Return and volatility spillover effects among Vietnam, Singapore and Thailand stock markets – A multivariate GARCH analysis

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Abstract

In this study, we examine the own- and cross-effects of the return and volatility spillover between the equity markets of Vietnam and the two ASEAN countries, namely, Singapore and Thailand using monthly stock returns. In attempt to explore the level and magnitude of the spillover effects of the other markets on the Vietnamese stock market, we apply the multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) framework. By utilizing the time-varying conditional volatility and conditional correlations between the stock markets which are resulted from estimation of the GARCH-BEKK model, the study also further shed light on the issues of portfolio diversification. In general, the study found the weak return linkages among the markets. Specifically, the study found no return linkages between Vietnam and Thailand and the unidirectional relationship between Vietnam and Singapore. However, the volatility linkages are highly significant for the three stock markets. It is found that the shock transmission relationship between emerging markets (i.e. Vietnam, Thailand) and developed market (i.e. Singapore) is unidirectional in direction to the emerging markets and the volatility transmission relationships between those are bidirectional. Besides, the variation in Vietnamese stock volatility is found to be more strongly influenced by the past own-shock effects than the past cross-shock effects. This indicates the low level of financial integration of Vietnam into the regional markets and implies the potential rooms for the international portfolio diversification gains. The findings on the return and volatility linkages have several important implications for both investors and policy makers. Firstly, because of the low correlations between the stock markets found, the investors can earn the gains from the portfolio diversification in the three markets. Secondly, the Vietnamese policy makers should be concerned with the harmful volatility spillover originating in the Thailand market that can affect the stability of the stock market. Thirdly, the implication is related to the monetary policy. The finding that the own shock transmissions have the strongest impact on the Vietnamese market's volatility suggest that the policy makers should pay more attention to the domestic shocks so that the adequate and timely policy can be made.

Keywords

Stock Return, Volatility spillovers, Vietnam, Singapore, Thailand, Multivariate GARCH

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DECLARARTION

With exception of due references specifically specified in the text and such helps clearly acknowledged in the thesis, I hereby declare that this thesis is my own work and has not been previously submitted for any other degree or diploma to any other University or Institution.

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VO THI NGOC TRINH

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ABSTRACTS

In this study, we examine the own- and cross-effects of the return and volatility spillover between the equity markets of Vietnam and the two ASEAN countries, namely, Singapore and Thailand using monthly stock returns. In attempt to explore the level and magnitude of the spillover effects of the other markets on the Vietnamese stock market, we apply the multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) framework. By utilizing the time-varying conditional volatility and conditional correlations between the stock markets which are resulted from estimation of the GARCH-BEKK model, the study also further shed light on the issues of portfolio diversification.

In general, the study found the weak return linkages among the markets. Specifically, the study found no return linkages between Vietnam and Thailand and the unidirectional relationship between Vietnam and Singapore. However, the volatility linkages are highly significant for the three stock markets. It is found that the shock transmission relationship between emerging markets (i.e. Vietnam, Thailand) and developed market (i.e. Singapore) is unidirectional in direction to the emerging markets and the volatility transmission relationships between those are bidirectional. Besides, the variation in Vietnamese stock volatility is found to be more strongly influenced by the past own-shock effects than the past cross-shock effects. This indicates the low level of financial integration of Vietnam into the regional markets and implies the potential rooms for the international portfolio diversification gains.

The findings on the return and volatility linkages have several important implications for both investors and policy makers. Firstly, because of the low correlations between the stock markets found, the investors can earn the gains from the portfolio diversification in the three markets. Secondly, the Vietnamese policy makers should be concerned with the harmful volatility spillover originating in the Thailand market that can affect the stability of the stock market. Thirdly, the implication is related to the monetary policy. The finding that the own shock transmissions have the strongest impact on the Vietnamese market's volatility suggest that the policy makers should pay more attention to the domestic shocks so that the adequate and timely policy can be made.

Key words: *Stock Return, Volatility Spillovers, Vietnam, Singapore, Thailand, Multivariate GARCH.*

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LIST OF ABBREVIATIONS

ACF: Autocorrelation Function

ADF: Augmented Dickey-Fuller

APEC: Asia-Pacific Economic Cooperation

ARCH: Autoregressive Conditional Heteroskedasticity

ASEAN: Association of Southeast Asian Nations

BEKK: Baba, Engle, Kraft and Kroner

BFGS: Broyden-Fletcher-Goldfarb-Shanno method

CCC: Constant Conditional Correlation

DAX: Deutscher Aktien indeX

DCC: Dynamic Conditional Correlation

ECM: Error Corrected Model

EGARCH: Exponential Generalized Autoregressive Conditional Heteroskedasticity

FTSE: Financial Times Stock Exchange Index

GARCH: Generalized Autoregressive Conditional Heteroskedasticity

GDP: Gross Domestic Product

GJR-GARCH: The Glosten-Jagannathan-Runkle GARCH

ISEQ: Irish Stock Exchange Overall Index

LM: Lagrange Multiplier

MGARCH: Multivariate GARCH

OLS: Ordinary least squares

PARCH: Power Autoregressive Conditional Heteroskedasticity

PP: Phillips-Perron

RSET: Returns of SET index

RSGE: Returns of SGE index

RVNI: Returns of VN index

SEATS: Signal Extraction in ARIMA Time Series

SET: Stock Exchange of Thailand

SGE: Singapore Stock Exchange

TRAMO: Time series Regression with ARIMA noise, Missing observations, and Outliers

U.K.: the United Kingdom

U.S.: the United States of America

VAR: Vector Auto-Regression

VNI: VN Index

WTO: World Trade Organization

CHAPTER 1

INTRODUCTION

1.1.Problem Statement

Global economic integration interworked with technological innovation and financial liberalization has led to increased international capital flows and facilitates the trading in international securities on different national markets. Associated with the growing trend of integration in financial markets, the stock markets around the world have become more interlinked and interdependent over time. Understanding the interrelationship between financial markets and knowing how the volatility is transmitted between cross stock markets becomes very crucial for investors, market analysts and policy makers over the years. Firstly, it could be helpful to investors in formulating the optimal portfolio diversification. For instance, low extent of correlation between returns of different national stock markets offers the opportunities to investors in diversifying their wealth across national markets to receive maximum returns at the lowest risk. In addition, investors desire to improve the returns by investing in international securities which are expected to have higher rates of returns. Secondly, understanding the market behaviors assists policy makers in issuing relevant financial regulation or effective monetary policies. According to Corsetti et al. (2005), as knowing how shocks of foreign financial markets transmit to the domestic market, the policy makers would have appropriate adjustments in regulation and adequately supervision of financial market, which help to maintain the stability of the overall financial systems.

Acknowledgement of that importance, studies on the correlation and volatility transmission between different national markets have been growing in financial literature over years. The early studies were conducted in the 1970 decade such as Levy and Sarnat (1970), Grubel and Fadner (1971), Lessard (1973), and Solnik (1974). These studies mainly focus on the determinants of international diversification benefits and find the common result that the international financial markets are less interlinked. More recent studies (e.g. Kasa, 1992; Karolyi, 1995; Kearney and Patton, 2000; Elyasiani and Mansur, 2003; and Choudhry, 2004), however, find the unidirectional and bidirectional relationship of return and volatility between the different national markets. The general findings also reveal that in addition to high correlation between these markets, the financial market interdependency has increased after the stock exchange crash in 1987. Nevertheless, these studies almost pay attention to the relationship among the developed stock markets as the common feature. Since the financial crisis in late 1990s, studies for emerging financial markets began to increase. Perhaps due to severe consequences of the crisis, most of studies have been focused on the impact of volatility transmission among emerging markets during financial turmoil and calm period. The findings of these studies, however, were diverged and depended on difference in the research methodologies.

Studies on the financial integration of Asian equity markets have diversified in two directions. One direction of the studies is on the influence of the advanced markets (such as the U.S and Japan) on the Asian stock markets (Liu and Pan, 1997; Xu and Fung, 2002; and Li and Rose, 2008). It is consistently found that the Asian equity markets are strongly influenced by the developed stock markets in terms of return and volatility transmission. Another direction of the studies is on the intra-regional interaction and shock transmission among the Asian stock markets (In et al., 2001; Jang and Sul, 2002; Worthington and Higgs, 2004; Gunasinghe, 2005; and Hashmi and Tay, 2007). Jang and Sul (2002) studied the change in level of correlation between Asian stock markets during the period of Asian Financial Crisis and found that the correlation among these markets increase during the crisis time. Hashmi and Tai (2007) found supportive evidence of the financial market interrelationship between Asian markets including Korea, Thailand, Singapore, Taiwan, Malaysia and China. Furthermore, these studies have established the dominant role of the developed Asian stock markets including Japan, Hongkong and Singapore as largest investment centers in Asia with large extent of influence and volatility transmission. Still, other Asian markets such as Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand are classified as emerging markets.

It is the common belief that the deregulation and liberalization in financial markets in Association of Southeast Asian Nations (ASEAN) region since the latter 1980s have brought the significant development in the regional economies. With competitive rate of returns and the high output growth rate, the ASEAN stock markets have become an attractive source of investment opportunity for foreign investors, hence attracted the large flow of international portfolio investment. As a latest member of ASEAN in 1995, the Vietnamese stock market is likely the youngest market among the six ASEAN stock markets (namely, Singapore, Indonesia, Malaysia, the Philippines, Thailand and Vietnam). Since established in July 2000, Vietnamese stock market has quickly become a vital channel of the financial system in promoting capital mobility, short- and long-term investment as well as effective capital allocation, which have considerably contributed to the economic growth by providing funds for the economic activities. Beginning with the market value of less than 1% of GDP and about 26 listed firms in the first four years, the stock market has dramatically developed and reached the peak in 2007 with 121 listed companies and nearly 1150-points VN index, accounting for approximately 30% of the GDP. However, since the negative impacts of the global financial crisis in 2008, despite the number of listed companies increased to 275, the ratio of market capitalization to GDP declined to 22% in the year 2010. The significant growth of Vietnamese stock market has been possibly attributed to the financial openness and integration to the world (i.e., participation of Vietnam in ASEAN, APEC, and recently WTO). However, it is the fact that the increasing trend of globalization has brought not only great benefits to the Vietnamese financial market and the overall economy of Vietnam, but also the general challenge to Vietnamese stock markets. As an illustration, during the global financial market crisis began in summer 2007, the Vietnamese stock index dropped from the recorded high at 1138 points in February 2007 to 245 points in February 2009, equivalent to about 75% loss. Likewise, the GDP growth rate declined to 5.3% in 2009 from 8.5% in 2007.

In spite of such greatly international impact, it seems that the studies of international relationship of Vietnamese stock market have not attracted much interest of the researchers. Although there are many studies on volatility, linkages, and volatility transmission among intra-regional ASEAN stock markets, these studies have not constantly included the Vietnamese stock market. In fact, there are a few studies on the development of Vietnamese stock market and the policy impact on the Vietnamese stock market (e.g., Loc, 2006; A. Farber, Vuong Q.H et al., 2006; Thuan LT., 2011). However, the studies on the relationship between Vietnamese stock market and the other regional stock markets have not been conducted adequately. Therefore, it is our great desire to study about the interrelationship between Vietnamese stock market and other intra-regional stock markets, specifically Singapore and Thailand markets. The Singapore and Thailand stock markets are specifically selected in analyzing the interactions with the Vietnam stock market for several motivations. *Firstly*, the Singapore stock market is the leading financial center in ASEAN region. With long history of share trading for over one hundred years, Singapore stock market is known as the largest exchange in the region in terms of market capitalization and trade volumes.

Although Singapore was not spared from the contagion effects of the 1997 Asian financial crisis and the 2007 global crisis, the Singapore stock market has been kept to a manageable level and has recovered its health better than the other regional markets. So far, the Singapore stock exchange is still a premier global exchange where foreign companies account for 45% of its market capitalization. *Secondly,* the inclusion of Thailand in the study is due to some reasons. Thailand is likely to have the significant influence on the other regional economies although it is considered as the newly industrializing country. It is commonly believed that the Asian financial crisis originating from the depreciation of Thailand currency in 1997 has the extremely negative effects on the other countries in the region as well as beyond the region. In addition, the Thailand's economic structure is likely similar to the Vietnam's, which heavily rely on the agricultural production. Furthermore, Thailand stock market is still a closest neighboring market to the Vietnam's. For such reasons, it would be worthwhile to include Thailand market in examining the interdependent relationship with the Vietnamese stock market. Different from the existing empirical studies that they merely focus the attention on the first moment linkages or the return spillovers, our study considers both the first and the second moment linkages (i.e. return spillover and volatility transmission) among the three selected ASEAN equity markets, namely Vietnam, Singapore, and Thailand. As indicated by Chuang et al. (2007:3) that *"the multivariate GARCH models have been proven to be very successful at capturing volatility clustering and the dynamic relationships among volatility processes of multiple-asset returns"*, our method of choice suggested in this study is the multivariate GARCH approach with unrestricted BEKK[1] specification to jointly model the conditional mean and conditional volatility of stock returns (see Engle and Kroner, 1995), hence it is possible to capture the own and cross volatility spillovers among the studied markets. Furthermore, the multivariate GARCH approach allows identifying the direction of interrelationship in analyzing the multiple financial series.

1.2.The Research Objectives

The broad objective of the research is to identify the cross-market linkages between Vietnamese stock market and the major ASEAN stock markets, namely the Stock Exchange of Thailand and Singapore. Based on the estimated results, the weights of one index in an

[1] BEKK stands for Baba, Engle, Kraft, and. Kroner

optimal portfolio diversification are calculated. From there, investment strategies and policy implications are suggested. The specific purposes of the study are:

(1) To examine the return/mean spillover between Vietnamese and the two regional stock markets.
(2) To examine the process of volatility transmission across the regional equity markets through the conditional volatility and conditional correlation effects. Volatilities are examined through the past shocks and volatility both existing in each market and coming from other markets.
(3) To suggest the policy and investment implication.

1.3.The Research Questions

According to the thesis objectives, the research questions are addressed as follows:

(1) Do the linkages among three stock markets in ASEAN-3 region exist in terms of return? How does a country's stock market influence on other stock markets in the region if such linkages exist?
(2) How much of the volatility in a country's stock returns can be explained by the own- and the cross- innovations and volatility? Which channels of the innovation and volatility transmissions are more influential in explaining the volatility of one stock market?
(3) Are there any portfolio diversification benefits among the three markets? With such portfolio of these markets, what are the weights of the stocks in the optimal portfolio holdings?

1.4.The Research Contribution

In existing literature, the relationships between the stock exchange of Vietnam and other regional countries, in terms of both the return linkages and volatility spillover, still remain unexplored. Therefore, it is expected that this study will help to get extra understanding the return linkages and volatility transmission process among Vietnamese stock market and the larger equity markets in the ASEAN region, namely Singapore and Thailand. The empirical findings will support investors in well diversifying their wealth and adequately adjusting their portfolios by observing the trend of conditional correlation and the process of cross-market volatility transmission. Likewise, policymakers have useful information in making appropriately regulatory decisions for improving the efficiency of home stock markets. Lastly, the study is hoped to contribute to moderately existing literature for Vietnamese stock market.

1.5.Structure of the thesis

The remaining chapters in this thesis are organized as follows:

Chapter 2 provides an overall comparison of three studied stock markets through discussing the restrictions on foreign investment in each equity markets, market comparison (i.e., market size, liquidity and portfolio equity net inflow) and the trends of stock indices.

Chapter 3 reviews the literature relevant to the thesis objectives. Both theoretical and empirical reviews of international stock market linkages are presented in terms of return interdependencies and volatility transmission. In addition, the development and widely application of the multivariate GARCH approach are reviewed in this chapter.

Chapter 4 presents the research methodology, which includes data collection and data source. The statistical tests and econometric models employed in this study are also discussed in detail.

Chapter 5 presents the data description and research findings to answer the research questions. The descriptive statistics and the empirical results are reported and analyzed in this chapter.

Chapter 6 ends the thesis with a conclusion, policy implications, and limitations. A recommendation for further studies is also included.

CHAPTER 2

THE STOCK MARKETS IN COMPARISON

This chapter focuses on a comparison of the three ASEAN countries' stock markets and thus explores several concerned issues to the interrelationship among these markets such as (1) overview of the foreign investment restrictions in the equity markets under study; (2) market comparison in terms of market capitalization, liquidity and the portfolio equity inflows; and (3) the trends of movement of the stock market indices.

2.1.Overview of the restriction on the foreign equity ownership of the stock markets

Among many types of constraints on capital movements across markets (i.e. discriminatory taxes, asymmetric information, macroeconomic uncertainty, and different standards of public disclosure), the restrictions on foreign security ownership create significant barriers in direct portfolio investments which reflect the level of stock market integration (Bekaert and Harvey, 2000). The fewer barriers to foreign portfolio investment, which are normally associated with the higher foreign capital flows into the stock market, imply the larger extent of market integration. Because the integration in capital market represents the linkages among the world capital markets, the barriers to portfolio investment in one market can indicate the extent of linkages between that market and the foreign markets. In light of that, this section reviews the regulatory restriction on foreign portfolio investment in each stock market under study in order to have a visual view of the linkages among the national markets.

Through reducing the barriers of foreign investment since 1980s, the major foreign investment of Thailand has been dominated by the short-term portfolio investment in the stock market. However, foreign investment was restricted by limiting the percentage of foreign shareholders up to 49% of the total in Thailand companies. Besides, foreign companies are not allowed to list in Thailand stock market. The Stock Exchange of Thailand has segmented into the local and foreign board of trading in securities. While the local board is used for trading common shares to the local investors as the main board, the foreign board is used for trading in securities to the foreign security holders. The share price in the foreign board is higher than in the main board. In despite of the limitation of foreign ownership in stock market, foreign investment in Thai market still increases over years. This can be explained by either the capital gain in stock price or dividend from high stock return.

Recently, the new law of capital control to foreign investors in 2007, which narrowed the sectors subject to the limitation of foreign ownership, has much eroded the foreign investor confidence. Specifically, the foreign investors have been required to sell their holdings or to give up any voting rights in case that their ownership stake exceeds 50 percent or even less than that. This restriction is widely believed as a reaction to the event of large-scale selling of shares in the telecommunications company owned by the previous Prime Minister Thaksin's family to a Singapore state-owned enterprise. Although this rule has significantly affected many listed companies in revising their structure of equity holdings, the new restriction showed the positive effect in recovering Thai stock index as soon as proposed (*source: The Associated Press Published on January 9, 2007*). Evidently, the restriction seems to be successful in protecting the national market from the international influence by reducing the accessibility of foreign investors in seeking portfolio investment to Thai Stock Exchange. This also implies that the linkages between Thailand equity market and other abroad markets have more diminished since the new barriers appeared.

In Vietnamese stock market, the percentage of foreign ownership is limited differently upon certain sectors. Specifically, foreign investment is limited to 49 percent in all public companies and to 30 percent in joint stock commercial banks. In addition, a further restriction related to the trading capacities of foreign investors (i.e. a prohibition against selling shares for three years) makes trouble to the foreign shareholders who join in the company's management. However, the constraints placed on foreign investors have been eased since Vietnam's membership of the WTO. Specifically, the domestic investors and foreign investors are treated equally and allowed to invest in all economic sectors, with exception of defense-related sectors. Recently, the activities of foreign investors in Vietnam's stock market have been expanded through the Decision 121/2008/QD-BTC effective on 1st February 2009, which allows foreign investors to trade in listed and unlisted securities in Vietnam. Therefore, Vietnam's securities market has attracted the large attention of foreign investors in the recent years.

In the meantime, there are no restrictions in foreign trading in local shares of Singapore Stock Exchange, with exception of limitations of foreign ownership in some major industries, in particular, defense-related industries, banking, airline, shipping, and media companies. Recently, the Singapore government has removed the constraint on the foreign ownership of 40% in locally incorporated banks and eased the restriction on that of listed companies in the Singapore stock market from 49% to 70%. While investment in national defense sector is prohibited for both foreign and local investors in Vietnam, the percentage of foreign holdings in defense-related industries in Singapore is less than 25 percent. Besides, Singapore residents are free to invest in foreign securities and investments. In general, due to few limitations in foreign investment, the Singapore market has attracted a large flow of capital into the stocks and become one of the premier international markets in the financial world with listed foreign companies accounting for 40% of market size.

2.2.Market capitalization, liquidity and the number of net portfolio equity inflows

The first two indicators, market capitalization and liquidity, might have an implication of the development of stock market. While market capitalization represents the size of the equity market, the stock market liquidity reflects the degree of equity trading relative to the size of the stock market. The market capitalization is calculated as the product of total amount of issued stocks and the respective stock prices at a given time. The greater stock market capitalization indicates the bigger value of that market. The stock market liquidity is calculated by the ratio of the total stock value traded to the average market capitalization for the period, which is known as the turnover ratio. The higher turnover ratio of the stock market means the higher extent of liquidity of that market, hence attracting more interest to the investors. Meanwhile, the third indicator, net portfolio equity inflows, which is defined as the net inflows from purchasing equity securities into local stock markets by foreign investors (defined by the World Bank), involves the international spillover of return and volatility among international equity markets. It is explained that the stock markets with larger participation of foreign investors might be more volatile because the foreign investors can adjust their international portfolios against shocks in one stock market towards another market, possibly making a shock transmission from that market to another market.

Figure 2.1 presents the picture of market size in billion US dollars of three stock markets, namely, Singapore, Thailand and Vietnam. Again, it shows that Singapore is the largest stock market in terms of market capitalization among these markets. While the Thailand stock market is the second largest, Vietnamese stock market is by far the smallest.

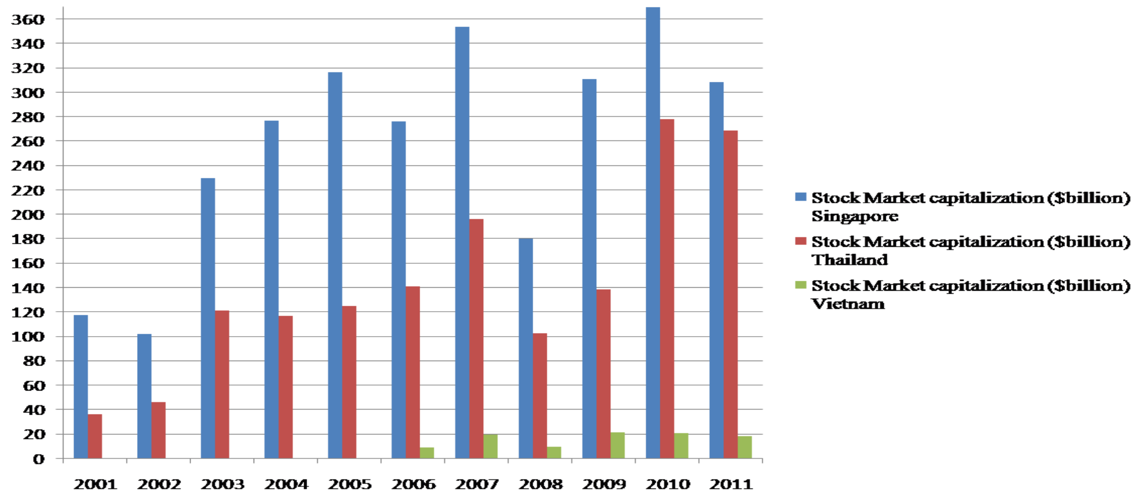

Figure 2.1 – Market capitalization in US$ billion
Source: WTO 2011

Figure 2.2 presents the turnover ratio, which measures the liquidity of the stock market. The turnover value of the Singapore stock market fluctuated over years. The ratio is highest in 2007 and 2010, but has declined in the recent year. The liquidity of Thailand market seems to be higher and more stable than that of Singapore. However, after the 2007 global financial crisis, Thailand has lower level of liquidity compared to Singapore's. This fact reconfirms the better capacity of Singapore stock market in weathering the crisis impact. The Vietnamese market is still the stock exchange with the least liquidity among three markets. However, it is surprised that Vietnam has the highest liquidity level in 2009. This fact might be due to the positive effect of more reforms in 2009, such as ongoing process of equitization and relaxation of constraints on foreign ownership, which make the some securities more liquid for foreign investors to trade.

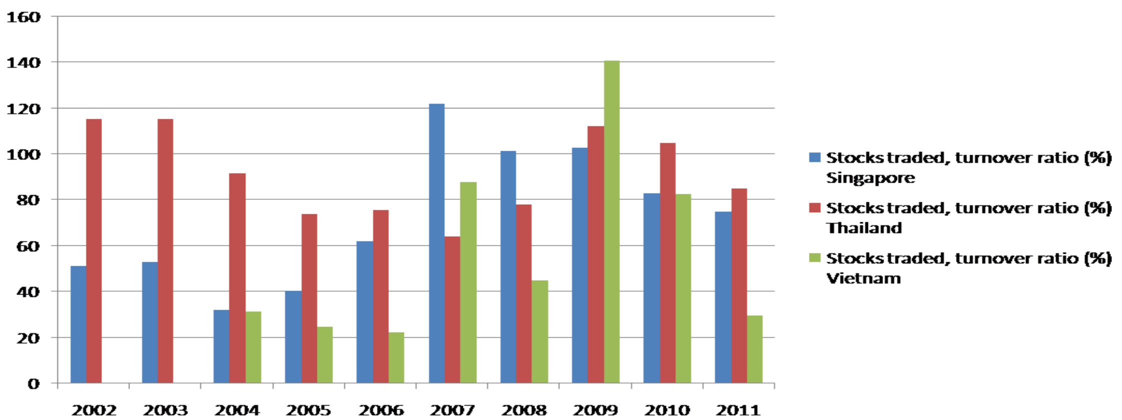

Figure 2.2 – Turnover Ratio in percentage
Source: WTO 2011

The patterns in net equity inflows provide much information about the market integration as well as the market interdependency of different national stock markets. The Figure 2.3 indicates that the portfolio equity net inflows in three stock markets have dramatically increased prior to 2007 global financial crisis. However, this indicator was negative for the three markets in 2008 and then back to positive in the later years, with the exception of Singapore. This phenomenon is attributable to the widespread capital withdrawals of foreign investors from these markets during the crisis time. Among the three markets, Singapore seems to be the most responsive market when the portfolio equity inflow reached the highest level in 2007, but then fell to the lowest level during the global crisis. For Thailand, after falling to negative equity inflows in 2007, this market brought more confidence to the foreign investors with the high increase in the foreign portfolio inflow in one year later. However, Thailand market is still uncompetitive compared with the Singapore in attracting the foreign portfolio investment in the recent years. The amount of equity inflows into the Vietnamese market is still the smallest over years excepting that in 2007 when the bubble in Vietnamese stock market presented. As already mentioned, the portfolio equity flows into a stock exchange indicates the extent of stock market linkages because the foreign investors have flexibility to shift from one market to another market in necessary cases. As a result, the portfolio equity investment tends to be volatile. It also means that the high volume of net portfolio inflows in one stock market indicates the high level of vulnerability of that market.

Portfolio equity, net inflows (US$million)

Years	Singapore	Thailand	Vietnam
2003	2,786	1,787	
2004	2,383	1,319	
2005	4,895	5,121	115
2006	10,143	5,242	1,313
2007	18,306	4,268	6,243
2008	-11,697	-3,802	-578
2009	-324	1,695	128
2010	3,559	2,606	2,383

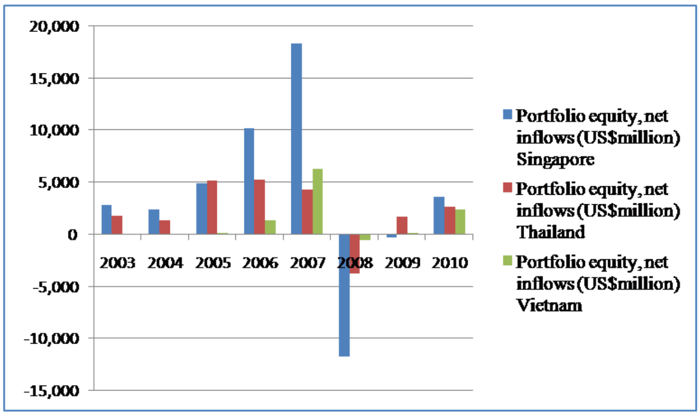

Figure 2.3 – Net portfolio equity inflows
Source: World Bank, 2011

2.3.Trends of the stock market indices

Figure 2.4 presents time plots of the stock index series of three ASEAN countries. The first impression is that all indices have a similar trend of movement. The Singapore index, however, is less fluctuated than the others, except the high trend of decline during the period of the global financial crisis in 2008 - 2009. The Vietnamese and Thailand stock market indices reflect quite a similar trend over time among the three markets. The explanation possibly is that the group of closest neighbor markets might be impacted by similar macroeconomic fundamentals. Moreover, it can be seen that all the indices reached the peak in year 2007 before sharply falling in year 2008. The significant decline in stock indices in 2008 can be attributed to the global effect of the financial crisis. It also implies that all the three stock markets seem to have the similar reactions to the effect of global crisis. However, the downward trend in Singapore market is less than that of Thailand and Vietnam in the same period, which seems to support the finding that the emerging markets are more influenced by the contagion effect of the crisis than the well-developed markets (Dungey et al., 2002). Nevertheless, all stock indices have the significantly upward-trend during recent years, especially SGE index and SET index.

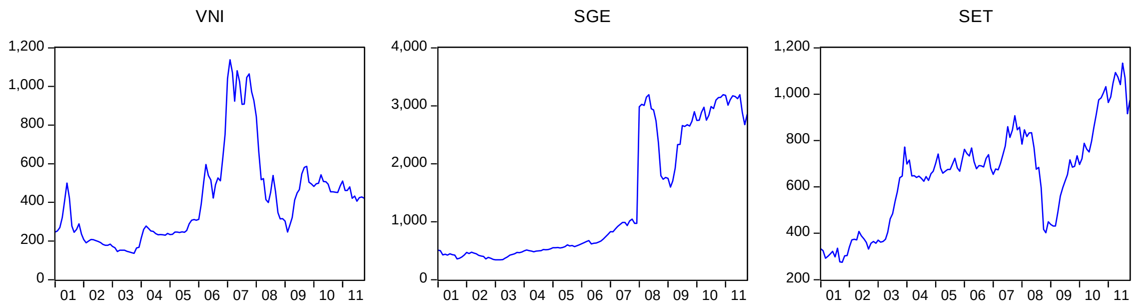

Figure 2.4 - Trends of the stock market indices over years

Finally, several matters have been emerged subsequent to the simple observation of the trend of the indices. First, the fact that Thailand and Vietnamese market seems to move together could be a signal of close relationship between the two. Second, the largest market in the region such as Singapore stock market might have the largest impact on the others, as the previous empirical studies found. These issues can be examined in particular through the empirical analysis in the following sections.

CHAPTER 3

LITERATURE REVIEW

This chapter provides the existing literature on the various issues regarding returns linkages and volatility transmission among stock markets. The chapter is classified into three sections. The first section reviews the theoretical background of the international linkages of equity markets. The second section reviews multivariate GARCH models and their extensive application. The last section focuses on the empirical evidences of the issues that the literature seeks to address, i.e. return interrelationships and volatility spillover effects among international stock markets.

3.1.Theories on the international linkages of equity markets

Modern portfolio diversification theory

The earliest studies, Tobin (1958) and Markowitz (1959), can be seen as the most influent works in establishing the theory of portfolio diversification. It is found that the portfolio benefits including either gain in expected return or reduction in risks could be optimized by investing in different securities or assets relied on the correlation of asset returns. Grubel (1968) develops the model of portfolio into the internationally diversified portfolios and find that the benefits of portfolio diversification can be remarkably improved by holding the assets in different countries. Accordingly, there are four categories of portfolio diversification: (i) the portfolio comprises of different securities in the same financial market, i.e. investors buy shares of different firms or sectors; (ii) the portfolio comprises of the same securities of different financial markets in the same countries such as stocks market, foreign exchange market, or bond market; (iii) the portfolio includes the same securities of the same financial markets in the different countries, e.g. stocks from Vietnam, Singapore and Thailand equity markets; and (iv) the portfolio contains international securities in different financial markets, e.g. bonds from Vietnam and stocks from Thailand.

There are several arguments in favor and against the portfolio diversification theory. The basic argument in favor of portfolio diversification is that the total risk of the portfolio can be reduced owning to either the weak correlation or the negative correlation among the assets included in that portfolio (Glezakos et al., 2007:25). If the portfolio comprises of the negatively correlated assets, the loss from one negative-return asset will be compensated by the gain from other positive-return assets in the same portfolio. This helps the investors avoid the possibly huge losses. However, there are also some debates against the portfolio diversification theory because the correlations in reality can be changed over time. It is observed that the correlations have the upward tendency in the turbulent financial period. Longin and Solnik (1995) find that the linkages among world stock markets are significant and tend to increase over time through estimating the correlation and covariance matrices. The increase in correlation in asset returns could diminish the gains from the portfolio diversification. In addition, other factors such as high transaction costs, taxes, market liquidity, and regulatory risks have also affected the gains of international portfolio diversification.

The issue of international portfolio diversification has led to an enormous number of researches in the co-movements among different financial markets. As suggested by many previous studies such as Darrat and Benkato (2003:1090), Levy and Sarnet (1970), Morana and Beltratti (2006:2), Solnik (1974), the strongly or positively correlated stock markets could be driven by common shocks and hence co-moved in the same way. Consequently, much of international diversification benefits would be diminished. However, if stock market returns across the national markets do not move together, the opportunities to diversify internationally are fairly large and diversifying the portfolio is beneficial to the international investors.

The logic of volatility transmission between stock markets

In general, the co-movement among national stock markets can be explained in several ways. The first explanation is related to the concept of "market interdependency" which results from the process of economic integration. It means that the more integrated economies produce the more stock market interdependency. The second explanation is related to 'contagion effect', which is defined as a part of change in the stock market correlation that is caused by unanticipated shocks from the foreign markets, not from the economic fundamentals.

The increasing trend of economic integration and financial market liberalization allows that the domestic stocks can be traded in foreign countries and the foreign investors can buy the shares in the local stock market, hence increasing the capital inflows. The capital inflows serve as an alternative capital source for the firm's manufacturing expansion. The rapid development in financial market associated with innovations in communication technology accelerates the integration of the world financial markets. As a part of that process, the stock markets in different countries are integrated or linked together, which is referred as the “stock market interdependence” (Sheng and Tu, 2000).

The interdependence among international stock markets is identified with two major types: the interdependence of the first moments (i.e. return spillover effects) and the interdependence of the second moments (i.e. volatility transmissions). The typical previous studies examined the degree of interdependence for returns such as Hilliard (1979), Errunza and Losq (1985). These studies find the high degree of equity returns interaction among the stock markets. In addition to mean spillover effects, other empirical studies investigated the volatility transmissions among different markets such as Hamao et al. (1990), Karolyi (1995), Liu and Pan (1997), In et al. (2001), Jang and Sul (2002), Chou, Lin, and Wu (1999), Cotter J. (2004), Worthington and Higgs (2004), Li (2007). These studies find that the interdependence of international stock markets has been increasing since the 1987 Stock Market Crash and volatility of returns exhibits time-varying.

Does stock market integration affect volatility of stock returns? Holmes and Wong (2001) argued that the volatility in stock prices is positively correlated with the participation of foreign investors in the equity market. An explanation might be due to the short-term property of the fund which is considered as speculative investment. The uncertainty of the capital source induces the stock prices to be higher volatile. The greater volatility in stock prices causes aversion to foreign investors in holding stocks, leading to the large-scale selling of foreign shareholdings in the stock market. These greatly affect the local investor behaviors through the domino effects and hence destabilizing the stock market. Owning to the communication technology advance, the volatility in stock market from a country can be quickly transmitted to the other countries. The shock transmissions from the other markets might affect both the local and foreign investors in the market and hence impact on the equity price changes. As a result, the volatility transmission increases the interdependency of stock markets in different countries. As supported by the empirical findings, Nilsson (2002) investigates the changes in return volatility in stock markets of four largest Nordic countries and find that volatility in stock market returns tends to be higher along with the degree of financial integration. It is a common belief that either the increasing market interdependence or the higher degree of volatility spillovers across nations reduces the opportunities to international investors in seeking benefit maximization from the portfolio diversification. So, it is really important to examine the volatility spillover effects across national stock markets so as not to ignore the essential information about the market behaviors (Rigobon and Sack, 2003).

However, another explanation for co-movements in stock markets across countries is concerned with the 'contagious' manner. Contagion is defined as the change in stock market correlation among different markets that results from the contemporaneous effects of unanticipated shocks originating from either the foreign markets, which is not related to the macroeconomic factors. The spillovers of the 1997 financial crisis which led to the extreme volatility in the regional financial markets and the New York Stock Exchange Crash in Oct 1987 might be the typical examples of the contagion effect. Besides, the 'herding behavior' of stock market traders can be considered as the contagion effect in relative meaning. If stock traders believe that other traders will sell the specific securities, then they will do the same activity for the same securities. This will cause a sell-off of securities in the market when a large amount of investors respond alike, causing the widespread downswing in that market. In sum, the contagion effect is referred as the phenomenon that a collapse of one stock market cause a widespread decline in stock prices of the other markets (Gonzalo and Olmo, 2005:4).

3.2. Approaches to research the volatility tranmission

There are two main approaches which have been employed by most of empirical studies to examine the interrelationship of different stock markets, specifically, *(i) Granger causality and Cointegration method* (Eun and Shim, 1989; Kasa, 1992; Richard, 1995; Choudhry, 1996a; Kanas, 1998a; Ng T.H., 2002; Syriopoulos, 2004); and *(ii) the family of GARCH models* (Kroner and Ng, 1988; Hamao, Masulis, and Ng, 1990; Susmel and Engle, 1994; Karolyi, 1995; Aggarwal et al., 1999; Sharma and Wongbangpo, 2002; Worthington and Higgs, 2004; Ahn and Lee, 2006). While the first approach is concerned to the cointegration of stock returns in the long run, the second approach allows modeling the variance (volatility spillover) to capture the properties of financial time series such as time-varying variance and volatility clustering in addition to the examination of return spillover among markets. Since our main objectives focus on researching the relation of volatilities and co-volatilities of three regional stock markets, we utilize the framework of multivariate

GARCH models in the study. For that reason, this section provides the general reviews of development and empirical application of multivariate GARCH models.

The ARCH (Autoregressive Conditional Heteroscedasticity) model has been supposed as the first volatility models which was introduced by Engle (1982). ARCH model shows as the most successful model in capturing the various ‘stylized facts’ of the financial time series such as time-varying volatility clustering (i.e. the present level of volatility is followed by its level in either sign) and volatility persistence (i.e. the past volatility has a significant influence on the current volatility). However, this model then exhibited some weaknesses (see Tsay R.S., 2010:119). Then, Bollerslev (1986) extended ARCH model to a univariate GARCH model which permits the conditional variance equation to depend on its own lags. With the increasing trend of financial market integration over the world in recent years, studying jointly multiple return series becomes greatly important in understanding the interrelationship between financial markets. Thereby, multivariate GARCH (MGARCH) models are introduced as the econometric methods of multivariate time series analysis, which are constructed from univariate GARCH in two modes.

Firstly, MGARCH models is produced from direct generalizations of the univariate GARCH models through directly modeling the variance-covariance matrix, including VEC, BEKK[2], and Factor models (F-GARCH) which can be seen as a particular BEKK model (Lin, 1992). Among them, BEKK are the most popular solution in empirical studies. Firstly, VEC model was suggested by Bollerslev et al. (1988). The advantage of this model is that it is easy to interpret the estimated coefficients directly. However, the main disadvantage of VEC model lies in a large number of parameters to be estimated (i.e. $k(k+1)[k(k+1)+1]/2$ parameters, where k is number of assets). For instance, there are 78 unknown parameters to be estimated for trivariate case. Thereby, VEC model is probably the most suitable for bivariate case only. Besides, it is difficult to impose the positivity of variance-covariance matrix. To improve VEC model, Engle and Kroner (1995) proposed BEKK model which is quadratic formulation for the parameters that automatically ensure the positivity of variance-covariance matrix. Furthermore, the number of parameters in BEKK model is remarkably reduced as it seems to grow linearly with the number of series (i.e. $k*(5k+1)/2$ parameters). In addition, BEKK formulation does not impose restriction of cross market innovation to be zero which is imposed in case of univariate GARCH. However, the fact that it is hard to

[2] BEKK stands for Baba, Engle, Kraft and Kroner

interpret the coefficients directly in BEKK model is still a problem of BEKK specification. For all that, BEKK specification has been the most popular application in the empirical studies. Karolyi (1995) specify that BEKK model is the most appropriate econometric tool in multivariate time series analysis after suggesting and comparing several specifications for the variances-covariances matrix.

Secondly, MGARCH models are produced from linear or nonlinear combination of the univariate GARCH models. Linear combination of the univariate GARCH models creates Orthogonal GARCH (O-GARCH). Nonlinear combination of the univariate GARCH models creates constant conditional correlation (CCC-GARCH) model, dynamic conditional correlation (DCC-GARCH) models, and general dynamic covariance model (GDCC-GARCH) (Bauwens, Laurent & Roumbouts, 2003). In the indirect analysis of the multivariate time series through the conditional correlation matrices, CCC- and DCC-GARCH are preferred because they are simple to estimate with two-step methods and keep the flexibility of univariate GARCH. CCC-GARCH model was proposed by Bollerslev (1990) by modeling indirectly the correlation between the time series under assumption of constant conditional correlation. Although it seems to be an innovation with fewer parameters and easy estimation of coefficients, CCC-GARCH has a disadvantage that imposes restriction of cross market innovation to be zero. In addition, the assumption of time-invariant correlation is unrealistic in the financial markets which is verified by Longin and Solnik (1995), Bera and Kim (2002) and Sheedy (1998). To make the conditional correlation matrix vary over time, Engle (2002) and Tse and Tsui (2002) suggested DCC-GARCH. However, DCC models also have a limitation as all the correlation processes in the model are restrained to follow the same dynamic structure.

Regarding empirical application of MGARCH in the financial literature, MGARCH methods, in general, have been extensively applied and become the most suitable econometric approach in jointly modeling the international shock transmission between stock market indices. Bollerslev (1990) used MGARCH models to examine the coherence in a set of five nominal European U.S. dollar exchange rates, while Karolyi (1995) use the similar technique to examine the dynamic price co-movement between stock markets of the US and Canada. Kanas (1998b) using multivariate exponential GARCH model investigated the volatility spillovers among the UK, France and Germany and found the evidence of asymmetric volatility spillover effects among the three largest European stock markets. Kim and In (2002) employed bivariate GARCH model to examine the linkages between stock markets of Australia and three major countries and found the significant effects from the major stock markets on the Australian stock markets. Following this line of research with regard to Asian stock markets, Miyakoshi (2003) use bivariate EGARCH model to examine the magnitude of return and volatility spillovers from the US and Japan to seven Asian countries. Johanson & Ljungwalls (2008) employ DCC - MGARCH method to analyze the relationships among four Asian bond markets and find the highly time-varying correlation between the markets. Harris and Pisedtasalasai (2006) utilize MGARCH with CCC specifications in investigating the return and volatility spillover effects between the three equity indices of U.K. stock market and find the significantly positive spillover effects from portfolio of larger stocks to the portfolio of smaller stocks.

Through reviewing the extensive financial literature, the BEKK specification with dynamic covariance and dynamic correlation has proved the preferred model among MGARCH frameworks because it allows cross-market interdependency as well as estimation of spillover effects in multi-dimension without imposing the restriction of positivity of the second moment equation and constant conditional correlation. Cotter J. (2004) employ MGARCH – BEKK model to examine the market linkages between the Irish, German, UK and the US stock markets and find the significant spillovers effects from the foreign markets to the Irish market in terms of both return and volatility. He even indicates that "*the mean equation in VAR model examines the direction and magnitude of the return linkages whereas the BEKK specification determines the causality and extent of volatility linkages*". Kearney and Patton (2000) employed a BEKK specification in series of three, four and five variables to detect the international volatility transmission of exchange rate across European Monetary System (EMS) currencies, while Brooks and Henry (2000) use the asymmetric BEKK formulation to model volatility spillovers effects between the US, Japanese and Australian stock markets. Similarly, Caporale et al. (2002) utilize BEKK representation to test the causality-in-variance between stock prices and exchange rates volatility in four East Asian countries. Worthington and Higgs (2004) apply the BEKK parameterization of the MGARCH model to find the non-homogenous volatility transmission of equity returns from the well-developed Asian stock markets (Hong Kong, Japan and Singapore) to the other emerging markets (Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand). More recently, Li (2007) explores the GARCH-BEKK model to examine the linkages among the stock markets of the main Chinese, Hong Kong and United States. Also, Saleem K. (2009) uses the bivariate GARCH-BEKK model to examine the international linkage of Russian equity market and analyze the contagion effects of Russian Financial crisis 1998.

In summary, we have reviewed the econometric approaches to study the volatility spillover effects among different national stock markets. It is argued that MGARCH models are the successful approach in investigating the volatility transmission mechanism across markets. The next section would specify the related empirical studies in more details.

3.3. Relevant empirical studies

In the financial literature, there are a vast amount of empirical studies on co-movement in international stock markets, i.e. Eun and Shim (1989), Hamao et al. (1990), Karolyi (1995), Mike K. P. So, K. Lam and W. K. Li (1997), Chou, Lin, and Wu (1999), Forbes and Rigobon (2002), Johnson and Soenen (2003), Worthington and Higgs (2004), Morana and Beltratti (2006), Li (2007), and Rao (2008). Although they apply various empirical methodologies such as Granger causality test, VAR, cointegration test, and ARCH/GARCH approach, the consistent findings include (i) the significant co-movements across national stock markets (ii) the evidence of volatility transmission and positive correlation between world stock markets. Moreover, correlations between world stock markets tend to be increased in the period of financial turbulence.

Hamao et al. (1990) utilizes the GARCH family of statistical models to investigate returns spillover and volatility spillover from one stock market to the others for three major markets: London, New York, and Tokyo around the 1987 U.S. stock market crash. The close-to-close data were divided into open-to-close and close-to-open. The results indicate the significant mean spillovers and price-volatility spillovers among three developed markets in all direction after the October 1987 crash period. The later work of Hamao et al (1991) also verifies that result. Later, *Karolyi (1995)*, using bivariate GARCH models and VAR models in daily stock indices at closing prices during April 1987 to December 1989, examines the short run dynamic relation between price movements of stocks listed on the Toronto Stock Exchange (TSE300) of Canada and New York Stock Exchange (S&P 500). The findings vary between the models applied. It is found that the return and volatility spillover effects measured with VAR models are somewhat exaggerated compared to those measured by bivariate GARCH in terms of the shock magnitude and persistence. In addition, the study emphasizes the robust application of bivariate GARCH specification in modeling the conditional volatilities of cross-market dynamics. It is noted that most of the earlier studies mainly focused on analyzing interactions among developed stock markets due to the availability and reliability of data. Since the 1987 crash, the number of studies on volatility spillover effects from the mature to emerging markets has been grown. Bekaert and Harvey (1997) documents four general properties of stock returns in emerging markets such as “high mean returns”, “high volatility”, “more predictable returns”, and “low correlation with developed markets”. Verifying the fourth characteristic of emerging stock returns, Scheicher (2001) finds the very limited interaction of emerging markets to developed markets. This study also finds that international transmission between emerging markets tends to be in terms of returns rather than volatilities. However, these findings are inconsistent with the other empirical studies.

Mike K. P. So, K. Lam and W. K. Li (1997) studies the volatility persistence, volatility variability, and volatility transmission of the seven Southeast Asian stock markets, namely, Thailand, Malaysia, Singapore, Hong Kong, Philippines, South Korea and Taiwan, during period 1980 to 1991, using the two-step ARV (Autoregressive Random Variance) approach. They find the strong evidence of persistence in shocks and volatility for Taiwan stock market. In addition, Singapore stock market has the least volatility and Thailand stock exchange has the strongest volatility among stock markets under study. The significance of the volatility spillover effect from Hong Kong to Taiwan, Malaysia to Singapore and Singapore to Malaysia is also found in the study.

Chou, Lin, and Wu (1999) examine the price changes and short-term volatility transmission from the U.S. to Taiwan stock markets, employing the multivariate GARCH in BEKK formulation. The dataset includes close-to-open, open-to-close, and close-to-close returns of the TAIEX and S&P500 during January 1, 1991, to December 31, 1994. The empirical results include (i) the high correlation between the US and Taiwan stock markets, implying high correlation between the developed stock market and the emerging stock market; (ii) the significant spillover effects in both volatility and return from the advanced to the emerging markets.

Cotter J. (2004) examines the dual relation in return and volatility spillovers between the Irish equity market (ISEQ) and three major stock markets, namely the US (S&P500),

U.K. (FTSE), and German (DAX30) by using three different approaches: (i) the cointegration techniques to find the long-run relationship between the markets; (ii) the VAR models including variance decomposition and impulse response analysis to examine the dynamic relationship among the markets; and (iii) MGARCH framework with BEKK specification to examine volatility linkages between the Irish markets and the other markets. The study finds the evidence of long-run relationship between the ISEQ and FTSE only, but lack of consistency among periods. Regarding the dynamic relationship among markets, the Irish stock market has negligible influence on other markets while the shocks from majors markets are rapidly transmitted to the Irish market in large magnitude. In multivariate GARCH analysis, although the effects of the return and volatility spillover in sub-periods are various in magnitudes, both the mean and volatility spillover effects are positive in direction of, but not from, the ISEQ index. As comparing the two econometric techniques, Cotter J. (2004) contended that *"using cointegration techniques might be tenuous and this might explain the inconsistent findings of previous studies"*, while multivariate GARCH analysis is appropriate to detail volatility spillovers with expected and more consistent findings.

Worthington and Higgs (2004) examines the spillover of mean and volatility among Asian markets, namely, Hong Kong, Japan, Singapore, Indonesia, Korea, Malaysia, the Philippines, Taiwan, and Thailand using weekly returns during the period of 1988 to 2000. The first three markets are noted as advanced markets whereas the others are considered as emerging markets. The MGARCH model with BEKK parameterization is employed to quantify the spillover effects. In the study, the return for Thailand is influenced by the lagged return of Singapore whereas Singapore markets are not influenced by returns of any markets in Asia. The diagonal coefficients for GARCH effects indicate that Singapore has highest own-volatility persistence among Asian stock markets. Briefly, the study finds the evidence of high integration of Asian stock markets, whereby the mean and volatility spillovers are significantly positive in direction of emerging markets. The return spillovers, however, are not homogeneous across the emerging markets. Through MGARCH adaptation, the past innovations in all nine Asian markets have significant influence on the volatility of the other markets. In addition, the own volatility spillover effects in the emerging markets are found to be larger than those in the developed markets. Also, for the emerging markets, the own volatility spillover effects are greater than the cross-volatility spillovers. Both the studies of Cotter (2004) and Worthington and Higgs (2004) find that the return and volatility spillover are transmitted from the developed markets to the emerging stock markets. Similarly, Miyakoshi (2003) used the bivariate EGARCH model to quantify the spillover effects of return and volatility from stock markets in Japan and the U.S. to the Asian equity markets. It is found that the Asian markets are influenced more from Japanese market than from the US in terms of volatility. However, in terms of returns, the Asian markets are influenced more from the U.S. market. Besides, the Asian stock markets also have the impact on the volatility of Japanese market.

Li (2007) explores four-variable MGARCH- BEKK model to examine the linkages between two emerging stock exchanges of China, namely, Shanghai and Shenzhen of China and two mature markets, namely Hong Kong and the United States, using daily date during the 2000 – 2005 period. Li cannot find the direct linkage between the stock exchanges in China and the U.S. in terms of return and volatility. However, it is found that (i) the evidence of unidirectional volatility spillover from US stock exchanges to Hong Kong market; (ii) the weak linkage between Hong Kong and China in direction to the China's stock exchanges; (iii) the bidirectional shock spillover between the stock exchanges in intra-mainland China. Furthermore, the effect of own past innovations on volatility is significant in all four markets. But the response of volatility in all four markets was asymmetric.

Rao (2008) combines the MGARCH with VAR methodology to examine the cointegration and volatility spillover across the six emerging Arabian Gulf Cooperation council (AGCC) equity markets with the developed markets in the period from February 2003 to January 2006. The study finds the significant own and cross spillover of innovations. Besides, the volatility spillover and persistence among AGCC markets are also found. More recently, Beirne and Caporale et al. (2009) use trivariate VAR-GARCH(1,1)-in-mean models with the BEKK representation to test for the spillovers of means and variances as well as the spillovers from the second to the first moments (GARCH-in-mean effects) across the forty one emerging stock markets in Asia, Europe, Latin America, and the Middle East. The results found the evidence of cross-market linkages and cross-market GARCH-in-mean effects, but the nature of linkages varies across countries and regions. While the spillovers in mean returns dominate in Asia, the spillovers in volatility mainly act in emerging Europe. Lastly, the results reveal that global spillovers are crucial in Asia and the regional spillovers are large in Latin America and the Middle East.

Referring to studies on Vietnamese stock markets, *Hsu-Ling Chang, Chi-Wei Su (2010)* employes the threshold ECM with bivariate GJR-GARCH model to examine the linkages between Vietnam stock markets and the international stock markets, namely, United States, Japan, Singapore and China. It is found that the Japan and Singapore stock markets have the most influence on the stock returns in Vietnam. *Wang, K.M. (2011)* investigates the contagion effects between the stock markets in Vietnam, China, and the U.S. during the period from October 9, 2006 to June 19, 2009 by exploring the bivariable DCC - EGARCH model. The study finds the existence of contagion effects in the Vietnamese stock market, especially after the sub-prime mortgage crisis. The results also show that the contagion risks on Vietnamese stock market are spread from the stock markets in China rather than those in the U.S. Similarly, *Thuan L.T. (2011)* explores the Generalized Autoregressive Conditional Heteroscedasticity - Autogressive Moving Average (GARCH- ARMA) model on daily indices from 2003 to 2009 to investigate the effects of two stock indices of the U.S. (i.e., the S&P 500 and the Dow Jones) on the Vietnam stock market index. Different from the other empirical studies, Thuan L.T. (2011) takes into account changes in the relationship between Vietnam and the U.S. due to the political events in the sub-periods (i.e. the official visit of the U.S. and Vietnam governments). The findings are mostly consistent for all sub-periods, including (i) the existence of the positively significant influence of the S&P 500 and the Dow Jones Indices on the VN Index in term of returns and (ii) the significantly stronger influence after the political events. In addition, the study shows the stronger effects of Dow Jones Index in comparison with the S&P 500. However, the study cannot find the effect of the two U.S. stock indices on the VN Index in terms of volatility.

In conclusion, the empirical literature was focused on relevant studies related to the returns and volatility linkages among well-developed and emerging markets. In the context of growing integration of global financial markets, the linkages between stock markets are documented to increase accordingly. Generally, a majority of empirical studies on these respects consistently finds the existence of the co-movement and the return and volatility transmission across national markets. Besides, most studies' findings support that the spillover effects of returns and volatility tend to be unidirectional from the developed to the emerging stock markets. As for Vietnamese stock market, there are a few empirical studies on this subject. It was established that Vietnamese stock market is influenced by the larger markets such as the U.S, the Japan, and the Singapore. However, the interrelationship among the three intra-regional markets such as Singapore, Thailand and Vietnamese stock markets has not been examined in the previous studies. Therefore, it is exciting to contemporaneously examine the returns linkages and volatility transmission among the three intra-regional markets. Furthermore, the empirical studies verified the robust application of the multivariate GARCH frameworks with BEKK specification among variety of econometric approaches in modeling the volatility transmission of the multiple financial time series. Therefore, this study examines the mean and volatility transmission among the three selected stock markets in the presence of time-varying variance by adopting the MGARCH - BEKK technique. Subsequently, the research methodology and the data used in the study are discussed in detail in the next chapter.

CHAPTER 4

RESEARCH METHODOLOGY AND DATA COLLECTION

The main objectives of the study are to simultaneously investigate the return and volatility linkages among the regional equity markets, namely, Vietnam, Singapore, and Thailand. Based on the main objectives, the study has addressed the three main research questions. Following the methodologies adopted in previous studies to allow the variance varying across the time, the study utilizes a multivariate GARCH with BEKK specification (Engle and Kroner, 1995) which can characterize own- and cross-market linkages in time-varying market interdependency to answer the first two research questions. The third question related to the issues of portfolio diversification is answered by analyzing the conditional variance-covariance and correlations between the markets and calculating the risk-minimizing portfolio weights through the Kroner and Ng's (1998) formulation. Additionally, it is necessary to perform other statistical testing procedures for the financial time series before estimation.

4.1. Testing for stationarity

According to Gujarati (2005:496), a stochastic process for which mean and variance are constant over time and a serial covariance is uncorrelated are referred as the stationarity, the so-called a 'white noise' process. The condition of stationarity makes important sense in the ordinary least squares (OLS) regression for two reasons: (i) it is possible to make forecasts for stationary series; (ii) the results of OLS regressions are possibly non-sense or spurious in case of non-stationary series. Therefore, it is necessary to test stationary condition of financial time series before proceeding to estimation.

There are several popular methods to test the stationarity in the literature such as observing the graphical plots of data, the Autocorrelation Function (ACF) and Correlogram, and the unit root test. In this study, the presence of roots is examined through the standard unit root tests such as the Augmented Dickey Fuller (ADF) and the Phillips-Perron (PP) tests. These tests are selected due to their high commonality in empirical studies[3]. In general, the ADF and the PP tests have the same null hypothesis of a unit root. Rejection of the null hypothesis implies that the series has no unit root or the series is stationary. However, the

[3] Referring Brooks (2002) for more understanding the ADF and PP tests

ADF test is based on the assumption of random error terms while the PP test allows for fairly mild assumption concerning the distribution of errors.

4.2. Seasonal adjustment

Empirically, the calendar effects in stock returns have been well documented in the finance literature (Heston & Sadka, 2008). Because the data analysis in the following chapter shows the existence of monthly seasonal effects in Vietnamese stock returns, it is necessary to filter the seasonal fluctuations from the return series for more robust estimated results. There are several procedures of seasonal adjustment using quite standardized techniques such as the Census X-11, the Census X-12, and the TRAMO/SEATS procedure. Among them, the Census X-12 technique greatly enhances the standard X-11 method which decomposes the original series into seasonal, trend, trading day, and irregular components (see Eviews 6 User Guides I, page 341). By improving the estimation of the seasonal factors, it is widely applied by many statistical agencies. Without exception of this study, we utilize the Census X-12 algorithm to adjust the seasonality in the stock returns. There are two forms of seasonal decomposition such as the multiplicative and the additive, whereby we choose the additive option of the procedure and automatic Henderson filter selection.

4.3. The model specification of multivariate GARCH - BEKK

The study utilizes the unrestricted multivariate GARCH - BEKK models of Engle and Kroner (1995) in examining the volatility transmission spillovers between multiple different markets.

Let R_t be a vector (3x1) of stochastic return series, namely Ho Chi Minh Stock Exchange (RVNI), Singapore stock exchange (RSGE), and Stock Exchange of Thailand (RSET). It is noted that the stock exchanges in Vietnam, Singapore, and Thailand are ordered as 1, 2, and 3 respectively. The conditional mean of stock return is the 3 x 1 vector at time t for the markets modeled as in equation [1]. Let Ω_{t-1} be the market information set at time t-1.

$$R_t = \alpha + \Gamma R_{t-1} + \varepsilon_t \qquad [1]$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, Ht)$$

Where α is a 3 x 1 vector of constant or long-term drift coefficients; the 3x1 vector of random errors ε_t is unexpected return for the markets at time t as specified:

$$\varepsilon_t = H_t^{1/2}(\theta) * Z_t \ .$$

Where $H_t(\theta)$ is the conditional variance matrix of R_t and Z_t is an independent and identically distributed (i.i.d.) vector of error process such that $\mathrm{E}(Z_t) = 0$ and $\mathrm{Var}(Z_t) = I_3$ (i.e. an 3x3 identity matrix); θ is a finite vector of parameters.

Γ is a 3 x 3 matrix for parameters associated with the one period lag return. The diagonal elements in matrix Γ (γ_{ii}) measure the effects of own lagged returns on the mean stock returns of one market. The off-diagonal elements (γ_{ij}) capture the effects of lagged return of market j^{th} on the current return of market i^{th}, which is referred as the cross-mean spillover effects. Obviously, the multivariate structure allows us to measure the magnitude of mean spillover effects across markets.

Given the above mean equation, BEKK (Baba, Engle, Kraft and Kroner) modeled the conditional variance-covariance matrix H_t as a function of the cross products of past innovations ε_{t-1} and the one-period-lagged volatility H_{t-1} for each market:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + G'H_{t-1}G \qquad [2]$$

Within this framework, C is 3×3 lower triangular matrix of constant. A, G are 3×3 square symmetric matrice of the coefficients. The ARCH and GARCH coefficients are derived from the A and G matrices. The matrix A measures the extent to which the conditional variances are correlated to the past squared errors (i.e. ARCH effects), while the matrix G measures the dependence of the current conditional variances on its previous own lag (i.e. GARCH effects). The diagonal parameters in the matrices H, A and G (h_{ii}, a_{ii}, g_{ii}) measure the conditional variance, the ARCH effects, the GARCH effects of the stock market returns i^{th}, while the off-diagonal parameters, h_{ij}, a_{ij}, g_{ij}, measure the covariance of the stock market returns i^{th} and j^{th}, the cross-market effects of shocks and volatility spillovers from market i^{th} to market j^{th}, respectively. From the equation [2], it can be expressed as the following form:

$$
\begin{bmatrix} h_{11t} & h_{12t} & h_{13t} \\ h_{21t} & h_{22t} & h_{23t} \\ h_{31t} & h_{32t} & h_{33t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix}' + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon_{1,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 & \varepsilon_{2,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{3,t-1}\varepsilon_{1,t-1} & \varepsilon_{3,t-1}\varepsilon_{2,t-1} & \varepsilon_{3,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} +
$$

$$
+ \begin{bmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{bmatrix}' \begin{bmatrix} h_{11t-1} & h_{12t-1} & h_{13t-1} \\ h_{21t-1} & h_{22t-1} & h_{23t-1} \\ h_{31t-1} & h_{32t-1} & h_{33t-1} \end{bmatrix} \begin{bmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{bmatrix} \qquad [3]
$$

Within the framework of standard BEKK specification, H is a symmetric square matrix. Thereby, the equation [3] of variance-covariance matrices can be specified into three variance equations and three covariance equations as follows:

The three variance equations are:

$$
\begin{aligned}
\sigma_{11,t} = {} & c_{11}^2 + c_{21}^2 + c_{31}^2 + a_{11}^2\varepsilon_{11,t-1} + a_{21}^2\varepsilon_{22,t-1} + a_{31}^2\varepsilon_{33,t-1} + \\
& 2a_{11}a_{21}\varepsilon_{12,t-1} + 2a_{11}a_{31}\varepsilon_{13,t-1} + 2a_{21}a_{31}\varepsilon_{23,t-1} + \\
& g_{11}^2\sigma_{11,t-1} + g_{21}^2\sigma_{22,t-1} + g_{31}^2\sigma_{33,t-1} + \\
& 2g_{11}g_{21}\sigma_{12,t-1} + 2g_{11}g_{31}\sigma_{13,t-1} + 2g_{21}g_{31}\sigma_{23,t-1}
\end{aligned} \qquad [4]
$$

$$
\begin{aligned}
\sigma_{22,t} = {} & c_{22}^2 + c_{32}^2 + a_{12}^2\varepsilon_{11,t-1} + a_{22}^2\varepsilon_{22,t-1} + a_{32}^2\varepsilon_{33,t-1} + \\
& 2a_{12}a_{22}\varepsilon_{12,t-1} + 2a_{12}a_{32}\varepsilon_{13,t-1} + 2a_{22}a_{32}\varepsilon_{23,t-1} + \\
& g_{12}^2\sigma_{11,t-1} + g_{22}^2\sigma_{22,t-1} + g_{32}^2\sigma_{33,t-1} + \\
& 2g_{12}g_{22}\sigma_{12,t-1} + 2g_{12}g_{32}\sigma_{13,t-1} + 2g_{22}g_{32}\sigma_{23,t-1}
\end{aligned} \qquad [5]
$$

$$
\begin{aligned}
\sigma_{33,t} = {} & c_{33}^2 + a_{13}^2\varepsilon_{11,t-1} + a_{23}^2\varepsilon_{22,t-1} + a_{33}^2\varepsilon_{33,t-1} + \\
& 2a_{13}a_{23}\varepsilon_{12,t-1} + 2a_{13}a_{33}\varepsilon_{13,t-1} + 2a_{23}a_{33}\varepsilon_{23,t-1} + \\
& g_{13}^2\sigma_{11,t-1} + g_{23}^2\sigma_{22,t-1} + g_{33}^2\sigma_{33,t-1} + \\
& 2g_{13}g_{23}\sigma_{12,t-1} + 2g_{13}g_{33}\sigma_{13,t-1} + 2g_{23}g_{33}\sigma_{23,t-1}
\end{aligned} \qquad [6]
$$

The three covariance equations are:

$$
\begin{aligned}
\sigma_{12,t} = \sigma_{21,t} = {} & c_{21}c_{22} + c_{31}c_{32} + a_{11}a_{12}\varepsilon_{11,t-1} + a_{21}a_{22}\varepsilon_{22,t-1} + a_{31}a_{32}\varepsilon_{33,t-1} + \\
& (a_{12}a_{21} + a_{11}a_{22})\varepsilon_{12,t-1} + (a_{12}a_{31} + a_{11}a_{32})\varepsilon_{13,t-1} + (a_{22}a_{31} + a_{21}a_{32})\varepsilon_{23,t-1} + \\
& g_{11}g_{12}\sigma_{11,t-1} + g_{21}g_{22}\sigma_{22,t-1} + g_{31}g_{32}\sigma_{33,t-1} + \\
& (g_{12}g_{21} + g_{11}g_{22})\sigma_{12,t-1} + (g_{12}g_{31} + g_{11}g_{32})\sigma_{13,t-1} + (g_{22}g_{31} + g_{21}g_{32})\sigma_{23,t-1}
\end{aligned} \qquad [7]
$$

$$\sigma_{13,t} = \sigma_{31,t} = c_{31}c_{33} + a_{11}a_{13}\varepsilon_{11,t-1} + a_{21}a_{23}\varepsilon_{22,t-1} + a_{31}a_{33}\varepsilon_{33,t-1} + (a_{11}a_{23} + a_{21}a_{13})\varepsilon_{12,t-1} + (a_{13}a_{31} + a_{11}a_{33})\varepsilon_{13,t-1} + (a_{21}a_{33} + a_{31}a_{23})\varepsilon_{23,t-1} + g_{11}g_{13}\sigma_{11,t-1} + g_{21}a_{23}\sigma\varepsilon_{22,t-1} + g_{31}g_{33}\sigma_{33,t-1} + (g_{11}g_{23} + g_{21}g_{13})\sigma_{12,t-1} + (g_{13}g_{31} + g_{11}g_{33})\sigma_{13,t-1} + (g_{21}g_{33} + g_{31}g_{23})\sigma_{23,t-1} \quad [8]$$

$$\sigma_{23,t} = \sigma_{32,t} = c_{32}c_{33} + a_{12}a_{13}\varepsilon_{11,t-1} + a_{22}a_{23}\varepsilon_{22,t-1} + a_{32}a_{33}\varepsilon_{33,t-1} + (a_{13}a_{22} + a_{23}a_{12})\varepsilon_{12,t-1} + (a_{13}a_{32} + a_{12}a_{33})\varepsilon_{13,t-1} + (a_{23}a_{32} + a_{22}a_{33})\varepsilon_{23,t-1} + g_{12}g_{13}\sigma_{11,t-1} + g_{22}g_{23}\sigma_{22,t-1} + g_{32}g_{33}\sigma_{33,t-1} + (g_{13}g_{22} + g_{23}g_{12})\sigma_{12,t-1} + (g_{13}g_{32} + g_{12}g_{33})\sigma_{13,t-1} + (g_{23}g_{32} + g_{22}g_{33})\sigma_{23,t-1} \quad [9]$$

The variance-covariance equations [4] to [9] describe full elements that predict the volatility of stock return for each market. Accordingly, the return variances are predictable based on the lagged squared innovations, the interaction of cross lagged innovations, the lagged variances, and the lagged co-variances. However, for purpose of simplicity, this study ignores the interaction of cross lagged innovations, but merely observes the volatility spillover effects by measuring the impact of the lagged squared error terms (or past shocks) $\varepsilon_{11,t-1}$, $\varepsilon_{22,t-1}$, and $\varepsilon_{33,t-1}$ and the effect of the lagged variances $\sigma_{11,t-1}$, $\sigma_{22,t-1}$, and $\sigma_{33,t-1}$ on the present variances ($\sigma_{11,t}$, $\sigma_{22,t}$, $\sigma_{33,t}$) and covariances ($\sigma_{12,t}$, $\sigma_{13,t}$, and $\sigma_{23,t}$).

The BEKK equations can be estimated by using the log likelihood function under assumption of quasi-normal distributed random or t-distributed error terms. Let L_t be the log likelihood of observation t, the conditional log likelihood function of joint distribution L is specified as

$$L = \sum_{t=1}^{T} L_t$$
$$L_t = -\frac{n}{2} + \frac{1}{T} log2\pi - \frac{1}{2}\ln|H_t| - \frac{1}{2}\varepsilon_t' H_t^{-1}\varepsilon_t$$

Where T is the number of observations and n is the number of series.

Since popular commercial statistical software like Eviews only support the diagonal BEKK styles, not the full BEKK specification estimation, we use the *'MGARCH package'* of R-plus software to estimate the maximum likelihood parameters and corresponding standard errors in the unrestricted BEKK models. It is also noted that the optimization has not converged with the default optimization method, BFGS algorithm; so a more flexible alternative optimum method, the Nelder-Mead Simplex Algorithm[4], is utilized in estimating the maximum likelihood function. Overall, our model has nine parameters in the mean

[4] Accessing the site http://finzi.psych.upenn.edu/R/library/stats/html/optim.html for more information

equation (excluding the constants), twenty four parameters in the variance-covariance equation (including six intercepts, nine white noise, and nine volatility parameters).

Finally, the Ljung-Box portmanteau tests were performed on standardized and standardized squared residuals to test the null hypothesis that the model is correctly specified or randomness in the error terms. The test statistic is formulated as

$$Q = T(T+2)\sum_{i=1}^{p}(T-i)^{-1}r_i^2 \sim \chi^2_{\mathrm{p-k}}$$

Where r_i^2 is the sample correlation at lag i calculated from the residual; T is number of observations. Q is asymptotically distributed as χ^2 with (p - k) degrees of freedom and k is the number of explanatory variables. If the Q statistics is greater than the critical value then the null hypothesis is rejected.

4.4. Data collection

The monthly data frequency is specifically chosen in this study for the following reasons. On the one hand, although the daily data is preferred to the weekly and monthly data in the financial time series analysis due to well-capturing the dynamic responses to the innovation within a day, it is argued that *"daily data are deemed to contain 'too much noise' and is affected by the day-of-the-week effect*" (Roca, 1999: 505). On the other hand, the daily and weekly information for stock indices is not publicly available to obtain.

This study analyzes the monthly stock index data for the three markets in ASEAN region (i.e. Vietnam, Singapore, and Thailand). The three indices used are the VN Index for Vietnamese market (VNI), the Strait Times Index for the Singapore Stock Exchange (SGE), the SET Composite Index of Thailand (SET). The data have been obtained directly from each country's stock exchange and its online database, covering the period from January 2001 to October 2011, giving a total of 130 observations for each individual market. All the monthly stock index data in this study are closing indices of the day of month-end. It is the fact that the trading time is insignificantly different between the three studied markets because the three markets belong to the Asian time zone. However, Singapore time is an hour ahead of Thailand and Vietnam. Closing time of Singapore stock exchange is at 4:00 pm, only half-hour earlier than that of Thailand, whereas Vietnamese closing time is around 11:00 am, much earlier than Singapore and Thailand's. Therefore, events that take place in

Singapore and Thailand will only be reflected in the Vietnamese stock price of the next trading day. Vice versa, events in Vietnam might affect the Singapore and Thailand in the same day.

Deriving from the stock index series, the monthly stock return in the market *i* at time t is defined as logarithmic difference of stock indices multiplying by 100.

$$R_{it} = 100\ x\ [\log(p_{it}) - \log(p_{it-1})]$$

Where R_{it} denotes as stock returns of market *i* for the period *t*; p is the stock price.

In summary, we have set out the empirical econometric models which are employed to answer the research questions addressed in the study. As well, we discussed how to select the data used in the study. We now go to the next chapter for summarizing the data description as well as analyzing the empirical results.

CHAPTER 5

DATA ANALYSIS AND RESEARCH FINDINGS

5.1. Summary of descriptive analysis

In addition to the historical change in the three Asian stock market indices over time presented in the Figure 2.4., Figure 5.1 plots the returns of the stock indices across the time. All the three series on figure 5.1 exhibit the volatility clustering which characterize the large/small volatility followed by the large/small volatility in either sign. The returns on Vietnamese stock exchange have very high volatility over the studied time, especially during a turbulent period between 2007 and 2010. The return on the other two markets also experience the period of financial turbulence of 2007 - 2010. Among the three series, the Singapore returns show more stable in terms of volatility.

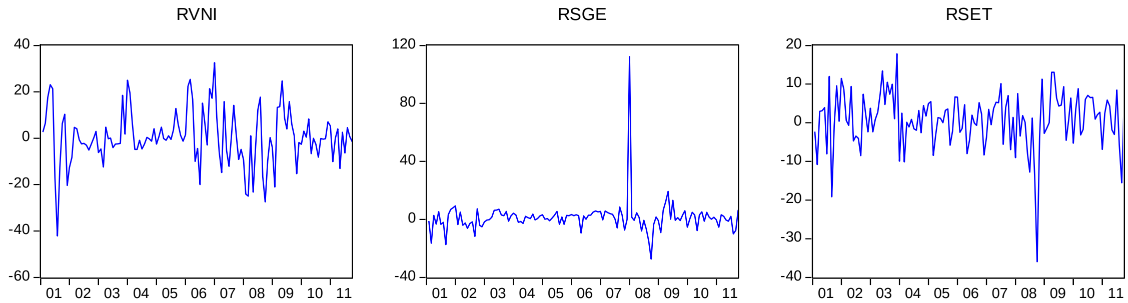

Figure 5.1 – Monthly Stock Returns, January 2001 – October 2011

Notes: RVNI, RSGE, RSET denote stock returns of Vietnam, Singapore, and Thailand markets, respectively.

Table 5.1 shows the summary of descriptive statistics for the monthly stock return series for the full period 2001 to 2011, including means, maximum, minimums, medians, standard deviation, skewness, kurtosis, and Jarque-Bera with their p-values for the return series. The mean of return series are rather small. Under the period, the performance of Singapore stock market, which is measured by the unconditional mean returns, is the highest (1.34%), followed by that of Thailand (about 0.83%), while Vietnamese market is the lowest (around 0.42%). The returns for Vietnam fluctuated between the minimum of -42.07% and a maximum of 32.57%. It is not surprised that Vietnam stock market returns are the most volatile and therefore the riskiest in the mean-variance framework because it has the highest standard deviation of return (11.74%). However, quite surprisingly, Singapore has a much higher standard deviation than Thailand, indicating that the total risks are higher for the Singapore market. This seems to contrast to the findings that the market risk which is proxied by the unconditional standard deviation tends to be higher in the emerging markets than in the advanced markets.

Table 5.1 – Descriptive Statistics of stock return series

	RVNI	RSGE	RSET
Mean	0.417	1.34	0.833
Median	-0.081	1.431	1.307
Maximum	32.575	112.328	17.833
Minimum	-42.073	-27.364	-35.919
Std. Dev.	11.744	11.475	7.181
Skewness	-0.15	6.885	-1.196
Kurtosis	4.128	69.476	7.462
Jarque-Bera	7.327	24771.685	137.749
Probability	0.0256	0	0
Observations	129	129	129

Notes: RVNI, RSGE, RSET denote stock returns of Vietnamese, Singapore, and Thailand markets, respectively.

In addition, the kurtosis of all the return series are positive and greater than 3.0, indicating that the monthly mean returns of all markets are more peaked and the tails of the stock returns (*leptokurtic*) are heavy relative to the normal distribution. The excess positive kurtosis of SGE index implies that the distribution of returns series tends to contain extreme values. With exception of the positive skewness of Singapore return, the skewness of returns on the Vietnam and Thailand markets are negative, indicating that the stock returns of these two markets are commonly more negative than positive. Finally, the Jarque-Bera statistic is highly significant for three returns series, implying strong rejection of the null hypothesis of normal distribution of returns. The properties of non-normal distribution are visually consistent with the fat tails of kurtosis as and the negative and positive skewness as well.

Along with the summary of statistics, the cross correlations among the three markets are revealed in Table 5.2. For the entire sample period, all correlation coefficients between the market returns are positive. The positive correlation coefficients imply the same directional movements of markets due to impact of a common factor. This is contrary to the international portfolio diversification theory because it requires the negative correlation between market returns so as the investors can minimize their loss when some markets will rise if others fall (Narayan and Smyth, 2005). However, their correlations are not so strong. The weak correlation coefficients among studied stock markets meet the other requirement of international portfolio diversification. More specifically, the correlation among the three return series are quite low, i.e. less than 25%. The Singapore stock returns are the highest correlated to both stock markets of Thailand and Vietnam (24.4% and 11.3%, respectively) whereas the correlation between Vietnam and Thailand stock returns is lowest (10%). This indicates that diversifying the international portfolio between the Vietnam and Thailand markets could bring the optimum benefit to the international investors.

Table 5.2- Pair-wise Correlations for Returns

	VNI – SGE	VNI – SET	SGE – SET
Full period	0.115	0.103	0.244^{*}
1^{st} sub-period	0.195^{**}	-0.127	0.545^{*}
2^{nd} sub-period	0.123	0.350^{*}	0.182

To strengthen the results, we divide the data into two sub-periods: the pre-crisis period from January 2001 to middle 2007 and the in-time-crisis and post-crisis period from middle 2007 until December 2011. As presented in Tables 5.2, the correlation coefficients decrease from the first to the second period, with exception of the correlation between Vietnam and Thailand markets. The decrease in correlation between markets might imply the more protection of that market from the outside influence after the crisis time. Before the global crisis, the correlation between Vietnam and Thailand stock markets is negative, which is quite adequate to one condition of the international portfolio diversification. However, Thailand and Singapore market returns are very highly positive correlated with each other (more than 50%), indicating the inefficiency in diversifying the international portfolio within these two markets. After the global financial crisis time, it is observed that the correlation between Singapore and the other markets become weaker, while the correlation of Vietnam and Thailand significantly increases.

Regarding the seasonal tendency in the data, the Figure 5.2 shows the patterns of average stock returns of each market by calendar month. As can be seen from the figures, the presence of seasonal cycle is clearly observed for the stock returns of Vietnam since the strongest and weakest months of the year seasonally are highlighted. The VN-Index worst months are February, July, and October. The average returns in these months declines to around -3%. Meanwhile, the best months of the year seasonally for Vietnamese stocks are January, April, and September with the average rallies around 2.7%, 4.59%, and 4.16%. In general, the seasonal tendencies have emerged before 2007 as stock returns tend to rise at the beginning of the year, fall in the middle of the year and rally again at the end of the year. However, since the middle of 2007, the seasonal cycle has changed to the different way through VN Index tends to bottom and rallies a little in recent years. However, for the markets of Singapore and Thailand, the seasonal cycle of stock returns is not obviously observed in the Figure 5.2.

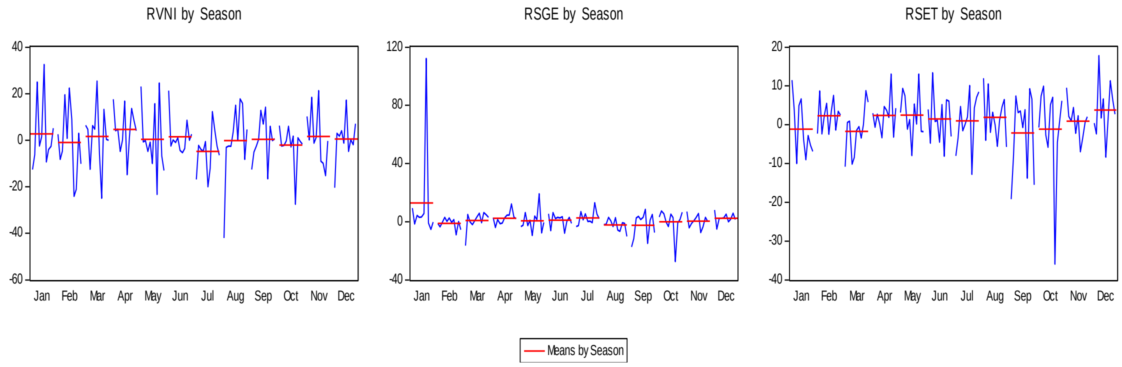

Figure 5.2 - The average Stock Return by calendar month

5.2. Unit root tests

<u>Stationary tests for series of stock price indices</u>

The two well-known methods of unit root tests are performed to check the stationary conditions of the stock market indices: the ADF test and the PP test. Because the visual plots in Figure 2.4 reveal the presence of trends in the stock price indices, the deterministic trend model on ‘intercept and trend’ option is selected to perform the unit root tests. The lag length of the ADF test was specified by the SIC at maximum of 12. The spectral estimation method of Bartlett Kernel was utilized in estimating the PP. The results of unit root tests are shown in Table 5.3 that both tests do not reject the null hypothesis for all series at level, but strongly reject the null hypothesis at difference once. Therefore, given the significance level of 1%, all the index series have a unit root at level but are stationary at 1st difference, indicating the first-order integration of the indices (i.e. I(1)).

Table 5.3 – Unit Root Test Results for stock index series

Series	ADF		PP	
	Level	*1st Difference*	*Level*	*1st Difference*
VNI	-2.277 (0.443)	-7.51018 (0.000)	-1.875 (0.343)	-7.778 (0.000)
SGE	-0.742 (0.831)	-10.571 (0.000)	-0.906 (0.783)	-10.36 (0.000)
SET	-1.921 (0.638)	-10.538 (0.000)	-2.345 (0.406)	-10.66 (0.000)

*Notes: VNI = VN Index; SGE = Singapore SE; SET = SE of Thailand

*Figures in the parenthesis indicate probability values.

Stationary tests for series of stock returns

Stationary tests for monthly log returns of each markets are done using the deterministic trend assumption of 'no trend and no intercept' since time plots of return in Figure 5.1 show neither trend nor intercept. Similar to the index series case, the ADF and the PP method have been applying to stationary tests for log return series. Table 5.4 reporting results from the both the ADF and the PP shows that the return series has no unit root at level. In addition, the stationary series of return for each market are non-normally distributed as presented in the descriptive statistics. Hence, I proceed to the estimation of BEKK models under assumption of multivariate t-distributed errors.

Table 5.4 – Unit Root Test Results for Return series

SERIES	ADF (at level)	PP (at level)
VNI	-7.562 (0.000)	-7.349 (0.000)
SGE	-10.486 (0.000)	-10.515 (0.000)
SET	-10.067 (0.000)	-10.274 (0.000)

*Notes: VNI = VN Index; SGE = Singapore Stock Exchange; SET = Stock Exchange of Thailand
*Figures in the parenthesis indicate probability values.

5.3. Empirical results

The study estimates the trivariate cases for the whole studied period to examine the interdependencies among the three regional markets. The conditional mean equations [1] and the conditional variance-covariance equations [3] are estimated simultaneously by maximizing the likelihood functions. The maximum number of iteration is 500 and convergence criterion is 0.0001 for all calculations.

It is noted that we report the results of the two models resulting from both the original stock returns (seasonally non-adjusted data) and the after-seasonally-adjusted returns of the Vietnamese stock market to observe the difference between the two. There are two reasons why the deseasonalization is applied to the Vietnamese stock returns only, not to the others. Firstly, when observing the seasonal tendency in the Figure 5.2, it is showed that the monthly seasonal effects exist in stock returns in the Vietnamese market while no seasonality is clearly observed for Singapore and Thailand stock markets. Secondly, the adequate model specification tests confirm the existence of the serial correlation of the Vietnamese returns as the Ljung-Box tests in Table A1 show the noise behavior of the standardized residuals of the Vietnamese returns[5]. Meanwhile, the standardized residuals of the other returns are quite white noise. The noise in the Vietnamese residuals is completely eliminated when we carry out the seasonality adjustment through X12 method. Hence the seasonally-adjusted returns of Vietnamese stocks are used to estimate the main findings while the original log returns are still applied for cases of Singapore and Thailand.

5.3.1. The linkages between the equity markets

The conditional return linkage analysis

As explained why the single returns of the VN Index are deseasonalized, Table 5.5 reports the estimated coefficients and t-values for the conditional mean return equations as specified in equations [1], including two panels: (i) Panel A shows the results estimated by the original log returns of stock markets in Vietnam, Singapore, and Thailand; (ii) Panel B shows the results estimated by the seasonal-adjusted Vietnamese return series and the original return series of Singapore and Thailand.

Table 5.5 – Conditional Mean Equation Estimates

(Estimated Equations: $R_t = \alpha + \Gamma R_{t-1} + \varepsilon_t$)

Panel A. Coefficients estimated by the original series of returns of the three markets

	RVNI (i=1)		RSGE (i=2)		RSET (i=3)	
	Coeff.	t-statistic	Coeff.	t-statistic	Coeff.	t-statistic
α_1	0.299	0.308	1.216	1.174	1.216	-1.174
γ_{i1}	0.385*	4.667	0.038	0.430	0.055	1.022
γ_{i2}	-0.160***	-1.848	0.039	0.426	0.126**	2.226
γ_{i3}	0.179	1.294	0.095	0.640	0.040	0.445

Panel B. Coefficients estimated by the deseasonalized return of Vietnam and the original returns of Singapore and Thailand markets

	RVNI (i=1)		RSGE (i=2)		RSET (i=3)	
	Coeff.	t-statistic	Coeff.	t-statistic	Coeff.	t-statistic
α_1	0.297	0.323	1.221	1.177	0.637	1.012
γ_{i1}	0.396*	4.830	0.020	0.212	0.075	1.343
γ_{i2}	-0.171**	-2.076	0.041	0.442	0.123**	2.180
γ_{i3}	0.196	1.491	0.098	0.663	0.041	0.454

*Notes: The asterisks indicate significance at the * - 1%, ** - 5%, and *** - 10% level.*

[5] The noise or white noise in the residuals will be explained more in the section of variance-covariance analysis.

As indicated in the section of methodology, the coefficients γ_{ij} measure the effects of the one month lagged returns of the market j^{th} on the present returns of the market i^{th}. Basically, both results are quite similar in terms of signs and significance of the γ_{ij} coefficients. In the Panel A, the magnitude of the own- and cross-mean spillover effects are smaller than those in Panel B, but negligibly. The common results of both cases are that Vietnamese stock market has the unidirectional relationship with the Singapore stock market, but no linkages with Thailand market in terms of return.

Because the standardized residuals of conditional mean estimate in Panel A are not white noise that violate the GARCH process, the estimate in the Panel B are primarily analyzed to examine the own and cross return linkages between stock markets hereafter. The coefficient γ_{11}, which measures the effect of own lagged return on the current return for Vietnamese market, is positive and highly significant at 1% level, indicating the presence of autocorrelation in the Vietnamese stock returns. It means that Vietnamese return in current month can be used to predict the return in future month. In terms of the cross-return linkages, the Vietnam exhibits the significant mean-spillover from the Singapore market. The negative coefficient γ_{12} shows that the current shocks of the Singapore have negatively significant impact on the future Vietnamese mean return at 5% level. In other words, information incorporated in the SGE composite return negatively affects the next month returns of the VN Index. However, the coefficient γ_{21} is not significant, indicating that the return of SGE index is not influenced by the past shocks in the Vietnamese returns. In other words, the results show the unidirectional return linkage between Vietnamese and Singapore stock markets in direction to the Vietnamese market. This suggests that information from the SGE returns in the previous month likely flows to the VN Index in this month but not vice versa that is supportive to the common findings of previous empirical studies that the larger stock markets have significant influence on the smaller markets.

In addition, the coefficient γ_{13} and γ_{31}, which measure the return linkages between Thailand and Vietnam, are insignificant, indicating the insignificant relationship between Vietnamese and Thailand stock markets in terms of monthly return. In other words, there is a lack of monthly information transmission between the Vietnamese and Thailand stock markets. An explanation might be due to the difference of the closing hours between the two market (i.e. the closing time of the Thailand Exchange is later than that of the Vietnamese stock exchange, e.g. 16:30 pm for SET Exchange vs. 11:00 am for VNI Exchange and the monthly stock indices are the last day's closing price of the month-end; so the information from SET returns is not likely to flow to the Vietnam stock market during the same month). Alternative explanation might be that the smaller stock market like the Vietnam cannot seem to bring about the influence on the larger stock market like Thailand.

In summary, it makes senses to consider the own- and cross-mean spillover effects among the markets. The past own-mean spillover effects are found to be significant for the current Vietnamese returns only, not for the other current returns. The results also found the unidirectional price spillovers of one-month-lagged Singapore return to current Vietnamese stock return. But the study found no spillover effects of Thailand return in last month on the current Vietnamese return. Moreover, the current Thailand market's returns are found to be affected by the past innovation in Singapore returns only. It is also noticed that the current returns of Singapore market are not influenced by the past innovation from the other markets. However, the Singapore stock market shows the powerful capacity in transmitting information across the region. This might be due to the position of the Singapore Stock Exchange as the leading financial center in the ASEAN region. The findings are quite consistent with the previous studies that the significant innovation in returns tends to transmit from developed markets to the emerging markets.

The conditional variance – covariance matrices analysis

Now, we move on analyzing the estimated results of the conditional volatility equations in the system. The Table A1 and A2 in Appendix A report the estimated parameters and standard errors for the variance-covariance matrices of the trivariate GARCH-BEKK model together with Ljung-Box test statistics for the standardized residuals and the squared standardized residuals. While Table A1 shows the coefficients estimated from the original returns, Table A2 presents the estimated coefficients using the seasonal-adjusted returns.

Firstly, we verify the model specification by diagnostic tests on the standardized and squared standardized residuals. If the standardized residuals are white noise (*i.i.d.* and normal), the specified models are correct. Following Tsay R.S. (2005, p.27), we perform the diagnostic tests independently on the standardized residuals by the Ljung-Box Q statistics at lag m to detect the presence of serial correlation and heteroskedasticity in the residuals. Concerning the selection of the lag m, Tsay (2005) states that the rule of thumb that m is equal to the logarithm of the number of observations would give the better power performance. Accordingly, our number of lag included in the Ljung-Box statistics is equal to 5 for 130 observations of each stock index. In the estimated results by using the seasonally adjusted return series of Vietnam (Table A1), the Ljung-Box Q statistics are highly insignificant for Singapore and Thailand, except that of Vietnam. This suggests the presence of serial correlation in standardized residuals of Vietnam, indicating the model inadequately captures the persistence in the variance of Vietnamese return. However, by applying the seasonally adjusted return series, no evidence of autocorrelation in the standardized residuals is found in the results estimated in Table A2 because most of Q statistics for standardized, squared standardized residuals and cross product of standardized residuals are highly insignificant. Briefly, the Ljung-Box diagnostic tests has justified that the specification of the multivariate GARCH models using the seasonal adjusted data is more adequate than that using the original data in describing the conditional heteroscedasticity of return series. Therefore, we explore the estimated parameters depicted in the Table A2 to analyze the pattern of volatility and cross volatility spillovers among three studied markets.

In general, the volatility spillovers between the VN index and the SGE index and the SET index are significantly negative, implying that an increase in the volatility of the two indices is associated with a subsequent decrease in the volatility of the VN index. However, the volatility in the SET has more influence on the volatility in the VNI compared to the SGE volatility. For all the three indices, the sum of the ARCH and GARCH terms, $a_{ii} + g_{ii}$, suggests the high persistence in shocks to the conditional volatility. For instance, the volatility persistence, which is measured by the volatility half-life[6], are 4.6 months, 2.6 months and 1.64 months for the VNI, SGE and SET indices, respectively. This indicates that, coming after a shock, the VNI index would take 4.6 months to turn back to the level of unconditional variance with no further shocks, while the SGE and SET indices need 2.6 months and 1.64 months respectively to do the same. This further indicated that the predictability of future volatility levels based on the present volatility level is highest for the SET, followed by the SGE and lastly the VNI.

Analysis of ARCH effects

[6] Engle R. and Patton A. (2001) defined the volatility half-life as "the time taken for the volatility to move halfway back towards its unconditional mean following a deviation from it". The half-life of volatility is formulated as $h_i=\{\ln([(a_{ii}+g_{ii})/2]/\ln(a_{ii}+g_{ii})\}$.

Now we begin to analyze the ARCH effects in magnitude and multiple directions. Combining as specified by equations [4] to [6], the ARCH coefficients, a_{ij}^2, quantify the impact of the lagged innovation (i.e. the lagged squared residuals) of the market *i* on the present volatility of the market j. It is recalled that stock markets of Vietnam, Singapore, and Thailand were labeled as 1st, 2nd, and 3rd markets, respectively. Therefore, a_{11}^2, a_{22}^2, and a_{33}^2 represents the impacts of lagged own innovations on the present own volatility in the stock markets of Vietnam, Singapore, and Thailand, respectively. The coefficient a_{12}^2 reflects the extent of shock spillovers from the Vietnamese market to the Singapore market. On the contrary, a_{21}^2 measure the extent of shock spillovers from the Singapore market to the Vietnamese market. Similarly, the coefficient a_{13}^2 represents the extent of shock spillovers from the Vietnamese market to the Thailand market and a_{31}^2 measures the extent of shock spillovers from the Thailand market to the Vietnamese market. Derived from squaring the corresponding estimated parameters in Table A2, Table 5.6 shows the shock transmissions (or ARCH effects) between the stock markets, including the own- and cross-market effects. The own-market ARCH effects are shown in the Panel A and the cross-market ARCH effects are revealed in the Panel B.

Table 5.6 – Own- and cross-market ARCH effects

Shock transmission channels			
Panel A: Effects of lagged own shocks on market volatilities (squared diagonal parameters of matrix A)			
	Vietnam's variance (var_r1)	Singapore's variance (var_r2)	Thailand's variance (var_r3)
Vietnam	0.349*	-	-
Singapore	-	0.001 (*Insignificant)*	-
Thailand	-	-	0.057*
Panel B: Effects of lagged cross innovations on market volatilities (squared off-diagonal parameters of matrix A)			
	Vietnam's variance (var_r1)	Singapore's variance (var_r2)	Thailand's variance (var_r3)
Vietnam	-	*Insignificant*	0.171*
Singapore	0.066*	-	0.185*
Thailand	0.269*	0.014***	-

** It is noted that the asterisks indicate significance at the * - 1%, ** - 5%, and *** - 10% level*

As revealed in the Panel A, the impact of own shocks from previous month on the market returns volatilities are strongly significant with the exception of the Singapore market. This indicates the presence of serial correlation in the Vietnamese and Thailand's stock returns. Among the three stock markets, the own ARCH effects are found to be strongest in the Vietnamese market (0.35), followed by the Thailand market (0.057), but insignificant in the Singapore stock market.

In the Panel B, we find the evidence of both unidirectional and bidirectional shock spillovers among the three ASEAN markets. While the results show the bidirectional shock spillover between Vietnam and Thailand, the innovation spillover between Singapore and the other markets is found to be unidirectional that news and macroeconomic shocks in Singaporean market in last month will be associated with the subsequent volatility in the other markets in current month. Volatility of Vietnamese stock market is more influenced by the past shock spillovers from Thailand than from Singapore. For example, a one percent shocks in the last-month SET index is associated with 0.269 percent volatility in the VNI compared to 0.066 percent volatility from the last-month SGE Index. Therefore, the past own shocks of the VNI is found to be the most dominant impact (0.35) on the volatility in the VNI return among the effects of the arrival of news on the Vietnamese market. For the volatility in SET Index, it is significantly affected by the past shocks from the VNI and the SGE Index in addition to the past own shock effects.

In summary, the two-way shock transmission of Vietnamese and Thailand markets implies strong linkages between these two stock markets. Among the three studied stock markets, Singaporean market has unidirectional interrelationship in shock transmission across markets. The study observes that Singaporean stock market has insignificant spillover impact from either news emanating in other markets or even news originating in own market. Again, our finding is quite consistent with the previous findings (such as Worthington and Higgs, 2004) that the large stock markets have the significant impact on the small stock markets but uncommonly vice versa.

Analysis of GARCH effects

Similar to the ARCH effects, the coefficients g_{ij}^2 (GARCH coefficients) measure the impact of the lagged volatility persistence (i.e. the lagged variance) of the market i on the present volatility of the market j. Basically, all of the GARCH coefficients are statistically significant for own and cross volatility spillovers to the individual returns for the three studied markets, suggesting the existence of strong GARCH effects as well as the strong connection in term of volatility among the three markets. Table 5.7 depicts the magnitude of the volatility spillover effects between the markets, including two panels: Panel A reveals the own-market GARCH effects and Panel B shows the cross-market GARCH effects.

Table 5.7 – Own- and cross-market GARCH effects

Volatility transmission channels			
Panel A - Effects of lagged own volatility on market volatilities			
	Vietnam's variance (var_r1)	Singapore's variance (var_r2)	Thailand's variance (var_r3)
Vietnam	0.055*	-	-
Singapore	-	0.382*	-
Thailand	-	-	0.010***
Panel B - Effects of lagged cross volatility on market volatilities			
	Vietnam's variance (var_r1)	Singapore's variance (var_r2)	Thailand's variance (var_r3)
Vietnam	-	0.556*	0.009***
Singapore	0.002***	-	1.623*
Thailand	0.200*	0.307*	-

** It is noted that the asterisks indicate significance at the * - 1%, ** - 5%, and *** - 10% level*

Different from the ARCH effects on the Singapore's variance, the own volatility spillover effects is large and significant, even greater than the lagged volatility persistence of cross markets from Thailand (0.307). However, its own effects are still smaller than the cross effects from Vietnam (0.556) in terms of volatility spillover. This means that the past volatility shocks in Vietnam have a largest effect on the present volatility in Singapore. Conversely, for Vietnam, the past volatility shocks in Singapore might not induce the volatility transmission to the Vietnamese stock market or could only affect in negligible magnitude (0.002), while the past volatility in Thailand has the greatest effect on the present volatility in Vietnamese returns (approximately 0.2). For Thailand, while past volatility in Singapore has highest effect on current volatility in Thailand even higher than the own volatility spillover effect, there is a minor volatility spillover from Vietnam that influences to Thailand's volatility.

Comparing the importance of the effects of past shocks/news and volatility in explaining the future volatility of stock indices, the shock transmission is much larger for the Vietnamese market than the volatility spillover, indicating that past own- and cross-shocks/news in the VN Index are more important in predicting its future volatility than the past own- and cross- volatility. This also indicates that the VN Index is more sensitive to the past news, implying the weak interconnectedness of Vietnamese stock market with the other regional markets. Different from the VN Index, the effects of the past own and cross- shocks or news are negligible to the volatility of the SGE Index in comparison with the effects of past own- and cross- volatility, indicating that Singapore stock market is more sensitive to the past volatility. However, the results are mixed for the Thailand stock markets.

In summary, Thailand is the most influential market to Vietnam with regard to the magnitude of return and volatility spillover effects. The strong effect from Thailand might be explained that investors in emerging markets are usually not optimistic about volatility in another emerging market. They will then promptly react to that volatility by changing their investment and portfolios to more developed markets rather than to the other emerging markets. It is noted that Singapore market has a minor influence on the Vietnamese market, indicating the low correlation between the two markets. However, among the influential factors of the volatility in Vietnamese stock market, the shocks transmission plays more important role, implying the low extent of international financial integration of Vietnam. For Thailand market, the SGE Index could induce the largest volatility spillover effect to the SET Index in addition to the effects of cross-shock transmission from VN Index. For Singapore market, the volatility in the SGE Index is strongly influenced by the own- and cross-volatility (not by the shocks/news transmission) from the VN Index and the SET Index, but the influence of volatility originating from the VN Index is larger. The volatility transmission from the other markets to Singapore can be explained in some ways. Firstly, it is the fact that Singapore stock market is one of the most opened markets in the region. So it might be strongest influenced by other regional markets due to its opened nature of financial system. Secondly, it could be attributed to the closing time difference between the markets as Vietnamese market closing time is much earlier than the Singapore.

5.3.2. Trends in stock volatility and conditional correlation analysis

The conditional variance – covariance estimated by BEKK specification

Stock volatility can be seen as an indicator of risk in the equity market. From investors' point of views, if the investors predict stock volatility higher in future, they would adequately diversify the portfolio in time for minimizing possible risks. Alternatively, they may consider investing in lower risk assets like bonds or government securities. From policy makers' point of views, it is known that higher stock volatility or higher risk in the stocks could increase the capital costs[7]. The higher capital costs negatively affect the overall investment patterns in the economy; hence negatively impact on the government policies in targeting the macroeconomic indicators. Therefore, understanding the behaviors of stock volatility over time would be much helpful for investors and regulators.

We firstly observe the conditional volatility which is proxied by the conditional variance through the graphical plots. Figure 5.3 plot the graph of conditional variance for the returns of the three indices. It can be seen that the volatility in all indices are highly fluctuated associated with the 'volatility clustering' property. The highest volatility is seen for the SET Index, followed by the VN Index. The SGE index exhibits the lowest volatility. Moreover, there is no obvious trend of the conditional volatility over time as observing the graphical plots[8]. In addition, all the three indices are highly volatile during the global crisis time and then become more quite in the recent years. The excessive volatility during the crisis period could be due to the fact that the financial crisis has remarkably influenced on the equity markets and investors feel unsafe in stock investment and quickly response to the crisis, leading to the high volatility in stock markets.

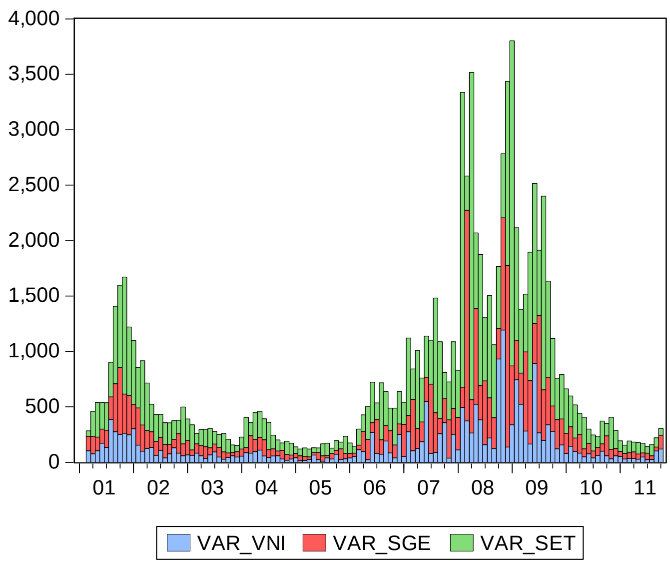

Figure 5.3 - The Conditional Variance of monthly returns of the VNI, SGE, and SET Indices

[7] According to CAPM, a measure of stock volatility, beta, is a key element to calculate the cost of equity/capital or the discount rate. Given things unchanged, the higher beta is, the higher discount rate or its cost of capital is.

[8] The insignificant trends of the conditional volatility series over time has been also verified by the regression of the volatility series against a constant and a time-in-month variable, but not shown in the text for saving spaces.

As evidenced in Figure 5.3 that the volatility of the three markets reached the peak in the period of global financial crisis, it is useful to examine the behavior of the conditional volatility during the financial crisis period. Hereafter, we estimate the magnitude of the crisis impact on the stock volatility series by conducting the empirical tests using regression of the conditional variance series against a constant and a dummy variable (*D_crisis). D_crisis* variable takes value of one for months in the period of global financial crisis and zero for the other months. It is known that the global financial crisis began with the U.S. subprime mortgage crisis in the summer of 2007 and spread to Asian economies in the first half of 2008. From October 2008 onwards was really the period of shocking and frightening to the world economy since the majority of international economies dramatically dropped. However, the shocking period seems to be over in the second half of 2009 and most economies have been recovered to some different extent since then. Therefore, the global financial crisis period is determined from July 2007 to June 2009.

Let denote VOL_i (i=1, 2, 3) denote the conditional volatility of the indices of VNI, SGE, and SET, respectively; β_1 is the constant and β_2 is the coefficient of the dummy variable. So, the regression model of behavior of volatility against the crisis is specified as follows:

$$VOL_i = \beta_1 + \beta_2\ D\_crisis + \xi_i$$

The conducted LM serial correlation tests shows the presence of serial correlation in the regression results, therefore the iterative procedure of AR(1) scheme is applied to capture the serial correlation in the regression. As expected, the Durbin Watson statistic is around 2, indicating the serial correlation has been eliminated. The justly estimated equations are shown as follows:

(i) $$\underset{(0.000)}{\mathrm{VOL\_VNI} = 103.23} + \underset{(0.000)}{263.48}\ D\_crisis + \underset{(0.011)}{0.225}\ \mathrm{AR(1)}$$

$R^2 = 0.36$ DW = 1.94

(ii) $$\underset{(0.000)}{\mathrm{VOL\_SGE} = 141.79} + \underset{(0.000)}{379.53}\ D\_crisis + \underset{(0.091)}{0.150}\ \mathrm{AR(1)}$$

$R^2 = 0.33$ DW = 2.03

(ii) $$\underset{(0.000)}{\mathrm{VOL\_SET} = 255.24} + \underset{(0.000)}{735.97}\ D\_crisis + \underset{(0.162)}{0.125}\ \mathrm{AR(1)}$$

$R^2 = 0.35$ DW = 2.07

**It is noted that the value in ( ) are the p-value*

In the three estimations, the coefficients of dummy variable *D_crisis* are highly significant, indicating the significant influence of the global financial crisis on the stock market volatility of the three countries. The positive sign of β_2 indicates that stock volatility of the three markets significantly increase in the crisis period. By comparison of the influence of the global crisis on the volatility of stock markets, the Vietnamese volatility is marginally influenced while the Thailand is strongly affected by the global crisis. This could be attributed to the facts that Vietnam has the least opened financial system, hence has the least response to the global crisis. Besides, Singapore stock volatility is found to be more stable during the financial crisis period in comparison with Thailand. This can be attributed to the fact that the investors feel more confident in allocating their funds to the developed stock markets than the emerging markets. Overall, the finding that Vietnamese stock volatility is less affected by the financial crisis compared with the others could be useful information to the investors in considering the investment plan on the VNI stocks as well as to the policy makers in making policies to stabilize the financial system.

The conditional correlations estimated by BEKK specification

The pair-wise conditional correlations, which are examined by MGARCH-BEKK models, are shown in Figure 5.4. During the studied period, the conditional correlations between the VN and SGE indices are almost always negative (around -0.43 on averages) and the conditional correlations between VN index and SET index are positive but rather small (0.06 on average). The conditional correlations between the SGE and SET indices are also negative at around -0.16 on average and varied widely between -0.8 and 0.72. There are some particular indications on the conditional correlations between stock returns. Firstly, the positive correlation of Vietnam and Thailand markets implies lightly positive co-movement of the two markets in response of the same shocks of the macroeconomic factors that might be attributed to the similar structure of the two economies. Secondly, the large negative conditional correlation between the indices of VNI and SGE implies that the stock markets of Vietnam and Singapore co-move in the opposite directions. Thirdly, the correlation of VNI - SET indices is more volatile in comparison with that of VNI - SGE indices. Finally, all pair-wise conditional correlations exhibit a dramatic fluctuation in the crisis time of 2008.

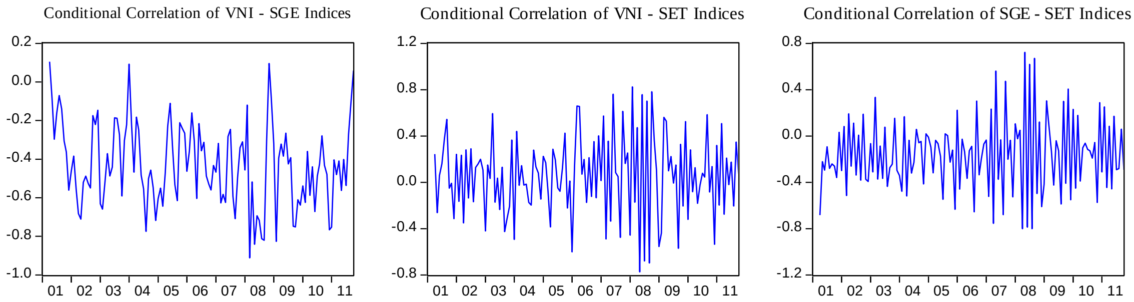

Figure 5.4 – The pair-wise conditional correlations for stock returns

Broadly speaking, the above analysis of the conditional correlation between indices contains several important implications. On the one hand, the low correlation between the VNI and the other indices in the region implies that the integration of the Vietnamese stock market into the regional markets is weak. This might be because of the government interference on the trading activity. One typical example of that interference is the constraint on the Vietnamese stock price. The price limit regulation, e.g. 5% limitation of daily price change of stocks, is hoped to be effective in keeping the stock prices from the high volatility in the short-run. However, the positive effects of the price regulation have not been documented in the stock market's history. Consequently, the constraints in the Vietnamese stock market results in the incompletion of its international integration into the world.

On the other hand, the low conditional correlation between the stock markets reflects the portfolio diversification benefits. Supposing that there are three bivariate portfolios for option such as: (a) the Portfolio A comprising of holding the VNI and SGE indices; (b) the Portfolio B comprising of holding the VNI and SET indices; and (c) the Portfolio C comprising of holding the SGE and SET indices. Under theoretical perspectives that the optimum portfolio is designed on either the negative correlation or the low correlation between two markets, the securities are diversified in the three portfolios could bring the diversification benefits to the investors. Among them, however, the portfolio A (VNI – SGE indices) seems to be the most favorite portfolio due to the lowest negative correlation between the two stocks.

5.3.3. Application of the estimated volatility for Optimal Portfolio Selection

While studying the dynamic relation between large and small return series by several popular multivariate GARCH approaches, Kroner and Ng (1998) applies the estimated conditional variance – covariance of the multivariate volatility models to calculate the portfolio weights and hedge ratios. Under assumption of zero expected returns, the portfolio weight of two-asset holdings is formulated by Kroner and Ng (1998) as follows

$$w_{12,t} = \frac{h_{22,t} - h_{12,t}}{h_{11,t} - 2h_{12,t} + h_{22,t}} \quad ; \quad w_{21,t} = 1 - w_{21,t}$$

Where $w_{12,t}$ and $w_{12,t}$ are the weight of the first and the second index in the portfolio of two indices at time t, respectively; $h_{11,t}$ and $h_{22,t}$ are the conditional variance of the index 1 and 2, respectively; $h_{12,t}$ is the conditional covariance between indices 1 and 2.

The optimal portfolio holdings of the first index at time t should be

$$w^*_{12,t} = \begin{cases} 0 & if \quad w_{12,t} < 0 \\ w_{12,t} & if \quad 0 < w_{12,t} < 1 \\ 1 & if \quad w_{12,t} > 1 \end{cases}$$

Hence, the optimal holdings of the second index at time t are: $w^*_{21,t} = 1 - w^*_{12,t}$

Following Kroner and Ng (1998), we utilize the conditional variance and covariance which have been estimated from the BEKK model to compute the risk-minimizing portfolio weights for designing the optimal portfolio holdings. Because the calculations of risk-minimizing portfolio weights are based on the estimated variance and covariance of the two markets, we assume that the investors will optimize the portfolios of two-asset holding instead of three-asset holding among only the three studied markets. The average weights of two-asset portfolio holdings for the indices are calculated according to Kroner and Ng (1998)'s formulation and reported in Table 5.8.

Table 5.8 - Optimal Portfolio Weights

Portfolio	**Average weights ($w_{12,t}$)**
Portfolio A: VNI / SGE	0.55
Portfolio B: VNI / SET	0.71
Portfolio C:SGE / SET	0.62

Notes: The $w_{12,t}$ is the weight of the index 1 relative to the index 2 in a bivariate portfolio at time t

The average value of $w_{12,t}$ of the Portfolio A is 0.55 means that the optimal holding would be 55 percent for the VNI index and 45 percents for the SGE index. The weight of the portfolio B is 0.71 indicates that a holding of 71 percent for VNI index and 29 percent for the SET index would be the optimal portfolio of the two stocks. Similarly, the portfolio holding comprising of 62 percent for the SGE index compared to 38 percent for the SET index is considered as an optimum of the Portfolio C. Based on the computed optimal portfolio weights, it is surprisingly that the investors are advised to possess more Vietnamese equity than both Singapore and Thailand equity in their portfolios. This is possibly because the own- and cross- shocks and volatility spillovers in Vietnamese stock market are relatively lower than those of the other two markets. In addition, investors should also own more Singapore stocks than the Thailand stocks to minimize risk without lowering the expected returns.

So far, the result on optimal portfolio weights is subject to some limitations. *Firstly*, the assumption that investors will only hold two-asset portfolios is so strong. This assumption is not practical as international investors will have more choices in diversifying their investment. They always desire to expand their portfolios in order to decrease the unsystematic risks[9]. *Secondly*, due to the facts that the Vietnamese stock market is the young market and hence the market performance could be impacted by the specific characteristics of the immature markets such as inadequately transparent environment, thin trading and potential stock manipulations, market inefficiency and severely affected by the irrational behaviors as well as herding behaviors of the market participants (Long, 2007; Loc et al., 2008; My and Truong, 2011), the conditional variance-covariance is possibly under-estimated, resulting in the possibility of over-estimated optimal portfolio weights. As an example, the arrest of financial tycoon Nguyen Tan Kien on 20 August 2012 has strongly affected the Vietnamese financial market. The VN Index fell nearly 10% within only three days after the news that is attributable to the psychological impact of the news on the financial market. It is evident that the VNI index is significantly distorted by market participants' irrational behaviors. Therefore, it is advised that the portfolios managers should not base solely on the theoretical optimal portfolio ratios but need to take the related market information into account in making portfolio investments.

[9] According to Howells and Bain (2005:174), the wider portfolio will make unsystematic risk decreased.

CHAPTER 6

CONCLUSIONS AND POLICY IMPLICATION

6.1. Summary of the study and conclusions

The study contributes to the financial literature by examining the return and volatility spillover effects between the Vietnamese stock market (the VNI index) and the other ASEAN markets such as Singapore (the SGE index) and Thailand (the SET index). In investigating the contemporaneous interdependence of return and volatility between the markets, the policy and investment implication are given. In the study, the main research questions are addressed, namely, whether the return spillover effects among the three regional stock markets exist; whether there are any volatility spillovers among the markets under study, and which are the influential channels of volatility transmission in explaining the market co-movement? Finally, the study identifies the markets that offer the potential investment opportunity for portfolio diversification benefits as well as designing the optimal portfolios. Majorly, the study applied the BEKK parameterizations of multivariate GARCH approach to answer the research questions. Before estimating the BEKK parameters, it is necessary to test for the stationarity of the financial series, for which the ADF and PP tests were used in the study. It is showed that all the indices were stationary in terms of either the first difference or the log return. In addition to the stationary tests, the adjustment of seasonality was also done to the return series for improving the empirical results. Next, we estimate the conditional returns and the conditional variance – covariance by GARCH-BEKK model to examine the own- and cross-linkages of return and volatility among the stock markets. The main results show the existence of the interdependence between the markets in terms of return and volatility. In addition, the volatility of all the markets (i.e. Vietnam, Singapore and Thailand, respectively) exhibits the high persistence in order of volatility half-life. The more detailed results are reported as follows.

The return linkage analysis revealed that there exist the unidirectional linkages of return between the Vietnam and the other stock markets. Among the return spillover effects to the Vietnamese stock market, the effects of the Singapore market were found to be negative and significant while those of the Thailand were positive and insignificant. The return spillovers, which are unidirectional to the Vietnamese market, not vice versa, are quite consistent with the previous empirical findings that the mature stock markets usually have major influences on the immature stock markets. In addition, the returns of Vietnamese market were still significantly impacted by the own one-month lagged return. The own innovations was found to be dominant in comparison with the cross innovations. Furthermore, the Singapore was found to be the most exogenous as it has the dominant influence on the other regional markets. The study found no monthly return linkages between the stock markets of Vietnam and Thailand. Overall, the findings concerned to return linkages seem to confirm that the Vietnamese stock market is not completely integrated into the regional stock markets.

For the volatility spillovers based on the GARCH-BEKK model, it was established that the volatility in the Vietnamese stock returns was influenced by both the own- and cross- innovation. The own innovation spillover effects, however, were found to be the most important for the variation in the Vietnamese market's volatility. This reconfirms the weak integration of the Vietnamese stock market into the regional markets. In addition to the innovation spillover effects, the own and cross- volatility spillover effects also play important role in explaining the volatility's variations in the Vietnamese market. Still, the cross volatility that originates in the Thailand market was found to be dominant in influencing on the volatility of Vietnamese returns. Surprisingly, the volatility in the Singapore equity market was found to be largely affected by the own volatility and the cross volatility originating in the foreign markets. Among them, the effects of volatility transmission from the Vietnamese market are the most influential to the Singapore volatility.

In addition, the trend condition of conditional volatility is graphically observed. It is remarked that the conditional volatility series are characterized with volatility clustering and have insignificant trend on time. Besides, the impact of the global financial crisis on the conditional volatility of stock returns is empirically tested. It is found that the stock volatility in the three markets have been significantly affected by the negative impact of global crisis and become severely high during the crisis period. Among the three markets, Vietnamese stock volatility is lowest influenced by the contagion effects of the global financial crisis. Singapore stock volatility is found to be more stable than Thailand in the financial crisis time. Regarding the conditional correlations which are estimated from the BEKK framework, the pair-wise correlations between the markets are relatively low that reflects the benefits from diversifying the portfolios. Among the portfolios comprising of two stocks, the portfolio made up of equities from Vietnam and Singapore stock markets is preferred due to the lowest and negative correlations between the two.

The last step in our empirical study was the application of the conditional volatility and co-volatility to calculate the risk-minimized weights of portfolio holdings in selecting the portfolios. Following the formulation of Kroner and Ng (1998), the calculated risk-minimized weights of portfolio holdings suggested that the investors should hold stocks in order of the VNI index, the SGE index, and the SET index for earning the optimal benefits from international portfolio diversification. However, there is a cave at the optimal portfolio ratios because of potential bias due to thin trading and strong assumption of only two risky assets in the portfolio.

Overall, the finding implies the weak integration of the Vietnamese stock market into the world stock markets. Thus, there exist opportunities of investment for benefits from diversifying the international portfolios. In addition to the dominance of the own innovation effects on the Vietnamese equity volatility, the closer relationship between the Vietnam and Thailand in terms of volatility transmission was found, that make an anxiety of unstableness in the stock market as the bad volatility in Thailand market can transmit to Vietnam. Finally, it is important for the portfolio managers and investors to pay attention to the prominent characteristics of the infant markets as well as the trading behaviors of irrational investors that might distort the market performance.

6.2. Implications for policy and investment

In the study, the empirical results have some valuable implications to both the policy makers and the investors. Firstly, the finding on low correlation between the Vietnamese stock market and the other markets implies that the international portfolio diversification may be profitable to the portfolio managers. Therefore, investors can rely on this to select the appropriate the portfolio for minimizing risks without lowering the expected returns. However, the finding on the optimal portfolio design should be referred as theoretical indicators in considering inclusion of the VNI index in the potential portfolios. In order to rebalance the portfolios, investors should not solely base on the calculated portfolio ratios, but need to understand thoroughly the market's characteristics and relevant risk factors (i.e. economic risks, political risks, interest rates and currency risks) before making investments.

However, the issues of either low correlation between the Vietnam and the others or weak integration of Vietnam market into the international market should be taken interest in the policy makers because this is related to the capital cost. It is known that the more integrated markets into world equity markets will be associated with the increasing foreign capital inflow. The higher level of foreign capital inflow would contribute to the increase in capital source as a whole that enhances the economic growth. For that reason, policy makers should encourage the foreign capital inflow by ensuring the constructive incentives for the foreign investors, specifically, creating a stable environment (for example, controlling the international investment problems such as currency risks, interest risks, information costs, etc.) and building infrastructure of legal rules in a practical and timely manner.

Secondly, the findings of closed relationship between the stock markets of Vietnam and Thailand raise a worry to policy makers that volatility transmission from Thailand markets can negatively impact on the volatility of Vietnamese stock market. Because the stock market is a part of the financial markets, any instability of the stock market would threaten the whole financial system's stability in accordance with the Financial Instability Hypothesis of Minsky (1986)[10]. Therefore, in addition to the financial openness, policy makers should pay attention to the volatility behaviors in Thailand stock markets in order to proactively drive it back.

The third recommendation is related to the monetary policy. It is believed that financial assets volatility has a strong causal relationship with the monetary variables. According to Mishkin (2001), escalating stock prices could increase the household spending through the wealth effects. This makes high pressures on inflation rate and hence interest rates increase. The higher interest rates could affect the economy in unexpected manners. Therefore, it is important for the regulators to supervise the equity volatility so as to control target interest rates. Inversely, any change in monetary variables (i.e. interest rate, money supply, and credit growth) would affect the stock prices both positively and negatively. An example of the negative effects of higher interest rate is that rapid increase in interest rates will reduce the value of stock portfolios because they increase the opportunity costs of holding stocks. Alternatively, the increased money supply has positive effects on the stock prices because domestic investors have more money to buy stocks as a speculation that pushes stock prices up. Therefore, the adequate monetary policy would help the stock market volatility more controllable to some extent. In general, since the study established that the volatility in stock markets is strongly affected by the own-shock and the own-volatility

[10] The Financial Instability Hypothesis of Minsky (1986) states that as financial markets are unstable, bubbles exist and are endogenous to the whole financial system.

transmission, the policy makers should closely monitor any variation in volatility of the stock markets in order to have the adequate and timely response. However, the government should also avoid changing policies suddenly because disrupted policies could create strong shocks, resulting in higher stock volatility.

Finally, as the Vietnam stock markets are integrating into the world financial markets, volatility transmissions are not avoidable; the government should implement the policies to strengthen both the ability of Vietnamese individual firms and the capacity of financial market to withstand the adverse shocks. Specifically, the policy makers should have programs to educate managers about the risk management to ensure that they have enough knowledge, definite goal as well as understanding the risk so as to employ relevant strategies to mitigate the impact of risk. Besides, the government should ensure that financial institutions have sufficient capital and liquidity resources in order to reduce the market vulnerabilities. Moreover, banking supervision needs to be improved by applying the international standards (for instance, Basel standards) towards strengthening the risk management capacity of Vietnam's financial institutions.

6.3. Limitation and further research

Although the study has made an attempt to follow the recent tendency of research methodology (i.e. the Multivariate GARCH approach) in investigating the contemporaneous spillover effects of return and volatility among the multiple financial time series, the study has used low frequency of financial time series due to the public availability of data, which has not captured the dynamic response to the innovation immediately. In addition, due to the complication of parameter analysis in the BEKK specification, the interaction terms of cross lagged innovations have been ignored in the analysis of volatility and co-volatility. Moreover, since the availability of the commercial statistic software for full BEKK estimation is limited, it is hardly to conduct the study on contemporaneous impact of more than trivariate cases in examining the wider multi-directional interrelationship between the stock volatility in Vietnamese markets and other markets.

Regarding the area for further research, it is recommended that the higher frequency of the time series (for instance, daily or weekly time series) should be selected for the analysis on this regard. In addition, since this study has merely concentrated on the interrelationships between stock markets, similar studies for the other markets such as money, foreign exchange, capital, and derivatives markets, or the inter-markets of one financial system are recommended. Such studies combined with this study will be much helpful for both investors in making adequate decision of investment as well as to policy makers in improving the stability and efficiency of the financial system.

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APPENDIX A

Table A1 - Estimated Coefficients for Trivariate GARCH-BEKK (using the original returns)

	VNI (i=1)		SGE (i=2)		SET (i=3)	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
c_{1i}	1.253*	0.280	-0.195	0.699	-0.302**	0.160
c_{2i}			1.252 *	0.228	-0.477 *	0.148
c_{3i}					1.436 *	0.105
a_{1i}	0.520 *	0.057	0.168 *	0.056	0.303 *	0.026
a_{2i}	0.562 *	0.079	0.374 *	0.057	0.165 *	0.050
a_{3i}	-0.285 *	0.140	0.396 *	0.099	0.250 *	0.030
g_{1i}	0.177 *	0.031	0.513 *	0.017	-0.030 *	0.002
g_{2i}	-1.500 *	0.054	0.431 *	0.024	-0.037 *	0.001
g_{3i}	0.292 *	0.053	0.227 *	0.026	-0.541 *	0.043
LB-Q(5)	10.34 (0.067)		1.77 (0.880)		2.72 (0.743)	
LB-Q^2(5)	17.22 (0.004)		0.18 (0.999)		7.94 (0.160)	
Loglikelihood	1378.11					
AIC	1402.11					

*Notes: LB-Qs = Ljung-Box statistics at lag 5 order. Figures in the parenthesis indicate p-values. Coefficcients C, A, and G capture constants, ARCH, and GARCH effects in the markets. . The asterisks indicate significance at the * - 1%, ** - 5%, and *** - 10% level.*

Ljung Box statistics of cross product of standardized residuals

	$Q^2(5)$	
	Statistic	*p-value*
VNI-SGE	12.3697	0.0301
VNI-SET	15.3825	0.0088
SGE-SET	2.3825	0.7941

Table A2 - Estimated Coefficients for Trivariate GARCH-BEKK (using deseasonalized VNI return)

	VNI (i=1)		SGE (i=2)		SET (i=3)	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
c_{1i}	1.469*	0.588	-1.006***	0.532	-0.352	1.016
c_{2i}			1.176***	0.788	-0.244	0.906
c_{3i}					1.353	1.835
a_{1i}	0.591*	0.067	-0.005	0.054	0.413*	0.130
a_{2i}	0.257*	0.105	0.037	0.036	0.430*	0.092
a_{3i}	0.519*	0.045	0.120***	0.077	-0.239*	0.113
g_{1i}	0.234*	0.059	0.746*	0.022	-0.095***	0.056
g_{2i}	-0.045***	0.031	0.618*	0.049	-1.274*	0.051
g_{3i}	-0.447*	0.029	0.554*	0.028	0.101***	0.062
LB-Q(5)	3.3174 (0.6512)		3.5341 (0.6182)		2.7515 (0.7382)	
LB-Q^2(5)	8.3496 (0.138)		0.9909 (0.9633)		2.0228 (0.846)	
Loglikelihood	1333.631					
AIC	1357.631					

*Notes: LB-Qs = Ljung-Box statistics at lag 5 order. Figures in the parenthesis indicate p-values. Coefficcients C, A, and G capture constants, ARCH, and GARCH effects in the markets. The asterisks indicate significance at the * - 1%, ** - 5%, and *** - 10% level.*

Ljung Box statistics of cross product of standardized residuals

	$Q^2(5)$	
	Statistic	*p-value*
VNI-SGE	3.883	0.5664
VNI-SET	4.9937	0.4166
SGE-SET	10.154	0.0069

APPENDIX B

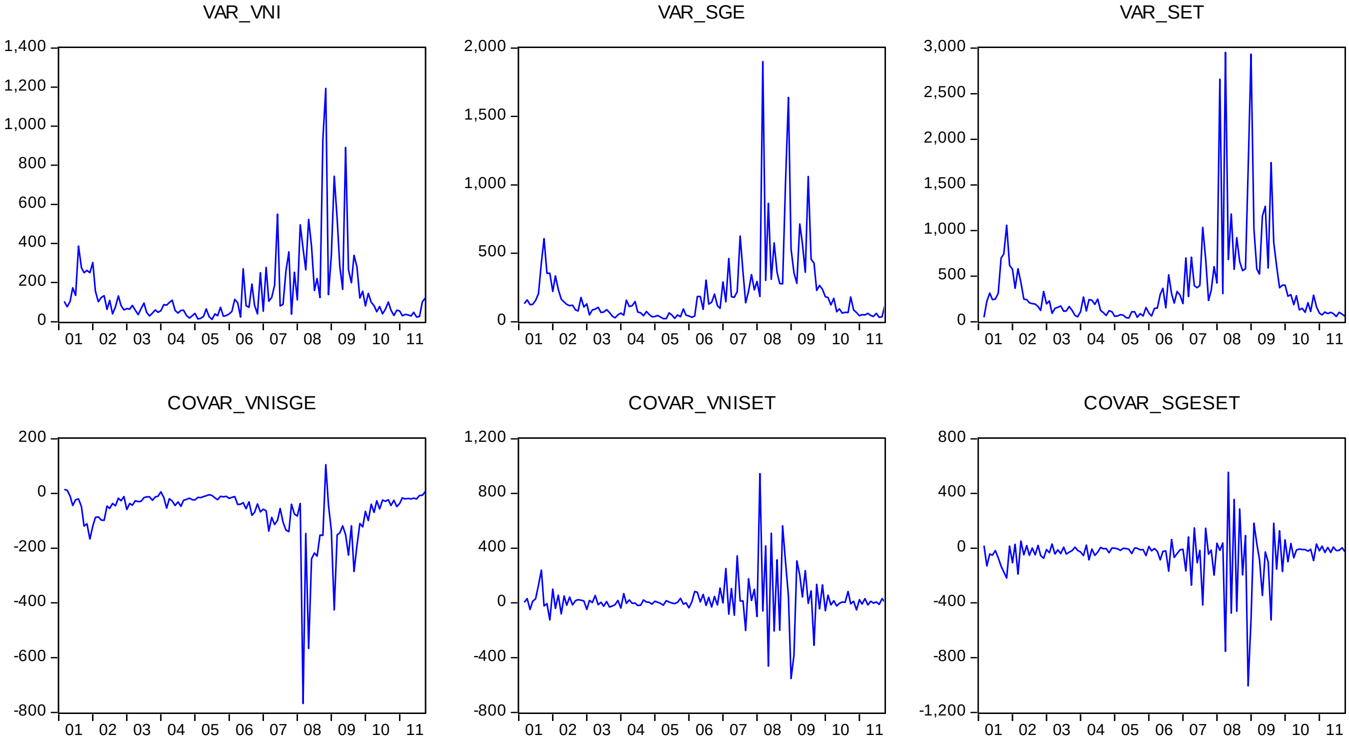

Figure B1 – The conditional variance – covariance estimated by BEKK models