{-}\hat{\lambda}_{r_0+1})$, which can be used to test $\text{H}_0\text{: rank}(\Pi)=r_0$ against $\text{H}_1\text{: rank}(\Pi)=r_0+1$. Both the trace and the maximum eigenvalue test statistics have nonstandard asymptotic distributions and thus simulation method is needed to obtain the critical values. The test starts with $r_0=0$ and the value of r_0 gradually increases. The number of cointegration vectors is the value of r_0 when we fail to reject the null hypothesis for the first time. (Tsay 2005: 383–385.)

5.3. Granger Causality

In order to determine the direction of causality between two related stock markets, Granger causality test can be conducted. For two time series x_{1t} and x_{2t}, if the variance of the optimum prediction error of x_{1t} when using all the past values of both x_{1t} and x_{2t} is smaller than that when using just the past values of x_{1t}, then it is called that x_{2t} Granger causes x_{1t}, denoted by $x_{2t} \Rightarrow x_{1t}$; if there exists a two direction Granger causality both from x_{1t} to x_{2t} and from x_{2t} to x_{1t}, then there is a feedback, denoted as $x_{2t} \Leftrightarrow x_{1t}$. (Granger 1969.)

For a VAR(p) model of x_{1t} and x_{2t}, Granger causality test can be carried out by testing the restrictions that some of the parameters are zero. For example, if we have the following VAR(p) model:

$$(9)\quad \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} = \begin{bmatrix} \alpha_{11,1} & \alpha_{12,1} \\ \alpha_{21,1} & \alpha_{22,1} \end{bmatrix} \begin{bmatrix} x_{1,t\text{-}1} \\ x_{2,t\text{-}1} \end{bmatrix} + \ldots + \begin{bmatrix} \alpha_{11,\mathrm{p}} & \alpha_{12,\mathrm{p}} \\ \alpha_{21,\mathrm{p}} & \alpha_{22,\mathrm{p}} \end{bmatrix} \begin{bmatrix} x_{1,t\text{-}\mathrm{p}} \\ x_{2,t\text{-}\mathrm{p}} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}.$$

The null hypothesis that x_{2t} does not Granger cause x_{1t} is equivalent to $\alpha_{12,i}=0$ (i=1,2,...p). Similarly, the hypothesis that x_{1t} is not Granger causal for x_{2t} can be tested by examining if all the parameters in the lower left corner of the parameter matrices in the above model are zero. One property for two cointegrated time series is that there must be Granger causality from one series to the other or feedback between the two series. (Lutkepohl and Kratzig 2004: 146.)

When the VAR model involves variables that are $I(1)$, standard test statistics for the hypothesis of zero coefficients (no Granger causality) have nonstandard asymptotic distribution. To solve this problem, a VAR(p+1) can be fitted when the true data generating process is a VAR(P) process and then tests can be performed only on the coefficients of the first p parameter matrices. By overfitting the model, standard test statistics would have standard asymptotic chi2 or F distribution. (Lutkepohl and Kratzig 2004:148–150.)

5.4. Variance decomposition

Variance decomposition can be used to determine the proportion of n-step ahead forecast error variance in variable i that can be explained by variable j. Therefore, it is suitable for measuring how one stock market is affected by each of the other stock markets. The methodology of this section is based on the study of Pesaran and Shin (1998). Suppose a m by 1 vector $\mathbf{x}_t$ follows a VAR (p) process and is covariance stationary; there exists an infinite moving average representation of $\mathbf{x}_t$:

$$(10)\quad \mathbf{x}_t = \sum_{i=0}^{\infty} A_i \boldsymbol{\varepsilon}_{t-i} \ ,$$

where $\boldsymbol{\varepsilon}_t$ is the m dimensional error term with mean zero and covariance matrix Σ ($\Sigma = (\sigma_{ij})$, i, j=1,...,m). Denote the Cholesky decomposition of Σ as PP'. Then the orthogonalized and generalized variance decomposition of the n-step ahead forecast error of variable i due to innovations of variable j are respectively

$$(11)\theta_{ij}^{*}(n) = \frac{\sum_{l=0}^{n} (e_i' A_l P e_j)^2}{\sum_{l=0}^{n} (e_i' A_l \Sigma A_l' e_i)} \text{, and}$$

$$(12)\theta_{ij}^{g}(n)=\frac{\sigma_{ii}^{-1}\sum_{l=0}^{n}(e_i'A_l\Sigma e_j)^2}{\sum_{l=0}^{n}(e_i'A_l\Sigma A_l'e_i)} \quad (n=0, 1, 2,...;i, j=1,...,m),$$

where e_j is an m dimensional column vector with one in the jth component and zeros elsewhere. A shortcoming of the above orthogonalized forecast error variance decomposition is that it may vary when the ordering of the variables in the Cholesky decomposition changes. On the other hand, the generalized counterpart is invariant to the ordering of the variables in the VAR model. However, one problem related to $\theta_{ij}^{g}(n)$ is that it may not sum up to one across all the variables. In order to solve this problem, the normalized version of the generalized variance decomposition would be used in this thesis, which is defined as

$$(13)\tilde{\theta}_{ij}^{g}(n)=\theta_{ij}^{g}(n)\Big/\sum_{j=1}^{m}\theta_{ij}^{g}(n).$$

To have a more comprehensive understanding of the interdependence among the stock markets, some index measures proposed by Diebold and Yilmaz (2012) will be constructed. Those indexes aggregate the information contained in the generalized variance decomposition and can be used to measure the cross-market influences. The first measurement is the total (return) spillover index:

$$(14)\quad S^{g}(n)=\frac{\sum_{i,j=1,i\neq j}^{m}\tilde{\theta}_{ij}^{g}(n)}{\sum_{i,j=1}^{m}\tilde{\theta}_{ij}^{g}(n)}*100=\frac{\sum_{i,j=1,i\neq j}^{m}\tilde{\theta}_{ij}^{g}(n)}{m}*100$$

Two other indexes are the directional spillovers from market *i* to all the other markets and directional spillovers from all the other markets to market *i*, which are respectively:

$$(15)\quad S_{.i}^{g}(n)=\frac{\sum_{j=1,\,j\neq i}^{m}\tilde{\theta}_{ji}^{g}(n)}{\sum_{i=1,\,j=1}^{m}\tilde{\theta}_{ji}^{g}(n)}*100=\frac{\sum_{j=1,\,j\neq i}^{m}\tilde{\theta}_{ji}^{g}(n)}{m}*100\text{, and}$$

$$(16)\quad S_{i.}^{g}(n)=\frac{\sum_{j=1,\,j\neq i}^{m}\tilde{\theta}_{ij}^{g}(n)}{\sum_{i=1,\,j=1}^{m}\tilde{\theta}_{ij}^{g}(n)}*100=\frac{\sum_{j=1,\,j\neq i}^{m}\tilde{\theta}_{ij}^{g}(n)}{m}*100\,.$$

Total spillover index can be used to assess the overall association between the markets. The other two directional spillover indexes indicate the strength of impact of one market on all the other markets or the effect of all the other markets on one market. The difference of those two indexes determines the net impact of a specific market versus all the other markets.

6. EMPIRICAL RESULTS

In this chapter, the methods discussed in the previous chapter would be utilized to evaluate the four stock markets under investigation and the empirical results would be presented.

6.1. Result of tests for unit root

As cointegration is the relationship of time series with the same order of integration, the first step is to test whether the included market indexes have the same number of unit roots. For each sub-period, both the index prices in local currency and in US dollar are examined, with the results shown in table 3 (for the price indexes in local currency) below and table 16 (for the price indexes in US dollar) in the appendix. Apart from the S&P500 index during the transition period, the ADF test results indicate that at the 5% significance level, all the market indexes, either in local currency or in US dollar, are non-stationary but the first difference of each price index is stationary, suggesting that all the indexes are $I(1)$. For the S&P500 index in the transition period, the test result is marginally significant (p-value=5%) if we assume there is a trend. Therefore, it will be treated as $I(1)$ for the cointegration analysis (the number of cointegrating vectors for the transition period does not change if the US market for the transition period is excluded). In addition to the ADF tests, PP tests were also conducted, the results of which are not reported; similar conclusion about the order of integration for the index values can be reached.

Table 3. ADF unit root test (local currency)**.**

	level		first difference	
	1	2	1	2
Pre-crisis period:				
US	-1.16	-2.65	-18.07***	-18.03***
JP	-1.52	-1.04	-13.89***	-13.92***
HK	-0.23	-2.83	-15.22***	-15.23***
CN	0.09	-1.59	-8.44***	-8.50***
Crisis period:				
US	-1.73	-0.92	-6.55***	-6.56***
JP	-1.62	-0.71	-7.74***	-8.00***
HK	-1.93	-0.94	-3.50***	-7.40***
CN	-1.95	-1.48	-7.62***	-8.76***
Transition period:				
US	-3.19**	-3.44**	-13.36***	-13.43***
JP	-1.95	-3.14*	-13.14***	-13.21***
HK	-2.47	-2.53	-12.00***	-12.17***
CN	-1.16	-2.25	-12.01***	-11.99***
Stable period:				
US	-0.78	-2.79	-11.72***	-11.65***
JP	-0.44	-1.69	-8.88***	-8.84***
HK	-2.00	-2.34	-9.12***	-9.07***
CN	-2.00	-2.29	-9.60***	-9.54***

Notes: “level” = natural logarithm of the index price. “1” and “2” are the ADF tests without trend and with trend, respectively. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

6.2. Result of cointegration tests

Having determined that all the analyzed stock market indexes are non-stationary with the same order of integration, the next procedure is to investigate whether those markets are cointegrated by Johansen test, the results of which are shown in table 4. To conduct the Johansen cointegration test, one needs to specify the lag length. The lag length for the test, and for the other analyses in this thesis, is chosen based on the information criterion: sequential modified LR test statistic (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ). The test was specified as “intercept (no trend) in cointegration equation and test VAR” (qualitatively similar outcome would be obtained if we instead assume “intercept and trend in cointegration equation – no intercept in VAR”).

Table 4. Cointegration test.

	Trace statistics			Maximum eigenvalue statistics		
H0	Local currency	US dollar	5% CV	Local currency	US dollar	5% CV
Panel A: pre-crisis period						
r=0	46,57	39,84	47,86	26,85	21,29	27,58
r<=1	19,72	18,56	29,80	11,53	9,66	21,13
r<=2	8,19	8,90	15,49	7,03	6,34	14,26
r<=3	1,16	2,56	3,84	1,16	2,56	3,84
Panel B: crisis period						
r=0	**59,60**	**60,38**	47,86	**28,03**	**38,35**	27,58
r<=1	**31,58**	22,03	29,80	20,05	12,73	21,13
r<=2	11,53	9,30	15,49	10,84	7,01	14,26
r<=3	0,70	2,28	3,84	0,70	2,28	3,84
Panel C: transition period						
r=0	39,34	34,51	47,86	19,13	18,80	27,58
r<=1	20,21	15,71	29,80	11,48	11,56	21,13
r<=2	8,73	4,15	15,49	8,72	3,53	14,26
r<=3	0,01	0,61	3,84	0,01	0,61	3,84
Panel D: stable period						
r=0	**49,29**	29,77	47,86	20,17	15,76	27,58
r<=1	29,12	14,00	29,80	17,50	8,04	21,13
r<=2	11,62	5,96	15,49	11,16	5,22	14,26
r<=3	0,46	0,74	3,84	0,46	0,74	3,84

Notes: 5% CV = 5% critical value. Test statistics that are significant at the 5% level are shown in bold.

For the time period before the financial crisis, both the trace test and the maximum eigenvalue test show that we cannot reject the null hypothesis of no cointegration among the four stock markets, which is the case either the indexes are expressed in local currency or in a common currency of US dollar. During the financial crisis period, higher level of integration between the investigated markets is observed. In local currency terms, trace test detects two long-term relationships and maximum eigenvalue test suggests the existence of one cointegration vector. When the market-wide indexes are denominated in US dollars, both the trace test and maximum eigenvalue test indicate that there is one long-run equilibrium relationships among the selected stock markets. For the transition and stable periods, there is no evidence that cointegration exists, with the exception that trace statistic shows the existence of one cointegrating relationship (only in the case of local currency) during the stable period but this result is not supported by the maximum eigenvalue test.

Therefore, the cointegration test suggests that the global financial crisis may have strengthened the long-run linkages of the stock markets in Mainland China, Hong Kong, Japan and US, which is in line with the previous studies (e.g., Sheng and Tu 2000, Yang et al. 2003 and Huyghebaert & Wang 2010). In addition, the test results also reveal that the strengthening effect of the financial crisis may be temporary as there is very weak evidence of cointegration during the stable period. On the one hand, this finding is consistent with Huyghebaert and Wang (2010) who find enhanced integration among the major East Asian stock markets during the Asian financial crisis but no cointegration after the crisis. On the other hand, this finding is in contrast to the research of Yang et al. (2003) suggesting that the intensified linkages among the Asian stock markets during the Asian financial crisis sustain after the crisis. Overall, the cointegration test result of this study tends to support the line of previous research which shows financial crises only temporarily increase the long-term equilibrium relationships of stock markets.

The existence of cointegration in the financial crisis ensures that the stock markets investigated would not drift far from the cointegrating linear relationship and thus suggests that the diversification benefits into those stock markets would be very limited during the crisis period. Other implications of cointegration include availability of a VECM as a result of Granger's representation theorem, and the decreased effectiveness of domestic economic policies (Syriopoulos 2007). This would imply that international cooperation may be the only effective way to cope with a financial crisis.

Table 5. Market exclusion test statistics.

	US	JP	HK	CN
Local currency	3,00*	5,14**	0,92	3,11*
	(0,08)	(0,02)	(0,34)	(0,08)
US dollar	6,19***	4,82**	20,06***	23,12***
	(0,01)	(0,03)	(0,00)	(0,00)

Notes: p-values are shown in the parentheses; one cointegration relation is assumed for both the local and common currency cases; *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

To examine whether some stock markets can be excluded from the cointegration equation, exclusion test was conducted for the crisis period, assuming one cointegration vector in both the local currency and the common currency case. The test statistics (chi 2 statistics) are presented in table 5. When the stock market prices are measured in local currency, only Hong Kong market is excluded at the 10% level. When the indexes are expressed in US dollars, none of the four markets can be excluded. Thus, there is evidence that all the included stock markets contribute to the cointegrating vector during the financial crisis.

In addition to the exclusion test, I also estimated the speed of adjustment parameters. Table 6 shows that both the Japanese and Hong Kong stock markets significantly respond to the disturbances in the equilibrium relations, while the Chinese market does not react to the deviations from the equilibrium. For the US market, the result depends on whether the data analyzed are in common currency or local currency: US market only significantly adjusts to the disequilibrium in the common currency case. In other words, the estimates of the adjustment coefficients indicate that the stock markets in the US (in local currency case) and Mainland China are weakly exogenous to the system.

Table 6. Speed of adjustment parameters.

	US	JP	HK	CN
Panel A: Local currency				
	0.11	0.74	0.58	0.26
	[0.54]	[3.75]	[2.24]	[1.07]
Panel B: US dollar				
	0.19	0.20	0.32	0.15
	[2.59]	[2.79]	[4.11]	[1.31]

Notes: t-statistics are shown in the brackets; one cointegration relation is assumed for both the local and common currency cases

6.3. Result of tests for Granger causality

After analyzing the long-term relations of the equity markets, I will derive the short-term Granger causality relationships in this section. Since this study concentrates on the impact of the financial crisis, the test results for the transition period are not reported due to its transitory nature.

Table 7. Granger causality test (local currency).

	Pre-crisis period		Crisis period		Stable period	
H0	F-stat	p-value	F-stat	p-value	F-stat	p-value
JP–/→US	1,10	0,33	3,23**	0,03	3,47*	0,07
US–/→JP	4,85***	0,01	2,46*	0,07	0,12	0,73
HK–/→US	2,30*	0,10	3,91***	0,01	0,53	0,47
US–/→HK	12,12***	0,00	2,99**	0,04	0,02	0,88
CN–/→US	3,55**	0,03	0,94	0,43	0,48	0,49
US–/→CN	7,26***	0,00	0,41	0,75	0,71	0,40
HK–/→JP	1,00	0,37	0,49	0,49	1,40	0,24
JP–/→HK	0,28	0,76	0,14	0,71	0,24	0,62
CN–/→JP	2,38*	0,09	3,64**	0,02	2,76*	0,10
JP–/→CN	4,95***	0,01	0,34	0,79	0,64	0,43
CN–/→HK	1,27	0,28	0,97	0,33	1,64	0,20
HK–/→CN	5,03***	0,01	1,09	0,30	0,10	0,76

Notes: "–/→" denotes the null hypothesis of no Granger causality; *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

The analysis of cointegration in the previous section suggests that the selected stock markets may be cointegrated in the crisis period. Therefore, Granger causality test based on the returns (first difference of the logarithmic price) may be invalid for the crisis period. To overcome this problem, a VAR(p+1) model is fitted to the data in levels, when the true data generating process is a VAR(P) process. The order p is determined by the information criteria. Then the tests are performed only on the first p parameters. (see Toda and Yamamoto 1995 and Lutkepohl and Kratzig 2004: 148–150).

When the data are expressed in local currency, table 7 above shows that before the financial crisis, there is evidence of two-way Granger causality for the following pairs of markets: Hong Kong-US, Mainland China-US and Mainland China-Japan. There is also indication of Granger causality from the US market to the Japanese market and from Hong Kong to Mainland China. During the financial crisis, stronger causality relationships from Japan to US and from Hong Kong to US are obtained, implying enhanced external impacts on the US market during this period. Unexpectedly, although there is feedback between US and Mainland China before the crisis, there is no evidence of Granger causality between them during the crisis. In the stable period, only the Japanese and the Chinese markets are found to be Granger causing the US and Japanese markets, respectively.

When the data are measured in US dollars, table 8 below reveals that compared with the pre-crisis period, increased lead-lag relations from Hong Kong and Mainland China to US are perceived during the crisis period. The US market leads the other three markets during both the pre-crisis and crisis periods. Interestingly, the one-way Granger causality from Japan to US has become insignificant during the financial crisis. In addition, statistically significant lead-lag relationships from Mainland China to Hong Kong during the financial crisis and from Japan to Hong Kong during the stable period are detected. Although the results of Granger causality test are different due to the influence of exchange rate, there is still some evidence that the US market is more strongly affected by the external Hong Kong and Chinese markets during the financial crisis than the pre-crisis period.

Table 8. Granger causality test (US dollar).

	Pre-crisis period		Crisis period		Stable period	
H0	F-stat	p-value	F-stat	p-value	F-stat	p-value
JP–/→US	3,17*	0,08	0,07	0,79	1,37	0,24
US–/→JP	4,90**	0,03	7,89***	0,01	0,48	0,49
HK–/→US	2,13	0,15	2,14*	0,09	0,49	0,49
US–/→HK	11,24***	0,00	3,20**	0,02	1,60	0,21
CN–/→US	0,89	0,35	3,21**	0,03	0,08	0,78
US–/→CN	16,05***	0,00	2,37*	0,08	0,21	0,65
HK–/→JP	0,03	0,87	0,91	0,34	1,12	0,29
JP–/→HK	0,00	0,98	0,68	0,41	5,32**	0,02
CN–/→JP	0,02	0,88	0,04	0,84	0,21	0,65
JP–/→CN	0,03	0,86	0,41	0,53	0,14	0,71
CN–/→HK	0,10	0,75	4,30***	0,01	0,66	0,42
HK–/→CN	0,16	0,69	0,53	0,66	0,09	0,76

Notes: "–/→" denotes the null hypothesis of no Granger causality; *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

The finding that external markets exert more significant impact on the US market in the crisis period is in line with Nikkinen et al. (2012) who find that the Estonian and Latvian stock markets have larger influence on the EUROSTOXX 50 index during the crisis than the pre-crisis period. In general, the Granger causality tests provide some evidence of stronger associations among the investigated stock markets during the crisis and the enhanced linkages disappear after the financial crisis as few market pairs show statistically significant Granger causality result during the stable period.

6.4. Variance decomposition

Following the assessment of cointegration and Granger causality of the selected stock markets in the previous two sections, this section further evaluates the variance decomposition of those markets. On the basis of the cointegration tests in section 6.2, the decompositions for the pre-crisis and the stable periods are obtained from VAR models in returns and the results for the crisis period are derived from a vector error correction model (VECM) assuming one cointegrating relationship, with the order of VAR or VECM chosen according to the information criteria.

The variance decompositions for the pre-crisis, crisis and stable periods are presented in the first five columns of table 9, 10 and 11 respectively (in the case of local currency). For the variance decomposition of a given market *i*, "cross shares" shown in the last column of each table is added to aid the analysis of the results; it represents the proportion of forecast error variance due to the effects of all the markets other than *i* or the "cross variance shares" as suggested by Diebold and Yilmaz (2012). This last column of "cross shares" is calculated as 100 minus the percentage of a market's own impact.

For the time interval before the financial crisis, shocks to the innovations of the US market account for around 8%, 20% and 23% of the forecast error variance of the stock markets in Mainland China, Japan and Hong Kong respectively. As indicated by the cross shares, the three markets in Asia explain about 44% of the US forecast error variance.

Table 9. Variance decomposition (local currency: pre-crisis period).

Period	US	JP	HK	CN	Cross shares
Variance Decomposition of US:					
1.00	58.40	18.13	21.42	2.05	41.60
2.00	55.44	18.26	22.24	4.05	44.56
3.00	55.44	18.18	22.20	4.17	44.56
4.00	55.37	18.14	22.15	4.33	44.63
5.00	55.36	18.14	22.15	4.35	44.64
Variance Decomposition of JP:					
1.00	18.79	60.53	19.69	1.00	39.47
2.00	20.44	58.74	19.16	1.66	41.26
3.00	20.38	58.32	19.24	2.07	41.68
4.00	20.58	57.91	19.25	2.27	42.09
5.00	20.58	57.89	19.24	2.29	42.11
Variance Decomposition of HK:					
1.00	20.79	18.43	56.66	4.12	43.34
2.00	23.16	17.75	54.58	4.52	45.42
3.00	23.34	17.63	54.22	4.81	45.78
4.00	23.39	17.63	54.09	4.89	45.91
5.00	23.39	17.62	54.07	4.93	45.93
Variance Decomposition of CN:					
1.00	3.12	1.46	6.47	88.95	11.05
2.00	8.01	5.00	9.68	77.30	22.70
3.00	7.96	5.05	9.47	77.52	22.48
4.00	8.51	5.25	9.62	76.63	23.37
5.00	8.52	5.24	9.63	76.61	23.39

Notes: variance decomposition is reported in the first five columns. For the variance decomposition of a given market, “cross shares” in the last column, calculated as 100 minus the percentage of the market’s own impact, represents the proportion of forecast error variance due to the effects of all the markets other than the market itself.

Table 10. Variance decomposition (local currency: crisis period).

Period	US	JP	HK	CN	Cross shares
Variance Decomposition of US:					
1.00	42.75	24.95	23.97	8.33	57.25
2.00	44.84	26.04	20.95	8.18	55.16
3.00	45.24	26.85	20.85	7.06	54.76
4.00	43.23	27.11	22.82	6.84	56.77
5.00	43.56	25.90	23.79	6.75	56.44
Variance Decomposition of JP:					
1.00	23.45	40.19	26.70	9.65	59.81
2.00	31.96	35.48	24.88	7.68	64.52
3.00	37.97	33.30	22.74	5.99	66.70
4.00	37.24	31.60	24.11	7.05	68.40
5.00	37.74	29.19	25.60	7.47	70.81
Variance Decomposition of HK:					
1.00	22.05	26.13	39.33	12.50	60.67
2.00	28.52	23.53	36.28	11.67	63.72
3.00	33.09	22.31	32.65	11.95	67.35
4.00	32.15	23.50	30.27	14.08	69.73
5.00	32.01	22.91	30.35	14.72	69.65
Variance Decomposition of CN:					
1.00	11.12	13.70	18.13	57.04	42.96
2.00	12.37	15.18	17.15	55.30	44.70
3.00	13.41	14.80	14.35	57.44	42.56
4.00	13.92	15.34	11.11	59.64	40.36
5.00	13.74	15.69	10.03	60.55	39.45

Notes: variance decomposition is reported in the first five columns. For the variance decomposition of a given market, "cross shares" in the last column, calculated as 100 minus the percentage of the market's own impact, represents the proportion of forecast error variance due to the effects of all the markets other than the market itself.

Additionally, it can be seen from table 9 that most of the error variance of a market can be attributed to the market itself, ranging from around 77% in Mainland China to about 54% in Hong Kong (five-week ahead forecast error variance decomposition). In other words, the linkages of the stock markets are low during the pre-crisis period.

Table 11. Variance decomposition (local currency: stable period).

Period	US	JP	HK	CN	Cross shares
Variance Decomposition of US:					
1.00	53.86	20.86	21.05	4.22	46.14
2.00	54.89	20.25	20.75	4.11	45.11
3.00	55.04	20.15	20.66	4.14	44.96
4.00	55.07	20.14	20.65	4.14	44.93
5.00	55.07	20.14	20.65	4.14	44.93
Variance Decomposition of JP:					
1.00	21.16	54.64	15.59	8.61	45.36
2.00	20.89	54.06	15.63	9.42	45.94
3.00	20.87	54.02	15.63	9.48	45.98
4.00	20.87	54.02	15.63	9.48	45.98
5.00	20.87	54.02	15.63	9.48	45.98
Variance Decomposition of HK:					
1.00	20.80	15.19	53.22	10.79	46.78
2.00	20.57	15.22	52.56	11.64	47.44
3.00	20.58	15.23	52.55	11.65	47.45
4.00	20.58	15.23	52.55	11.65	47.45
5.00	20.58	15.23	52.55	11.65	47.45
Variance Decomposition of CN:					
1.00	5.45	10.95	14.10	69.51	30.49
2.00	5.88	11.23	14.02	68.88	31.12
3.00	5.89	11.22	14.03	68.86	31.14
4.00	5.89	11.22	14.02	68.86	31.14
5.00	5.89	11.22	14.02	68.86	31.14

Notes: variance decomposition is reported in the first five columns. For the variance decomposition of a given market, "cross shares" in the last column, calculated as 100 minus the percentage of the market's own impact, represents the proportion of forecast error variance due to the effects of all the markets other than the market itself.

The variance decompositions during the crisis period are substantially different, compared with the pre-crisis period. For example, the effect of US market on the other three markets has increased considerably. The impact of the other markets on the US market has also become stronger. Moreover, the cross-market influence among the three markets in Asia has intensified. Thus, in comparison with the pre-crisis period, the interconnections of the analyzed stock markets have strengthened in the crisis period, which is also reflected by the larger cross shares during the crisis period.

If we define contagion as the increased cross-market linkages during a crisis period, the results in table 9 and 10 provide evidence of contagion. This conclusion is consistent with the previous research on the effect of the recent global financial crisis, such as Cheung et al. (2010) and Nikkinen et al. (2012).

Regarding the variance decomposition during the stable period, table 11 shows that either the US impact on the Asian markets or the impact of the Asian markets on the US market or the linkages within the Asian markets are lower than the crisis period but similar to the pre-crisis period, which implies that the association of the four stock markets has reverted to the pre-crisis level.

To gain a more clear understanding of the connections of the stock markets around the financial crisis, spillover indexes proposed by Diebold and Yilmaz (2012) are reported in table 12. Comparing the directional spillovers from a given market to all the other markets between the pre-crisis and crisis period, we find that the effects of a given market on the other markets have increased. For example, the US impact increased from 52.49% to 83.49%. Similar results for the total spillover index and the directional spillover from all the other markets to a given market are found. The perceived behavior of the spillover indexes in this study is analogous to the previous studies on the impact of the subprime crisis (see e.g., Awartani, Maghyereh and Shiab 2013).

Table 12. Spillover indexes (local currency).

	US	JP	HK	CN	From all
Panel A: pre-crisis period					
US	55.36	18.14	22.15	4.35	44.64
JP	20.58	57.89	19.24	2.29	42.11
HK	23.39	17.62	54.07	4.93	45.93
CN	8.52	5.24	9.63	76.61	23.39
To all	52.49	41.00	51.02	11.57	**39.02**
Panel B: crisis period					
US	43.56	25.90	23.79	6.75	56.44
JP	37.74	29.19	25.60	7.47	70.81
HK	32.01	22.91	30.35	14.72	69.65
CN	13.74	15.69	10.03	60.55	39.45
To all	83.49	64.50	59.42	28.94	**59.09**
Panel C: stable period					
US	55.07	20.14	20.65	4.14	44.93
JP	20.87	54.02	15.63	9.48	45.98
HK	20.58	15.23	52.55	11.65	47.45
CN	5.89	11.22	14.02	68.86	31.14
To all	47.34	46.59	50.30	25.27	**42.37**

Notes: the spillover indexes are obtained by the five-week ahead forecast error variance decomposition. "To all" in the last row of each panel is the spillover index from a given market (in the column) to all the other markets. "From all" in the last column is the spillover index from all the other markets to a given market (in the row). The numbers in bold are the total spillover indexes.

For the return spillovers during the stable period, we observe that the spillover indexes are smaller than the corresponding indexes in the crisis period and comparable to the figures in the pre-crisis period, indicating that the intensified interdependence of the stock markets during the global financial crisis disappeared after the crisis. One exception is the Chinese stock market which shows sustained higher connections after the crisis. This result, however, is not supported by the analysis using the data in common currency.

The evaluation of variance decomposition above is based on the data in local currency. Although there are some differences when the price levels in common currency are investigated, the results of which are reported in table 17 ,18, 19 and 20 in the appendix, the general conclusions about the effect of the recent global financial crisis are the same.

7. CONCLUSION

This thesis examines the integration and return spillovers of the stock markets in the US, Japan, Hong Kong and Mainland China for the time periods before, during and after the subprime crisis. The data both in local currency and in US dollar are applied in the study.

Some insightful findings are obtained from the study. Firstly, just as expected, the financial crisis has decreased the market returns and increased the market volatility. Secondly, the simple correlations between the included stock markets become stronger during the crisis. Then the degree of correlations declines to a level similar to that of the pre-crisis period, except for the Chinese stock market which shows continued stronger connections with the other markets after the crisis. The higher correlations observed during the crisis should be interpreted with caution as Forbes and Rigobon (2002) point out that simple correlations of the stock markets during a crisis period may be biased upward due to the impact of the market volatility.

Thirdly, the tests for cointegration indicate that the financial crisis has also intensified the long-term linkages of the stock markets and this strengthening effect tends to be impermanent. Fourthly, the Granger causality tests provide some evidence that the impact of the Asian stock markets on the US market during the crisis is larger than that of the pre-crisis period. Lastly, the variance decomposition suggests that the interdependences of the selected stock markets are stronger during the crisis period and the increased inter-linkages of the markets do not sustain after the crisis. The spillover indexes of the returns further confirm the results of the variance decomposition, suggesting that more intense cross-market spillovers occur during the crisis period. The spillover indexes also reveal that in the local currency case, the Chinese stock market has become more strongly integrated with the international markets during the stable period than the pre-crisis period.

Some practical implications can also be derived from the study. For instance, the increased stock market linkages during the crisis period, combined with the fact that the average returns during the crisis are negative, imply that the benefits of international diversification of the equity investments are limited and relative to the stock investment, fixed income investments generating positive returns may be a better way to invest the money during the crisis. Furthermore, the high interconnection (short-term and long-term) of the stock markets during a financial crisis entails the cooperated efforts between governments to cope with financial crises.

Future study of this topic could use other methods to explore the international stock market integration, such as dynamic conditional correlation model. The thesis could be expanded by further examining the return and volatility spillovers between the bond, foreign exchange and stock markets. The thesis could also be extended by a comparative study of the integration of the emerging and frontier stock markets.

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APPENDIX:

Table 13. Market indicators**.**

	2004	2005	2006	2007	2008	2009	2010	2011	2012
China									
Number of listed domestic companies	1384	1387	1440	1530	1604	1700	2063	2342	2494
Market capitalization (billions US$)	639.765	780.763	2426.326	6226.305	2793.613	5007.646	4762.837	3389.098	3697.376
Market capitalization (% of GDP)	33.1	34.6	89.4	178.2	61.8	100.3	80.3	46.3	44.9
Stocks traded, total value (% of GDP)	38.7	26	60.3	223	121	179.4	135.4	104.8	70.8
Stocks traded, turnover ratio (%)	113.3	82.5	102	180.1	121.3	229.6	164.4	188.2	164.4
Hong Kong									
Number of listed domestic companies	1014	1020	1021	1029	1251	1308	1396	1472	1459
Market capitalization (billions US$)	665.248	693.486	895.249	1162.566	1328.837	915.825	1079.64	889.597	1108.127
Market capitalization (% of GDP)	393.4	381.9	462.6	549.4	606	427.9	472.1	357.7	420.9
Stocks traded, total value (% of GDP)	166.5	162	208.7	433.3	741.6	695.9	698.5	623.8	467
Stocks traded, turnover ratio (%)	46.3	43.3	50.8	89.1	130.5	132.7	160.1	157.6	123.1
Japan									
Number of listed domestic companies	3220	3279	3362	3844	3299	3208	3553	3961	3470
Market capitalization (billions US$)	3678.262	4736.513	4726.269	4453.475	3220.485	3377.892	4099.591	3540.685	3680.982
Market capitalization (% of GDP)	79	103.6	108.5	102.2	66.4	67.1	74.6	60	61.8
Stocks traded, total value (% of GDP)	73.7	109.3	143.5	149.1	121.2	83.3	77.9	70.6	60.5
Stocks traded, turnover ratio (%)	102.1	118.8	132.1	141.6	153.2	127.1	114.5	108.9	99.8
United states									
Number of listed domestic companies	5231	5143	5133	5130	5603	4401	4279	4171	4102
Market capitalization (billions US$)	16323.73	16970.87	19425.86	19947.28	11737.65	15077.29	17138.98	15640.71	18668.33
Market capitalization (% of GDP)	138.4	135.1	145.9	142.9	82.5	108.5	118.9	104.3	119
Stocks traded, total value (% of GDP)	164.1	171.2	249.9	305.2	450.2	336.3	211.2	205.1	136.3
Stocks traded, turnover ratio (%)	126.5	129.2	182.8	216.5	404.1	348.6	189.1	187.6	124.6

Source: website of the World Bank.

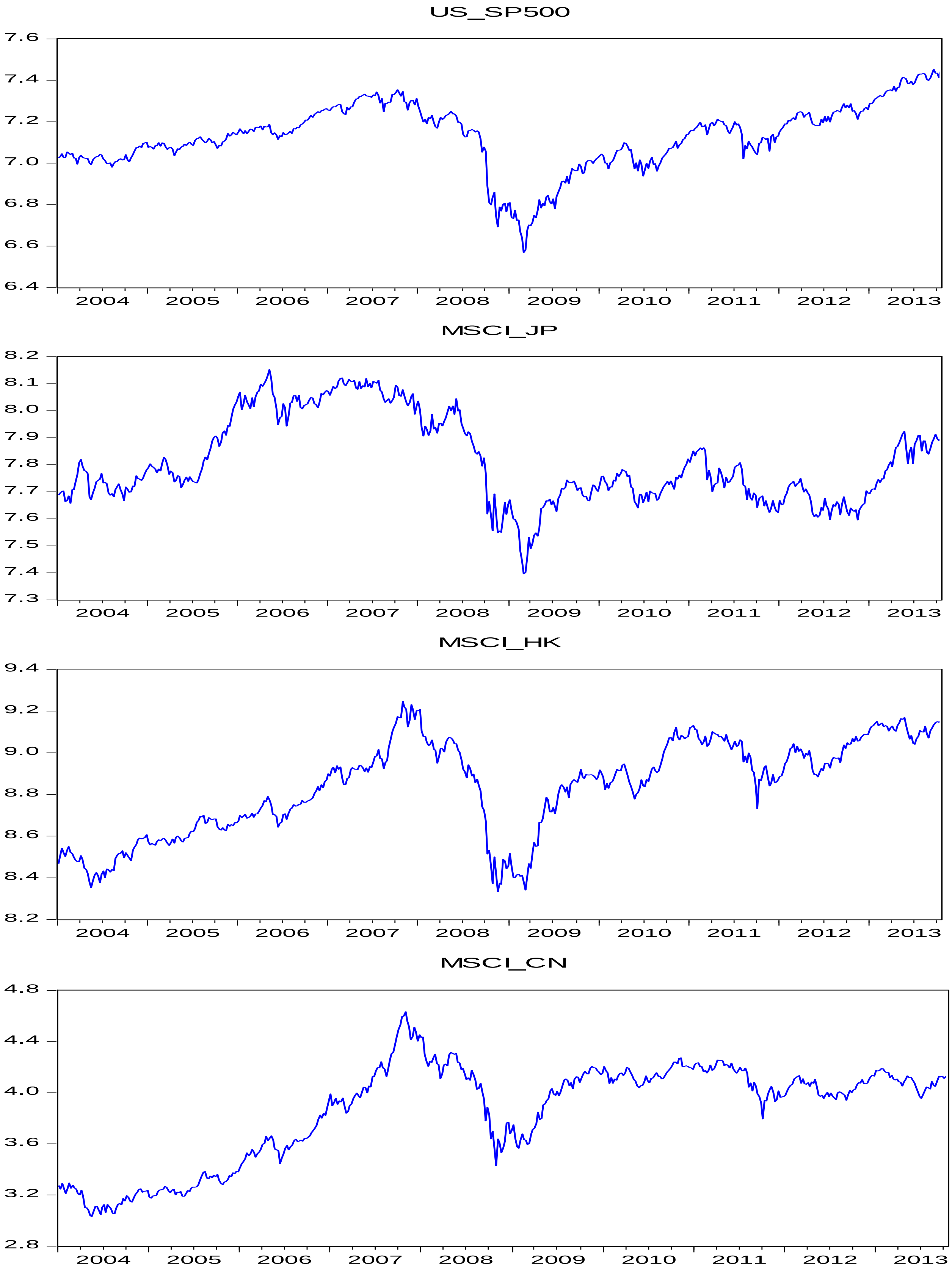

Figure 5. Time series of the indexes (common currency: natural logarithm of the index).

Table 14. Descriptive statistics of the returns (common currency).

	US	JP	HK	CN
Panel A: pre-crisis period				
Mean	0.10	0.14	0.27	0.45
Median	0.16	0.40	0.38	0.74
Maximum	4.00	6.11	7.81	8.45
Minimum	-6.25	-8.74	-10.43	-13.32
Std. Dev.	1.58	2.41	2.45	3.68
Observations	227.00	227.00	227.00	227.00
Panel B: crisis period				
Mean	-0.71	-0.61	-0.56	-0.51
Median	-0.27	-0.66	-1.08	0.51
Maximum	9.64	13.61	12.72	20.89
Minimum	-16.45	-15.06	-15.80	-18.63
Std. Dev.	4.44	4.53	5.29	7.27
Observations	58.00	58.00	58.00	58.00
Panel C: transition period				
Mean	0.27	-0.02	0.13	0.00
Median	0.52	0.01	0.13	0.23
Maximum	7.07	5.55	14.03	14.36
Minimum	-11.74	-10.76	-10.83	-12.41
Std. Dev.	2.64	2.44	3.16	3.66
Observations	129.00	129.00	129.00	129.00
Panel D: stable period				
Mean	0.32	0.25	0.29	0.17
Median	0.30	0.58	0.47	0.28
Maximum	3.86	7.06	5.01	5.83
Minimum	-3.64	-6.38	-5.43	-6.14
Std. Dev.	1.62	2.53	2.12	2.61
Observations	93.00	93.00	93.00	93.00

Notes: the table provides the descriptive statistics of the returns which are calculated as 100 times the difference of the ln(price index).

Table 15. Correlation of the returns (common currency).

	US	JP	HK	CN
Panel A: pre-crisis period				
US	1.00			
JP	0.42***	1.00		
HK	0.56***	0.53***	1.00	
CN	0.49***	0.50***	0.83***	1.00
Panel B: crisis period				
US	1.00			
JP	0.58***	1.00		
HK	0.65***	0.77***	1.00	
CN	0.55***	0.75***	0.86***	1.00
Panel C: transition period				
US	1.00			
JP	0.50***	1.00		
HK	0.64***	0.47***	1.00	
CN	0.66***	0.43***	0.93***	1.00
Panel D: stable period				
US	1.00			
JP	0.57***	1.00		
HK	0.56***	0.53***	1.00	
CN	0.55***	0.42***	0.83***	1.00

Notes: *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table 16. ADF unit root test (US dollar)**.**

	level		first difference	
	1	2	1	2
Pre-crisis period:				
US	-1.16	-2.65	-18.07***	-18.03***
JP	-1.64	-1.81	-14.98***	-14.98***
HK	-0.64	-2.89	-14.98***	-14.96***
CN	0.08	-2.69	-14.01***	-14.03***
Crisis period:				
US	-1.73	-0.92	-6.55***	-6.56***
JP	-1.93	-1.12	-7.91***	-4.45***
HK	-1.87	-0.66	-2.91**	-8.10***
CN	-2.04	-1.25	-7.94***	-7.60***
Transition period:				
US	-3.19**	-3.44**	-13.36***	-13.43***
JP	-2.43	-2.35	-12.99***	-13.13***
HK	-2.46	-1.95	-11.83***	-11.96***
CN	-2.41	-2.66	-12.60***	-12.72***
Stable period:				
US	-0.78	-2.79	-11.72***	-11.65***
JP	-0.79	-2.00	-10.34***	-8.44***
HK	-1.73	-2.26	-9.44***	-9.41***
CN	-2.10	-2.14	-9.48***	-9.42***

Notes: “level” = natural logarithm of the index price. “1” and “2” are the ADF tests without trend and with trend, respectively. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table 17. Variance decomposition (common currency: pre-crisis period).

Period	US	JP	HK	CN	Cross shares
Variance Decomposition of US:					
1.00	52.96	10.85	19.66	16.53	47.04
2.00	51.35	11.90	20.14	16.60	48.65
3.00	51.32	11.92	20.15	16.61	48.68
4.00	51.33	11.92	20.15	16.61	48.67
5.00	51.32	11.92	20.15	16.61	48.68
Variance Decomposition of JP:					
1.00	12.08	58.97	15.44	13.50	41.03
2.00	12.87	58.44	15.31	13.38	41.56
3.00	13.04	58.24	15.33	13.39	41.76
4.00	13.04	58.23	15.33	13.39	41.77
5.00	13.04	58.23	15.33	13.39	41.77
Variance Decomposition of HK:					
1.00	15.97	11.26	43.00	29.77	57.00
2.00	17.06	11.11	42.42	29.41	57.58
3.00	17.22	11.16	42.30	29.32	57.70
4.00	17.22	11.17	42.29	29.32	57.71
5.00	17.22	11.17	42.29	29.32	57.71
Variance Decomposition of CN:					
1.00	13.98	10.25	31.00	44.77	55.23
2.00	16.36	9.95	30.08	43.61	56.39
3.00	16.57	10.06	30.02	43.36	56.64
4.00	16.57	10.06	30.02	43.35	56.65
5.00	16.57	10.06	30.02	43.35	56.65

Notes: variance decomposition is reported in the first five columns. For the variance decomposition of a given market, "cross shares" in the last column, calculated as 100 minus the percentage of the market's own impact, represents the proportion of forecast error variance due to the effects of all the markets other than the market itself.

Table 18. Variance decomposition (common currency: crisis period).

Period	US	JP	HK	CN	Cross shares
Variance Decomposition of US:					
1.00	43.60	16.31	20.07	20.01	56.40
2.00	47.72	16.31	17.35	18.62	52.28
3.00	48.03	17.01	16.66	18.30	51.97
4.00	45.90	16.91	16.77	20.42	54.10
5.00	45.07	15.86	16.65	22.42	54.93
Variance Decomposition of JP:					
1.00	15.77	42.14	20.59	21.49	57.86
2.00	20.27	38.09	20.04	21.60	61.91
3.00	24.21	37.27	18.19	20.33	62.73
4.00	24.97	35.84	17.51	21.68	64.16
5.00	25.01	33.58	17.51	23.90	66.42
Variance Decomposition of HK:					
1.00	16.81	17.84	36.51	28.84	63.49
2.00	22.79	14.44	32.59	30.19	67.41
3.00	27.45	13.12	30.13	29.29	69.87
4.00	28.11	12.69	28.39	30.80	71.61
5.00	28.01	11.91	27.49	32.59	72.51
Variance Decomposition of CN:					
1.00	16.64	18.49	28.63	36.25	63.75
2.00	20.29	15.18	27.81	36.72	63.28
3.00	24.95	13.27	26.75	35.04	64.96
4.00	25.92	13.08	26.09	34.91	65.09
5.00	25.43	12.73	26.07	35.77	64.23

Notes: variance decomposition is reported in the first five columns. For the variance decomposition of a given market, “cross shares” in the last column, calculated as 100 minus the percentage of the market’s own impact, represents the proportion of forecast error variance due to the effects of all the markets other than the market itself.

Table 19. Variance decomposition (common currency: stable period).

Period	US	JP	HK	CN	Cross shares
Variance Decomposition of US:					
1.00	48.07	19.27	17.88	14.78	51.93
2.00	48.82	18.77	17.64	14.76	51.18
3.00	48.97	18.72	17.58	14.74	51.03
4.00	48.99	18.72	17.56	14.73	51.01
5.00	48.99	18.72	17.56	14.73	51.01
Variance Decomposition of JP:					
1.00	20.96	52.30	16.07	10.67	47.70
2.00	20.65	51.82	16.66	10.88	48.18
3.00	20.79	51.75	16.60	10.86	48.25
4.00	20.81	51.73	16.59	10.86	48.27
5.00	20.81	51.73	16.59	10.86	48.27
Variance Decomposition of HK:					
1.00	15.45	12.76	41.53	30.26	58.47
2.00	15.63	14.20	40.52	29.65	59.48
3.00	15.64	14.37	40.41	29.58	59.59
4.00	15.64	14.37	40.41	29.58	59.59
5.00	15.64	14.37	40.41	29.58	59.59
Variance Decomposition of CN:					
1.00	13.73	9.11	32.53	44.63	55.37
2.00	13.76	9.16	32.49	44.59	55.41
3.00	13.77	9.17	32.49	44.58	55.42
4.00	13.77	9.17	32.49	44.58	55.42
5.00	13.77	9.17	32.48	44.58	55.42

Notes: variance decomposition is reported in the first five columns. For the variance decomposition of a given market, “cross shares” in the last column, calculated as 100 minus the percentage of the market’s own impact, represents the proportion of forecast error variance due to the effects of all the markets other than the market itself.

Table 20. Spillover indexes (common currency).

	US	JP	HK	CN	From all
Panel A: pre-crisis period					
US	51.32	11.92	20.15	16.61	48.68
JP	13.04	58.23	15.33	13.39	41.77
HK	17.22	11.17	42.29	29.32	57.71
CN	16.57	10.06	30.02	43.35	56.65
To all	46.83	33.14	65.50	59.32	**51.20**
Panel B: crisis-period					
US	45.07	15.86	16.65	22.42	54.93
JP	25.01	33.58	17.51	23.90	66.42
HK	28.01	11.91	27.49	32.59	72.51
CN	25.43	12.73	26.07	35.77	64.23
to all	78.45	40.50	60.24	78.91	**64.52**
Panel C: stable period					
US	48.99	18.72	17.56	14.73	51.01
JP	20.81	51.73	16.59	10.86	48.27
HK	15.64	14.37	40.41	29.58	59.59
CN	13.77	9.17	32.48	44.58	55.42
To all	50.22	42.26	66.64	55.17	**53.57**

Notes: the spillover indexes are obtained by the five-week ahead forecast error variance decomposition. "To all" in the last row of each panel is the spillover index from a given market (in the column) to all the other markets. "From all" in the last column is the spillover index from all the other markets to a given market (in the row). The numbers in bold are the total spillover indexes.