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# Which Global Stock Indices Trigger Stronger Contagion Risk in the Vietnamese Stock Market? Evidence Using a Bivariate Analysis

**Summary:** This paper extends recent investigations into risk contagion effects on stock markets to the Vietnamese stock market. Daily data spanning October 9, 2006 to May 3, 2012 are sourced to empirically validate the contagion effects between stock markets in Vietnam, and China, Japan, Singapore, and the US. To facilitate the validation of contagion effects with market-related coefficients, this paper constructs a bivariate EGARCH model of dynamic conditional correlation coefficients. Using the correlation contagion test and Dungey et al.'s (2005) contagion test, we find contagion effects between the Vietnamese and four other stock markets, namely Japan, Singapore, China, and the US. Second, we show that the Japanese stock market causes stronger contagion risk in the Vietnamese stock market compared to the stock markets of China, Singapore, and the US. Finally, we show that the Chinese and US stock markets cause weaker contagion effects in the Vietnamese stock market because of stronger interdependence effects between the former two markets.

**Key words:** Vietnamese stock market, Contagion risk, EGARCH model, DCC estimation, Sub-prime mortgage crisis.

**JEL:** C12, C22, F30.

According to Vietnam's latest economic outlook, Vietnam is going through a deleveraging cycle, which is exposing serious issues in the banking sector amid a bursting real estate bubble. Economic growth should slow marginally to 5.5% in 2012, supported by robust domestic consumption. Agriculture, manufacturing, and services will continue to remain strong in 2012. The balance of payments (BOP) should also slightly improve thanks to strong foreign direct investment (FDI) and remittances. This will put the BOP in a positive territory for a second year in a row, and in turn, will somewhat alleviate the pressure on the currency. As inflation abates, we will see a gradual reduction in interest rates, thereby helping companies reduce their interest expenses. Overall, earnings will grow by 18% in 2011 and the Vietnam Ho Chi Minh Stock Index (VN-Index) will rise by a modest 20% by year end.<sup>1</sup>

Since the 1997 Asian financial crisis, the Vietnam's government has been following in the footsteps of China, by gradually shifting from communism to capitalism. However, tight government control still remains over certain industries, such as

<sup>1</sup> <http://www.vietnam-report.com/vietnam-economic-outlook-2012/>

the financial industry, as well as over state-owned enterprises. In 2000, Vietnam and the US entered into a bilateral trade agreement that allowed Vietnamese goods to be circulated freely in the US. This agreement also attracted a large amount of foreign investment into Vietnam. Since then, Vietnam has prospered by benefiting from exports based on its agriculture and industries. With cheap labor and low operational costs, large exports of agricultural produce (Vietnam is one of the three largest rice producers in the world) have created abundant foreign reserves. In 2001, the Vietnamese government initiated a ten-year economic reform program to speed up economic development. As a result, Vietnam's GDP growth (an average of 7.1%) is the fastest in the world after that of China. In 2006, Vietnam also became a member of the World Trade Organization (WTO), putting it formally and firmly on the trading map of the world. Although entry into the WTO has accelerated privatization and liberalization, Vietnam faces challenges from different parts of the world.

In addition to the significant influence of the US, most economists believe that changes in Vietnam's economic patterns are very similar to those of China. Both countries have recently transformed themselves from communist to capitalist countries by using cheap labor to attract FDI and by creating foreign reserves with exports. Therefore, they face the same problem of excess liquidity created by the ease of capital inflows and difficulty of capital outflows. This is why the stock markets and real estate markets are both booming in China and Vietnam.

However, high inflation results in increasing labor and operational costs. Since the Vietnamese government pegged its currency to the US dollar, the Vietnamese Dong has experienced drastic depreciation due to the sub-prime mortgage crisis in the US and the depreciation of the US dollar itself under selling pressure. This depreciation shook up the Vietnamese corporate world, plunging the VN-Index by nearly 60% between October 2007 and June 2008. In a bid to improve liquidity, on May 11, 2007, the Prime Minister signed Decision No. 559/2007/QĐ-TTg to convert the Ho Chi Minh City Securities Trading Center into the Ho Chi Minh Stock Exchange, thus creating a state-owned legal entity with a private seal and a private account, which would run as a limited company.

Since 2006, the Vietnamese government has faced several challenges. In early 2006, the International Monetary Fund (IMF) warned the Vietnamese government about its overheating economy. This prompted the government to take certain measures, such as increasing the interest rate and the deposit reserve ratio for banks, and even placing limitations on the rise and fall of single stocks in a day by 1%. However, none of these measures could stop massive capital inflows. The beginning of the US sub-prime mortgage crisis in 2007 led to a loss of confidence in Vietnamese exports due to the shrinkage in the purchasing power of the US. The resulting flight of international hot money nearly resulted in a complete stock market crash in Vietnam.

The world has seen many significant financial crises over the past few decades. These events are often difficult to predict. Each impulse has triggered major shocks and heavy losses around the globe. In extreme periods, when risk diversification is most needed, investors find it impossible to effectively diversify risk in a timely manner, and Vietnamese investors are no exception. Thus, financial crises have been detrimental to the diversification benefits of investments in Vietnam. A

seemingly perfect investment portfolio becomes highly corrected and risky under the impact of extreme events. Therefore, the correlation of market returns under all types of scenarios, especially during financial crises, is a concern for retail and institutional investors in Vietnam as well as in other parts of the world.

The most noticeable economic phenomenon in Vietnam has been the performance of its stock markets. There are currently two stock exchanges in Vietnam: the Ho Chi Minh Stock Exchange and the Hanoi Securities Trading Centre, which began operations on July 28, 2000, and March 8, 2005, respectively. Since stock markets are a credible window to a country's economy, the Vietnamese equity market provides the best showcase of its economic future. In line with what we have already noted, the Vietnamese equity market is influenced by stock markets in China and the US. Vietnam's major trading partners include Japan, Singapore, Hong Kong, Taiwan, Korea, and the European Union. Vietnam's trade with Asian economies constitutes approximately 80% of its total trade. Before 1990, Vietnam's chief trading partners included socialist countries, especially the Soviet Union.<sup>2</sup>

However, few previous studies have analyzed the Vietnamese stock market, let alone discussed its correlations with stock markets in other countries. This paper, thus, empirically tests the transmission of contagion risk between the Vietnamese stock market and stock markets in China and in the US from the perspective of the Vietnamese stock market, by examining crisis contagion effects.

One previous contribution to the body of knowledge on this topic is Hsu-Ling Chang and Chi-Wei Su (2010), which examined whether there are crisis contagion effects between the Vietnamese stock market and its major trading partners, namely the US, Japan, Singapore, and China, when financial crises occur.<sup>3</sup> Further, this paper investigated which stock market reported greater influence in terms of contagion risk. We find that the sub-prime mortgage crisis resulted in contagion effects between Vietnam, and China, Japan, Singapore, and the US, and interdependence effects between Vietnam, and China and the US. However, surprisingly, the Japanese stock market caused a stronger crisis contagion risk in the Vietnamese market compared to the markets of other countries. The Chinese and US stock markets caused weaker contagion effects in the Vietnamese stock market because there were stronger interdependence effects between these two markets. The investors in the Vietnamese stock market reviewed the performances of Vietnam's neighboring markets, and referred to financial exogenous impulses as a decision variable. Learning from the past, it is likely that ignorance of market information pertaining to different economies and the financials of neighboring countries will enhance uncertainties in returns on investments.

This remainder of this paper is organized as follows. Section 1 outlines the literature review of contagion effects; Section 2 introduces the empirical methods; Section 3 discusses the empirical results; and Section 4 concludes.

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<sup>2</sup> See: [http://www.economywatch.com/world\\_economy/vietnam/export-import.html](http://www.economywatch.com/world_economy/vietnam/export-import.html).

<sup>3</sup> For this, Chang and Su (2010) employ a threshold error-correction model with bivariate Glasten-Jagannathan-Runkle-GARCH model. Their results indicate that the Vietnamese stock market and return risks are influenced by the stock markets in Japan and Singapore. They also find that the volatility of the Vietnamese stock market and its trading countries have an asymmetrical effect.

## 1. Literature Review

At the forefront of contagion theory are propagation mechanisms, which explain the characteristics of co-movements between the markets in different countries. First, an exogenous impulse in one market travels to another country. Second, if routes for connections exist before the impulse, the transmission process in contagion effects are deemed to be independent effects. This is known as the non-crisis-contingent hypothesis because the transmission of any impulse is an extension of already existing connection routes.

Kristin J. Forbes and Roberto Rigobon (2002) explain the interdependent effects from four routes, namely trade, policy coordination, re-evaluation, and random aggregate shocks. The transmission of contagion effects can strengthen or weaken previous connection routes, or it may be triggered by other routes resulting from exogenous impulses. This is known as the crisis-contingent hypothesis. Forbes and Rigobon (2002) assume that multiple equilibrium, endogenous liquidity, politics, and economies are ex-ante connection routes in order to illustrate previously nonexistent routes through which exogenous impulses may be transmitted.

Frequently used methods to validate contagion effects in the empirical literature include market correlation coefficients, the GARCH model, co-integration tests, and the probability of specific events. Mervyn A. King and Sushil Wadhvani (1990) and Sang B. Lee and Kwang J. Kim (1993) apply correlation coefficients to stock market returns in order to examine how the market crash in the US in 1987 influenced the stock markets in Japan and the UK. If a significant increase in correlation coefficients is found, there are said to exist contagion effects. The empirical results show that the US stock market crash significantly increased the correlation coefficients between multiple markets. Therefore, the contagion effect hypothesis is supported. Further, Sara Calvo and Carmen Reinhart (1996) find contagion effects during the 1994 currency crisis in Mexico, as evidenced by a significant increase in correlation coefficients for stock and bond markets.

Forbes and Rigobon (2002) indicate that correlation coefficients are overestimated as a result of market heterogeneity variances, which tends to support contagion effects. They suggest that heteroskedasticity bias tests should be used instead. By using these adjusted correlation coefficients, they find interdependent effects but no contagion effects during the 1997 Asian financial crisis, the 1994 Mexico crisis, and the 1987 US stock market crisis (as evidenced by significant changes in the correlation coefficients) in the 29 countries sampled (i.e., nine in South East Asia, four in Latin America, 12 OECD countries, and four emerging economies). By contrast, Taimur Baig and Ilan Goldfajn (1999) refer to the correlation coefficients adjusted with heterogeneous variables and find that during the Asian financial crisis there were contagion effects between interest rates, currency rates, and stock returns in Thailand, Malaysia, Indonesia, South Korea, and the Philippines.

Yasushi Hamao, Ronald W. Masulis, and Victor Ng (1990) use the conditional variances estimated with a GARCH model to validate the correlation of market volatility during the 1987 stock market crisis in the US. The result shows spillover effects from New York to London and Tokyo and from London to Tokyo. Moreover, Sebastian Edwards (1998) finds that during the 1994 Mexico crisis, there were contagion

effects from Mexico to Argentina via capital control in the volatility of short-term nominal interest rates in government bond markets. Edwards and Raul Susmel (2001) apply the bivariate switching ARCH model to find a significant correlation between multiple stock markets in Latin America during periods of high market volatility. This finding proves the contagion effects of stock market volatility. Nikolaos Giannelis, Angelos Kanas, and Athanasios P. Papadopoulos (2010) examine the short-run dynamic relationships between stock market and real activity, within a country, for the UK and the US; the Cross Correlation Function testing procedure is applied to test for causality in mean and in variance between the stock market and the real economic sector. Through the multivariate specification form of the Exponential GARCH model. There is evidence of significant reciprocal volatility spillovers between the two sectors within a country, implying stronger interdependencies in the UK rather than in the US and asymmetric behavior only in the case of the UK.

After the potential benefits of international diversification declined during the 1990s, the focus gradually shifted to previously overlooked emerging markets. Arjun B. Divecha, Jaime Drach, and Dan Stefek (1992), Campbell R. Harvey (1995), and William N. Goetzmann and Philippe Jorion (1999) all report that the correlation between emerging markets and other markets is low and that investment diversification may offer some benefits. They suggest that international investors or fund managers incorporate emerging markets that have high volatility and high returns into their portfolios in order to diversify risk and enhance diversification benefits. Evrim Turgutlu and Burcu Ucer (2008) also explore the correlation between emerging markets and developed markets. José Soares da Fonseca (2008) used the methodology of cointegration to study the international integration of the national stock markets of sixteen European countries. The empirical results show that both European and non-European international factors are necessary to explain the international integration of the national stock markets under analysis. These studies raise the question of whether international diversification remains a suitable strategy in modern times, which is still an important issue following the sub-prime mortgage crisis.

Recently, Cristiana Tudor (2011) investigates causal relationships and short-term interaction mechanisms among six Central and Eastern European stock markets and the USA stock exchange, while paying special consideration to the effects of the 2007-2009 global financial crisis. The study find that during crisis these interactions become significantly stronger, and the leading role of the Russian market in the CEE region before the crisis. In addition, before the crisis CEE markets were significantly influenced by innovations in the USA market.

For research on the Vietnamese stock market, André Farber, Van Nam Nguyen, and Quan-Hoang Vuong (2006) provide empirical evidence of the following four findings. First, there exist anomalies in HSTC stock returns through clusters of limit-hits and limit-hit sequences. Second, there is a strong herd effect toward the extreme positive returns in market portfolios. Third, the specification of ARMA-GARCH can help capture issues such as serial correlations and fat-tails for a stabilized period. Further, by using more information and policy dummy variables, it is justifiable that policy decisions on the technicalities of trading can influence movements in risk level through the conditional variance behavior of HSTC stock returns.

Finally, policies on trading and disclosure practices have had profound impacts on the Vietnamese stock market. Moreover, the authors show that the overuse of policy tools can harm the market and investment mentality, while price limits become increasingly irrelevant and prevent the market from self-adjustment to equilibrium.

Finally, Vuong Minh Giang (2008) provides an overview of the constituents, regulations, and performances of emerging markets. Specifically, this paper examines the benefits and risks associated with such markets by assessing changes in the level and volatility of VN Index returns and finds that the predictive power and signs of heteroskedasticity are evident.

In summary, there has been no relevant research on the correlation between the Vietnamese stock market and other stock markets. This paper thus validates contagion risk from the multiple perspectives identified in various articles in the literature in order to materially improve the verification validity for contagion risk.

Before we describe the research design of the present study, it is important to first note that Forbes and Rigobon (2002) suggest that contagion effects are co-movements of markets within the same region where one country experiences an impulse and the relationship is significantly enhanced. However, this definition ignores impulses and positive influences; indeed, negative influences may also result from a noticeable decrease in co-movements. For example, if an Asian country experiences a major exogenous impulse, international fund managers should withdraw capital from that country and move it to another country in the same region by maintaining the same asset allocations for the region in order to sustain regional competitive positions and influences. This strategy may result in a marked reduction of co-movements between the two markets in the same region. Multiple equilibriums may therefore exist in regional markets. In light of the foregoing, this paper validates the contagion effect of stock returns and uses correlation coefficients to express the increase or decrease in market co-movements. This approach is different from the conventional one in which contagion effects are tested with market correlation coefficients ranking from low to high.

Second, testing the contagion effects of correlation coefficients requires the definitions of the samples before and after the crisis. The correlation coefficients of market variables of different samples are thus estimated in order to facilitate variance tests. The use of non-conditional correlation coefficients in the empirical literature implies the assumption that correlation coefficients are fixed during the sample periods. For instance, Forbes and Rigobon (2002) consider heterogeneous variances and adjust their correlation coefficients accordingly, while François Longin and Bruno Solnik (1995) indicate that from the 1960s to the 1990s, the correlation coefficients of market returns of the seven OECD countries sampled (including the US) increase significantly. Moreover, Ryan Suleimann (2003) argues that the correlation coefficients of five major stock markets (e.g., the US and Germany) change over time. Therefore, non-conditional correlation coefficients are unsuitable for estimating the correlation coefficients of stock markets. Rather, since economic and financial environments are dynamic, it is difficult to differentiate between the constancy of the correlation coefficients of different market variables over time. Robert Engle (2002), Ruey S. Tsay (2002), and Y. K. Tse and Albert K. C. Tsui (2002) all prove that dy-

dynamic correlation coefficient models demonstrate better estimation efficiencies compared with fixed correlation models (e.g., Tim Bollerslev 1990). In light of the foregoing, this paper thus applies the dynamic conditional correlation (DCC) model proposed by Engle (2002) to estimate the correlation coefficients of stock market returns over time and Mardi Dungey et al. (2005) contagion test. These approaches are consistent with real-life economic and financial environments and therefore they materially improve the verification validity for contagion effects compared with using fixed or adjusted correlation coefficients.

## 2. Contagion Definition and Research Method

According to the restrictive definition, contagion is identified as the general process of shock transmission across countries. This shock is supposed to occur during tranquil and crisis periods, and contagion is related to negative shocks and positive spillover effects. Meanwhile, a bivariate EGARCH model of DCC coefficients should be used to deal with the definition considered, because the propagation mechanism explains the co-movement among markets in different countries. The exogenous impulse will transmit to another country, and if the transmission process is guided by a path previously not in place before the impulse, it is called a contagion effect. However, according to the broad definition adopted by this study, the contagion effect refers to the transmission mechanism between countries or the spillover between countries. These may occur during economic recessions or booms and do not need to be guided by crises. If the impulse occurs before the transmission path comes into existence, it will further guide the impulse effects. In such instances, they are indicated as interdependence effects. The emphasis on the impulse transmission is the continuation of the ex-ante path (Forbes and Rigobon 2002). This paper thus uses this broad definition to examine the contagion effects of crises, as such effects influence the asset allocations of investment portfolios and thus the principles of risk diversification.

There are two principles of risk diversification. The first one is to invest in asset classes that have low or negative correlations, while the second is to invest in similar assets of different countries based on the international risk diversification principle. According to these principles, the occurrence of impulses may augment or weaken the correlations between assets. From the literature that has examined crisis transmission mechanisms, Forbes and Rigobon (2002) and Philip Arestis et al. (2005) are among the only studies to have focused on the augmenting effects of already existing communication paths. However, Kuan Min Wang and Thanh-Binh Nguyen Thi (2007) suggest that the transmission of the contagion effect might enhance or undermine already existing communication paths, whereas asset correlations are not only subject to the occurrence of impulses but can also be affected by good and bad news.

Claude B. Erb, Harvey, and Tadas E. Viskanta (1994), Giorgio De Santis and Bruno Gerard (1997), Andrew Ang and Geert Bekaert (1999), Sanjiv Ranjan Das and Raman Uppal (2001), Longin and Solnik (2001), and Chang and Su (2010) all found that the conditional variances of financial assets often experience asymmetric volatility. This implies that there are “leverage effects.” In other words, it suggests that the

volatility of asset price drops caused by negative information is greater than that caused by positive information. According to the broad definition of contagion effects mentioned earlier, the effects of asymmetric information are one of the reasons that lead to contagion effects resulting from changes to asset correlation coefficients. Because Forbes and Rigobon (2002) and Arestis et al. (2005) only considered the contagion effect under symmetric information and not under asymmetric information, a bivariate EGARCH model of DCC coefficients should be used to deal with the broad definition considered in this study.

The method used by this paper to test contagion risk focuses on DCC coefficients, as proposed by Engle (2002). We first make estimates with a univariate EGARCH model and then apply Engle's (2002) model to estimate the DCC coefficients between stock returns. Second, we use the contemporaneous transmission contagion test developed by Dungey et al. (2005) to examine whether there are contagion effects between Vietnam and the four countries of China, Japan, Singapore, and the US. The purpose of this analysis is to assess which countries trigger contagion risk in Vietnam.

## 2.1 The DCC Bivariate EGARCH Model

It is generally agreed that the EGARCH model is sufficient to capture the characteristics of the heteroskedasticity of stock and financial variables (Bollerslev, Ray Y. Chou, and Kenneth F. Kroner 1992). The EGARCH model in Equation (1) is thus used to estimate the stock returns and dynamic variances in the five investigated stock markets:

$$r_t = \alpha + \beta_1 DUM_t + \sum_{i=1}^p a_i r_{t-i} + \sum_{j=1}^q b_j \varepsilon_{t-j} + \varepsilon_t$$

$$\log(h_t) = \omega + \beta_2 DUM_t + \sum_{k=1}^o \delta_k \log(h_{t-k}) + \sum_{l=1}^s \delta_l \frac{\varepsilon_{t-l}}{\sqrt{h_{t-j}}} + \sum_{m=1}^w \gamma_m \left| \frac{\varepsilon_{t-m}}{\sqrt{h_{t-m}}} \right| \quad (1)$$

the stock return ( $r_{i,t}$ ) be the logarithmic difference between the closing stock price of the  $i$  market in the  $t$  period. Where, in the  $i$  market, the mean equation is the process of ARMA ( $p, q$ );  $DUM_t$  is the structural break point variable that is detected by the Phillips Perron (1997) unit root test considered in the mean and variance equations; and  $\varepsilon_t$  is the white noise residual of the message set  $\mathfrak{S}_{t-1}$  in the  $t-1$  period and under a normal distribution. Further, its mean is zero and variance is  $h_t$ . We assume a Generalized Error Distribution (GED) structure for the errors with the EGARCH model:  $f(v_t) = \frac{v \exp[-(1/2)|v_t/\lambda|^v]}{\lambda 2^{[(v+1)/v]} \Gamma(1/v)}$ .  $\Gamma(\cdot)$  is the gamma function,

$\lambda = \left\{ \frac{2^{(-2/v)} \Gamma(1/v)}{\Gamma(3/v)} \right\}^{1/2}$  is a constant, and  $v$  is a positive parameter that represents the thickness of the distribution tail. If  $v = 2$ , then  $\lambda = 1$ , and the equation  $f(\cdot)$  measures

a standard normal distribution. Moreover, the tail of the function distribution is thicker than the tail of the normal distribution if  $\nu < 2$ , but flatter if  $\nu > 2$ .  $\varepsilon_t$  is the absolute expected value:  $E|v_t| = \frac{\lambda 2^{(1/\nu)} \Gamma(2/\nu)}{\Gamma(1/\nu)}$ .  $E|v_t| = \sqrt{2/\pi}$  under a normal distribution.

The DCC model encompasses two EGARCH processes with stock returns and the standardized disturbance. The log-likelihood function also includes the stock return fluctuation and correlation coefficient:

$$L(\Theta, \Phi) = L_v(\Theta) + L_c(\Theta, \Phi) \quad (2)$$

where  $\Theta$  is the parameter of stock return volatility:

$$L_v(\Theta) = -\frac{1}{2} \sum_t (n \log(2\pi) + \log|D_t|^2 + e_t' D_t^{-2} e_t) \quad (3)$$

$\Phi$  is the parameter of the correlation coefficient:

$$L_c(\Theta, \Phi) = -\frac{1}{2} \sum_t (\log|R_t| + \varepsilon_t' R_t^{-1} \varepsilon_t - \varepsilon_t' \varepsilon_t) \quad (4)$$

Engle's (2002) two-step estimation is proposed to maximize the likelihood function of Equation (2). In other words, in the first step, we estimate Equation (3) in order to derive the optimal value of the market volatility parameter  $\hat{\Theta}$  and then use  $\hat{\Theta}$  in Equation (4) in the second step to estimate the optimal value of the correlation coefficient  $\hat{\Phi}$ . Engle (2002) proves that consistency in the first step guarantees consistency in the second step under standard conditions.

## 2.2 The Contagion Effect Test with DCC Coefficients

### 2.2.1 The Correlation Contagion Test

In order to test which stock market causes stronger contagion risk in the Vietnamese stock market, this paper estimates the DCC coefficients. The test is divided into two steps. Step 1 is to prove the existence of crisis contagion effects by identifying the time at which structural changes may take place. This is followed by the validation of whether there are significant changes in the correlation coefficients of the Vietnamese stock market and the stock markets in China, Japan, Singapore, and the US before and after the occurrence of structural changes. The result proves that contagion effects do exist between the five investigated countries. Step 2 is to verify the influence of the contagion risk triggered in these stock markets.

This study adopts  $t$  statistics in order to test for the contagion effect and contagion risk. The null and alternative hypotheses are:

$$\begin{aligned} H_0 : \mu_i &= \mu_j \\ H_a : \mu_i &\neq \mu_j \end{aligned} \quad (5)$$

where  $\mu_i$  and  $\mu_j$  are the means of the conditional correlation coefficients of the two samples. If the value of  $t$  is significantly greater or smaller than the critical value,  $H_0$  is rejected, suggesting the existence of a contagion effect.

### 2.2.2 Dungey et al.'s (2005) Contagion Test

According to Dungey et al. (2005), contagion is represented by the contemporaneous transmission of local shocks to another country or market on the condition that common factors exist in a non-crisis period. This is consistent with the paper of Forbes and Rigobon (2002), in which contagion is represented by an increased correlation during periods of crisis. Consider the case of contagion from country 1 to country 2. The factor model is augmented as follows:

$$\begin{aligned} y_{1,t} &= \lambda_1 w_t + \delta_1 u_{1,t} \\ y_{2,t} &= \lambda_2 w_t + \delta_2 u_{2,t} + \gamma u_{1,t} \end{aligned} \quad (6)$$

where  $y_{i,t}$  signifies the demeaned stock returns during the crisis period. The variable  $w_t$  represents common shocks that affect all asset returns with loadings  $\lambda_i$ . These shocks could represent the financial shocks that arise from changes in the degree of risk aversion of international investors or changes in world endowments. In general,  $w_t$  represents the market fundamentals that determine average asset returns across international markets in non-crisis periods. This variable is commonly referred to as a world factor, which may or may not be observed. For expositional purposes, this world factor is assumed to be a latent stochastic process with zero mean and unit variance. The properties of this factor are extended below to capture richer dynamics including both autocorrelation and time-varying volatility. The terms  $u_{i,t}$  are idiosyncratic factors that are unique to a specific asset market. The contribution of idiosyncratic shocks to the volatility of asset returns is determined by the loadings  $\delta_i > 0$ . These factors are also assumed to be stochastic processes with zero mean and unit variance. To complete the specification of the model, all factors are assumed to be independent:

$$E(u_{i,t} u_{j,t}) = 0 \quad \forall i \neq j \quad \text{and} \quad E(u_{i,t} w_t) = 0 \quad \forall i \quad (7)$$

The expression for  $y_{2,t}$  contains a contagious transmission channel that is represented by local shocks from the asset market in country 1, with its impact measured by the parameter  $\gamma$ . The fundamental aim of all empirical models of contagion is to test the statistical significance of the parameter  $\gamma$ . The bivariate tests of contagion focus on changes in the volatility of pairs of asset returns. Hence, a contagion

test is carried out by testing the restriction  $\gamma=0$ . The strength of contagion is thus determined by the parameter  $\gamma$ , which can be tested formally.

When N markets are taken into account:

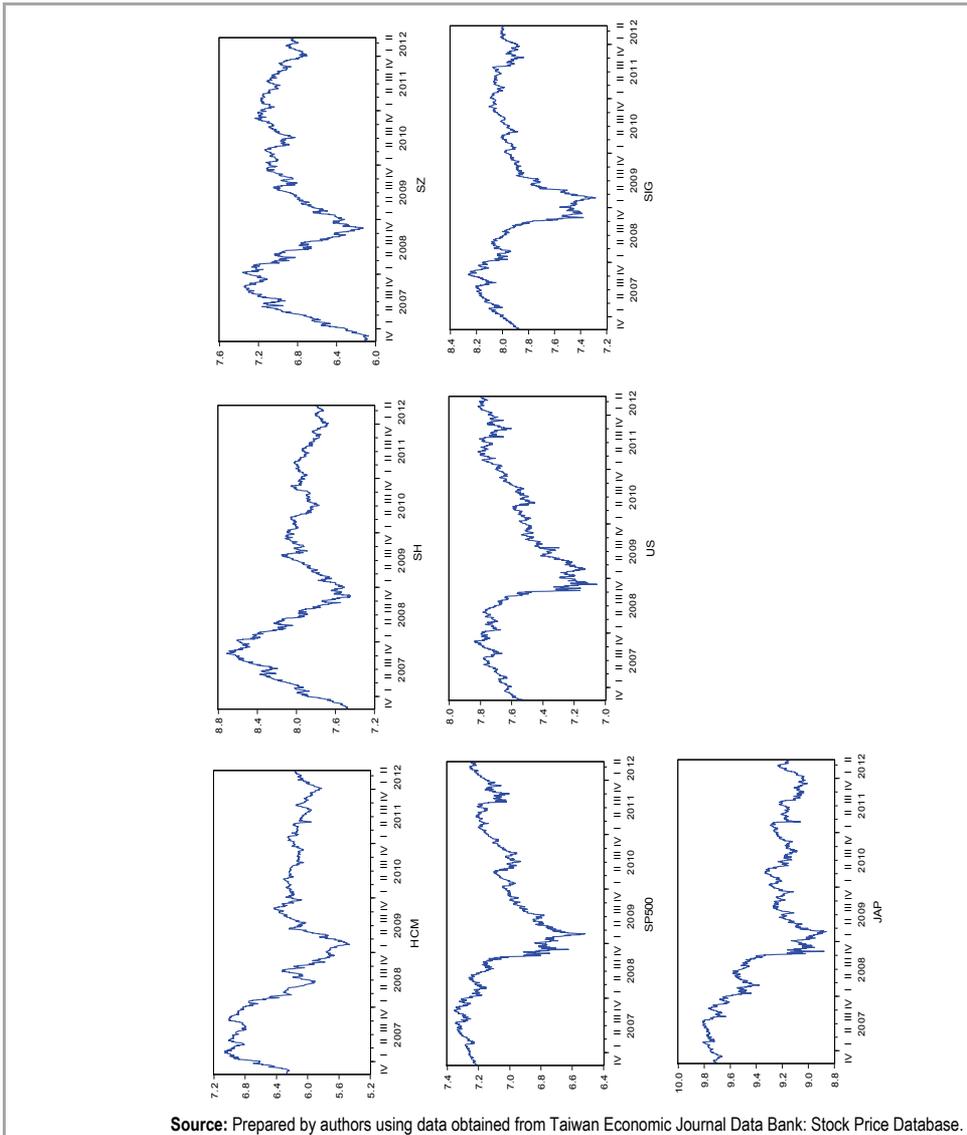
$$y_{i,t} = \lambda_i w_i + \delta_i u_{i,t} + \sum_{j=1, j \neq i}^N \gamma_{i,j} u_{j,t} \quad i=1,2,3,\dots,N \quad (8)$$

we can estimate the unknown parameters using the generalized method of moments. A joint contagion test, using the factor models, can be carried out by comparing the objective function from the unconstrained model,  $q_u$ , with the value obtained from estimating the constrained model,  $q_c$ , where the contagion parameters are set to zero. As the unconstrained model is just identified in this case,  $q_u=0$ , the test is simply a test that under the null hypothesis of no contagion  $H_0: q_c=0$ , which is distributed asymptotically as  $\chi^2$  under the null. As before, the contagion test can be interpreted as testing for changes in both variances and covariances (see Dungey et al. 2005 for more details).

### 3. Empirical Analysis

This paper sources data from the Ho Chi Minh Stock Index (HCM) in Vietnam, the Shanghai Stock Exchange Stock Index (SH) and the Shenzhen-Composite Index (SZ) in China, the American-Amex Composite Index (US) and the S&P 500 Index (SP500) in the US, the Nikkei 225 Index (JAP) in Japan, and the Strait Times Index (SIG) in Singapore. These indices are not only the main trading partners of Vietnam but also they are better able to reflect the correlations and interactions in traded commodities. In order to understand the crisis contagion effects on the Vietnamese stock market of the stock markets in China, Japan, Singapore, and the US before and after the sub-prime mortgage crisis, this paper samples data from October 9, 2006 to May 3, 2012. The data source is the Taiwan Economic Journal Data Bank: Stock Price Database. In addition, this paper leads and lags the data derived from different trading days for the empirical analysis, since these stocks are sometimes traded on different days.

First, we observe the trends in these seven stock indices. According to Figure 1, before March 21, 2007, the data entries showed an upward trend, but at this point, the indices began their gradual decline. After March 10, 2008, the indices plunged due to the worsening sub-prime mortgage crisis. The rebound only began after February 5, 2009. Figure 1 also shows that the sub-prime mortgage crisis caused all seven stock indices to fall. However, compared with the Vietnamese and Chinese stock markets, the US, Japan, and Singapore stock markets experienced more extreme slumps.



**Figure 1** The Trend of 7 Stock Indices

In order to estimate the conditional variance and conditional correlation coefficients, we need to conduct a preliminary analysis of the descriptive statistics of the sample. Table 1 displays the descriptive statistics for the seven markets. The mean returns of the two stock markets in Vietnam and Japan are negative, whereas the others are positive. Based on the standard deviations, Vietnam and the two markets in China have higher risk, while the markets in the US, Japan, and Singapore have lower risk. The returns and standard deviations show high returns and high risk, as consistent with market expectations. Meanwhile, information in emerging markets is

opaque or incomplete, which makes them more risky, whereas information in developed markets is transparent and complete and thus these markets are less risky. The impact of the sub-prime mortgage crisis in the US leads to USD-denominated returns on investment being significantly lower than stock market returns in China and Vietnam. Consequently, investors who want to maximize their profits shift their focuses to the stock markets in China. The crowd-out effect is also the reason for the sluggishness of the US stock markets. In terms of the coefficients of skewness, all seven markets have left-skewed distributions. Further, the kurtosis statistics indicate that all stock returns are leptokurtic distributions, which is typical of financial variables. The Jarque–Bera (J-B) test shows that not all returns follow a normal distribution.

**Table 1** Basic Statistics of Stock Returns

Index	HCM	SH	SZ	SP500	US	JAP	SIG
Mean	-0.008	0.022	0.053	0.002	0.017	-0.039	0.009
Standard deviation	1.776	1.898	2.085	1.577	1.570	1.714	1.428
Skewness	-0.053	-0.387	-0.628	-0.278	-0.332	-0.559	-0.121
Kurtosis	3.313	5.900	5.077	10.688	17.137	12.297	7.465
J-B	6.606**	545.3***	356.4***	3597.0***	12126.3***	5309.1***	1210.2***
N	1453	1453	1453	1453	1453	1453	1453

**Note:** J-B is the statistic of Jarque-Bera normal distribution test. N is the sample size, \*\* and\*\*\* denotes 5% and 1% significant levels, respectively.

**Source:** Authors' calculations.

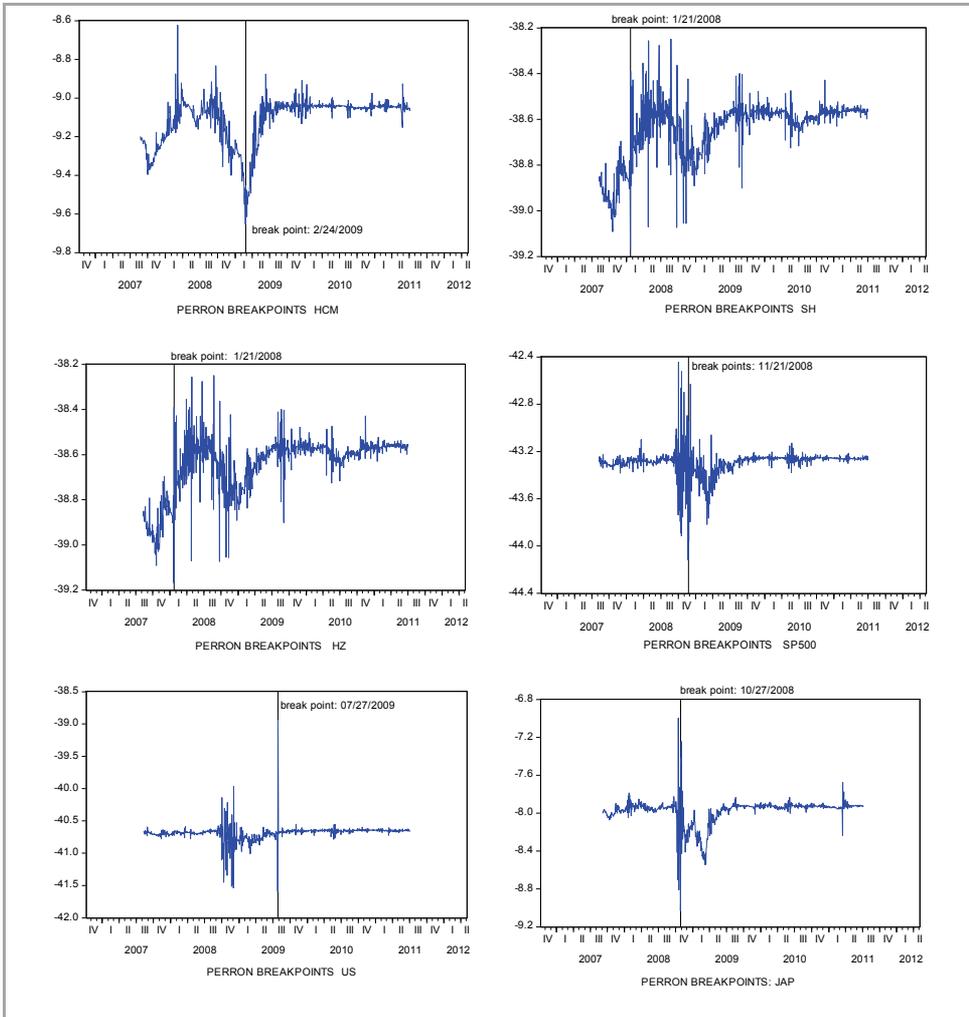
Table 2 presents the tests on the stationarity, residual autocorrelations, and break points of each market. LB (12) and LB2 (12) are the tests of the stock returns of the 12 lagging periods and the autocorrelation Ljung–Box statistics of the squares, respectively. The results show that at the 5% level of significance, the significant LB (12) statistics imply that the returns of all markets in all countries display a high level of autocorrelation. The significant LB2 (12) statistics imply that stock returns display heteroskedasticity. As the data in Table 2 indicate, the seven return series present conditional heteroskedasticity. The ADF and Perron unit root tests show that all seven return series have stationarity, while the Perron test detects the endogenous timing of the crises (i.e., the structural break points) in the seven series: HCM is 02/24/2009, SH is 01/21/2008, SZ is 01/21/2008, SP500 is 11/21/2008, US is 07/27/2009, JAP is 10/27/2008, and SIG is 10/27/2008. Figure 2 shows the break points of the seven returns under the Perron unit root test. In order to consider the standardized residual distribution as the GED cumulative density function and to test for the leverage effect of each market, we first estimate the univariate EGARCH model for the returns of each market. Second, we estimate the standardized residuals to obtain the DCC coefficients.

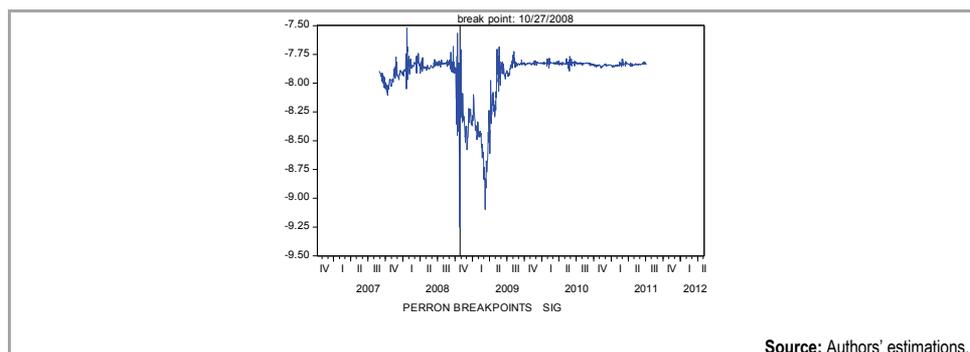
**Table 2** The Specification Tests on Stationarity, Residual Autocorrelation, and Break Point of Each Market

Index	HCM	SH	SZ	SP500	US	JAP	SIG
LB(12)	156.5***	24.77***	30.74***	44.50***	16738***	21.23**	18.43
LB2(12)	952.1***	165.44***	178.36***	1465.6***	647.0***	1668.4***	1075.7***
ADF unit root test	-15.36(3)***	16.98(3)***	16.18(4)***	-8.966(17)***	-29.25(1)***	-19.59(3)***	-7.834(16)***
Perron unit root test	-9.652(12)***	-39.16(0)***	-36.17(0)***	-44.11(0)***	-41.59(0)***	-9.029(22)***	-9.253(16)***
<b>Structural break time</b>	<b>02/24/2009</b>	<b>01/21/2008</b>	<b>01/21/2008</b>	<b>11/21/2008</b>	<b>07/27/2009</b>	<b>10/27/2008</b>	<b>10/27/2008</b>

**Note:** LB (12) is the 12-day lag return of Ljung-Box statistic, and LB2 (12) is the 12-day lag square return of Ljung-Box statistic. Augmented Dickey-Fuller (ADF) unit-root test statistic indicating that the regression includes a constant term, values in the parentheses are the optimum delay difference periods that are determined by applying the AIC criterion; the maximum is 18. The Perron (1997) unit root test with a break in the trend function at an unknown time. \*\* and \*\*\* denotes 5% and 1% significant level, respectively.

Source: Authors' estimations.





**Figure 2** The Perron Break Point of 7 Stock Returns

Table 3 provides the estimation of the EGARCH model for each market.  $Q_{12}(uh^{-1/2})$  and  $Q_{12}(u^2h^{-1})$  are the 12<sup>th</sup> order standardized residual ( $uh^{-1/2}$ ) and square standardized residual ( $u^2h^{-1}$ ) of the Ljung–Box statistics, respectively. At the 10% significance level, no autocorrelation between the standardized residuals and square standardized residuals exists. ARCH(12) is the 12<sup>th</sup> order ARCH effect test. The results show that none of the seven markets displays heteroskedasticity characteristics. We further test the crisis impact of structural change on the mean and conditional variance equations. From the value of the coefficient  $\mathcal{G}_1$ , we find that the impact of structural changes on the SH and SZ markets is negative in the mean equation, but positive for the SP500 and US markets, whereas the other results are not significant. Additionally, from the value of the coefficient  $\mathcal{G}_2$ , we find that the impact of structural changes on the HCM, US, and SIG markets is negative in the variance equation, whereas the other results are not significant. Further, owing to the significance of the coefficient  $\mathcal{N}_1$ , we can identify the existence of the leverage effect in all seven markets. The coefficient  $|\mathcal{N}_1|$  is also smaller than one, suggesting that a positive shock decreases market variance, whereas a negative shock increases market variance.

Moreover, because all  $\nu$  coefficients are smaller than two, the tails of the standardized residual function distributions are thicker than those of the normal distribution in the seven markets. In addition, we employ the sign test, negative size test, positive size bias test, and joint test to examine whether the asymmetry effect remains. The results show that all fitting models are the best and that no asymmetry effect remains. When the standardized residuals are not autocorrelated, the maximum likelihood method can be used to obtain the mean reverting DCCs. Table 4 reports the estimations of the mean reverting DCCs. We find that  $\theta_2$  is greater than  $\theta_1$ , under the restriction that coefficients are stable with  $\theta_1 + \theta_2 < 1$ . These results suggest that a large shock causes only a small correction in the oncoming mutual fluctuation (or covariance) between markets.

**Table 3** The Estimation of GED-EGARCH Model

	HCM		SH		SZ		SP500		US		JAP		SIG	
	estimate	p-value												
$\alpha$	-0.128	0.076	0.490	0.000	0.592	0.000	--	--	--	--	--	--	--	--
$\varrho_1$	0.095	0.342	-0.483	0.000	-0.508	0.000	0.081	0.000	0.107	0.001	0.014	0.686	0.030	0.307
$a_1$	0.261	0.000	--	--	0.055	0.018	--	--	--	--	--	--	--	--
$a_3$	0.044	0.034	0.039	0.051	--	--	--	--	--	--	--	--	--	--
$a_4$	0.070	0.002	--	--	--	--	--	--	--	--	--	--	--	--
$a_{10}$	--	--	--	--	0.049	0.023	--	--	--	--	--	--	--	--
$b_1$	--	--	--	--	--	--	-0.069	0.000	--	--	--	--	--	--
$\omega$	-0.343	0.000	-0.057	0.002	-0.056	0.071	-0.089	0.000	-0.073	0.000	-0.089	0.000	-0.259	0.000
$\varrho_2$	-0.046	0.083	-0.012	0.130	-0.017	0.242	-0.012	0.134	-0.015	0.013	0.003	0.731	-0.031	0.067
$\delta_1$	-0.034	0.012	0.983	0.000	0.945	0.000	0.976	0.000	0.984	0.000	0.972	0.000	0.169	0.486
$\delta_2$	0.932	0.000	--	--	--	--	--	--	--	--	--	--	0.322	0.109
$\delta_3$	--	--	--	--	--	--	--	--	--	--	--	--	0.477	0.012
$N_1$	-0.056	0.006	-0.033	0.049	-0.062	0.006	-0.306	0.000	-0.087	0.000	-0.131	0.000	-0.167	0.000
$N_2$	-0.016	0.440	--	--	--	--	0.140	0.005	--	--	--	--	-0.004	0.932
$\gamma_1$	0.348	0.000	0.118	0.000	0.189	0.000	-0.266	0.000	0.113	0.000	0.136	0.000	-0.028	0.610
$\gamma_2$	0.235	0.000	--	--	--	--	0.397	0.000	--	--	--	--	0.161	0.005
$\gamma_3$	--	--	--	--	--	--	--	--	--	--	--	--	0.242	0.000
$\nu$	1.958	0.000	0.995	0.000	1.144	0.000	1.234	0.000	1.264	0.000	1.288	0.000	1.538	0.000
$Q_{12}(uh^{-1/2})$	11.41	0.248	15.85	0.147	13.24	0.211	10.01	0.529	7.272	0.839	10.11	0.606	12.94	0.373
$Q_{12}(u^2h^{-1})$	12.99	0.163	7.278	0.776	5.07	0.886	10.32	0.502	8.956	0.707	12.62	0.397	16.14	0.185
ARCH(12)	11.30	0.354	15.85	0.147	5.107	0.953	10.13	0.604	8.929	0.708	11.30	0.502	17.25	0.140
SB	--	0.701	--	0.979	--	0.358	--	0.918	--	0.914	--	0.523	--	0.127
NSB	--	0.493	--	0.799	--	0.987	--	0.477	--	0.503	--	0.803	--	0.241
PSB	--	0.727	--	0.524	--	0.688	--	0.751	--	0.206	--	0.821	--	0.203
Joint	--	0.234	--	0.825	--	0.405	--	0.842	--	0.554	--	0.887	--	0.101
log L	-2664.1	--	-2770.9	--	-2950.3	--	-2206.9	--	-2307.5	--	-2486.3	--	-2275.6	--

**Note:** Statistics  $Q_{12}(uh^{-1/2})$  and  $Q_{12}(u^2h^{-1})$  represent the 12-order Ljung-Box statistics of the standardized residuals and the squares of them, respectively. Log L indicates the value of the maximum likelihood function. For the SB, NSB, and the PSB tests, we list the p-values of the t statistics. For the joint test (Joint), we list the p-values of the Chi-square statistics.

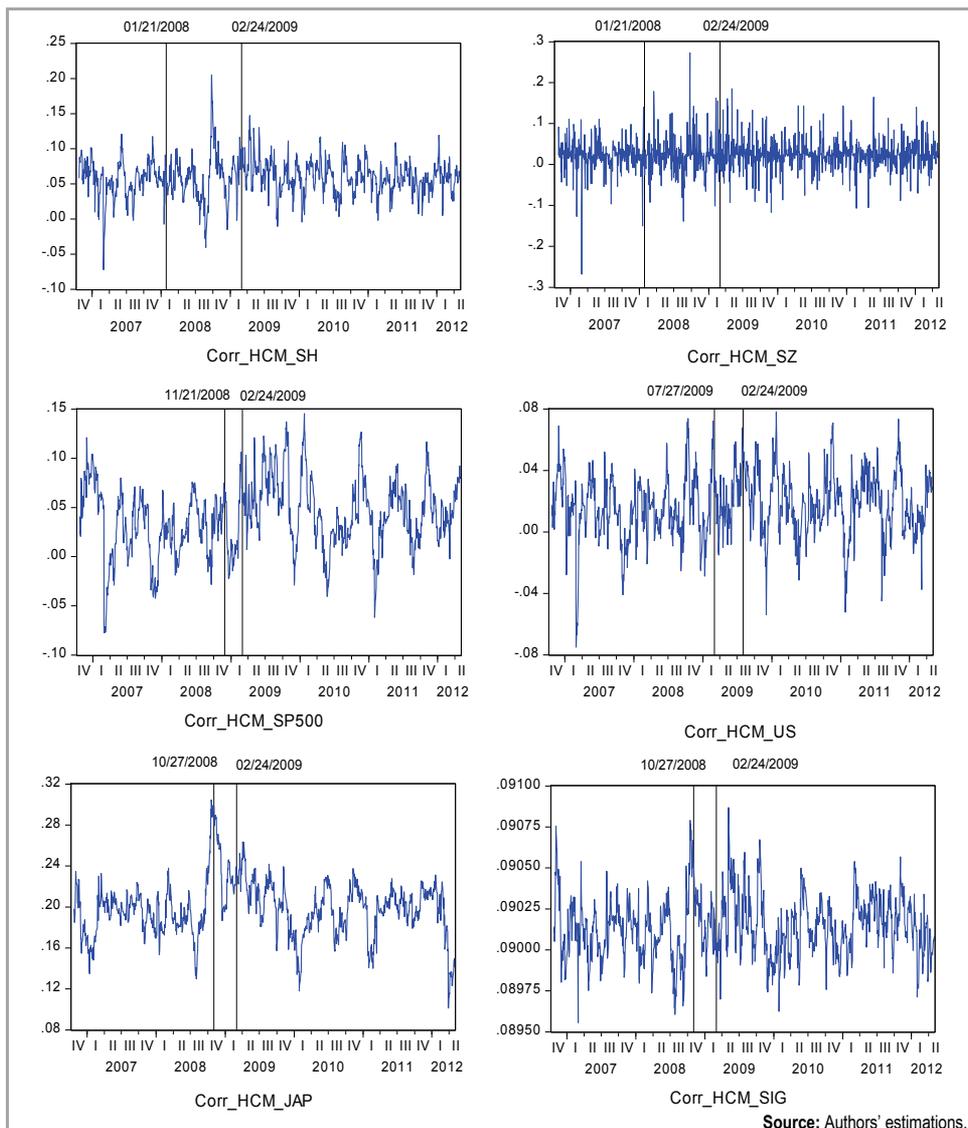
**Source:** Authors' estimations.

**Table 4** The Parameter Estimation of Mean-Reverting DCC-GARCH Model

Parameter	HCM-SH	HCM-SZ	HCM-SP500	HCM-US	HCM-JAP	HCM-SIG
$\theta_1$	0.013(0.001)	0.036 (0.027)	0.001 (0.336)	0.009 (0.560)	0.007(0.000)	0.0001(0.994)
$\theta_2$	0.842 (0.002)	0.138 (0.810)	0.936 (0.000)	0.952 (0.000)	0.963(0.000)	0.895(0.970)
$S(1 - \theta_1 - \theta_2)$	0.058 (0.120)	0.825 (0.150)	0.052 (0.530)	0.118 (0.711)	0.039(0.596)	0.104(0.996)
Log L	-2743.8	-2757.7	-2767.2	-2791.7	-2728.5	-2763.1

**Note:** Log L is maximum likelihood function, inside (.) is p-value.

**Source:** Authors' estimations.



**Figure 3** Structural Break Point, Periods, and Dynamic Correlation Coefficient of Return between Markets

Figure 3 depicts the DCC coefficients of six markets. By focusing on the DCC coefficients, we can observe the variation in the correlation between two markets. When the correlation is positive and close to one, this indicates the same direction of returns. By contrast, when the correlation is negative and its absolute value is close to one, this indicates the opposite direction of returns. In order to identify the events in other stock markets that might trigger a contagion effect on the Vietnamese stock market, this paper examines the DCC coefficients, as shown in Figure 3. This figure shows the common break point (02/24/2009) of Vietnam and the individual break

points for each market. Because there are two breaks and three regimes in each market, this study uses a Chow forecast test in order to revalidate whether there are structural changes at these time points. The test results are summarized in Table 5, where all results are shown to be significant except for the coefficients of HCM-SH at 02/24/2009.

**Table 5** Chow Forecast Test of Dynamic Correlation Coefficient of Return between Markets

Chow forecast test	HCM-SH	HCM-SZ	HCM-SP500	HCM-US	HCM-JAP	HCM-SIG
Common structural break LR	02/24/2009	02/24/2009	02/24/2009	02/24/2009	02/24/2009	02/24/2009
statistic	782.66	53.06	1336.8	1254.2	1044.3	1150.1
(p-value)	(0.892)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Individual structural break LR	01/21/2008	01/21/2008	11/21/2008	07/27/2009	10/27/2008	10/27/2008
statistic	2124.8	2143.5	1486.5	1064.5	1896.3	1348.4
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

**Note:** For the Chow forecast test, we list the LR test (p-value) of the Chi-square statistics.

**Source:** Authors' estimations.

According to Figure 3, we find that the volatility of the correlation coefficients during the sub-prime mortgage crisis saw the collapse of the hedge funds under the umbrella of Bear Sterns, which signaled the beginning of the crisis. Further, this figure shows that the crisis was at its worst from June to October 2008, during which time Fannie Mae and Freddie Mac went under, Lehman Brothers went bankrupt, and Iceland reported the worst financial crisis in its history.

In order to observe the changes in the correlation coefficients between the Vietnamese stock market and the other six stock markets during different sub-periods, we test the means in Table 6. Let  $\mu_A$  be the mean of the HCM-SH DCC coefficients,  $\mu_B$  the mean of the HCM-SZ DCC coefficients,  $\mu_C$  the mean of the HCM-SP500 DCC coefficients,  $\mu_D$  the mean of the HCM-US DCC coefficients,  $\mu_E$  the mean of the HCM-JAP DCC coefficients, and  $\mu_F$  the mean of the HCM-SIG DCC coefficients. Let  $\mu_i$  be the mean of sub-period  $i$  DCC coefficients,  $i=0, \dots, 3$ . We further validate that  $H_0: \mu = 0$ , while the results show that the means of all sets of DCC coefficients are significantly positive and different from zero.

This paper uses the following methods to validate the existence of contagion effects. The first approach is to test whether the mean  $\mu_1$  of the DCC coefficients of sub-period 1 is different from the mean  $\mu_2$  of the DCC coefficients of sub-period 2; the null hypothesis is  $H_0: \mu_1 = \mu_2$ , and thus we test  $H_0: \mu_2 = \mu_3$ . The purpose of these tests is to verify whether these two structural changes lead to contagion effects between the stock market in Vietnam and those in China, Japan, Singapore, and the US. The test results are summarized in Table 7.<sup>4</sup>

<sup>4</sup> Denis Pelletier (2006) recently considered the possibility of structural changes to the three bands. This is an innovative research method because the endogenous internal generation of dynamic coefficients determines the possible timeframes of crises. The author presented an empirical application that illustrates that the model can better fit the data compared with the DCC model proposed by Engle (2002). However, the correlation coefficients are just one of the metrics used to validate the contagion effect. Pelletier (2006) also discussed the structural change probabilities of the DCC coefficients of the three

**Table 6** Dynamic Conditional Correlation Coefficient and Contagion Effect Test

Periods	Full sample	Period 1	Period 2	Period 3
$H_0 : \mu = 0$	t-statistic (p-value)	t-statistic (p-value)	t-statistic (p-value)	t-statistic (p-value)
DCC mean	$\mu_0$	$\mu_1$	$\mu_2$	$\mu_3$
$\mu_A$ : HCM-SH	0.058 (0.000) [10/09/2006-05/03/2012]	0.056 (0.000) [10/09/2006-01/20/2008]	0.059 (0.000) [01/21/2008-02/23/2009]	0.060 (0.000) [02/24/2009-05/03/2012]
$\mu_B$ : HCM-SZ	0.023 (0.000) [10/09/2006-05/03/2012]	0.021 (0.000) [10/09/2006-01/20/2008]	0.023 (0.000) [01/21/2008-02/23/2009]	0.023 (0.000) [02/24/2009-05/03/2012]
$\mu_C$ : HCM-SP500	0.035 (0.000) [10/09/2006-05/03/2012]	0.030 (0.000) [10/09/2006-11/20/2008]	0.046 (0.000) [01/21/2008-02/23/2009]	0.048 (0.000) [02/24/2009-05/03/2012]
$\mu_D$ : HCM-US	0.017 (0.000) [10/09/2006-05/03/2012]	0.015 (0.000) [10/09/2006-07/26/2009]	0.019 (0.000) [02/26/2009-02/23/2009]	0.019 (0.000) [02/24/2009-05/03/2012]
$\mu_E$ : HCM-JAP	0.198 (0.000) [10/09/2006-05/03/2012]	0.193 (0.000) [10/09/2006-10/26/2008]	0.201 (0.000) [10/27/2008--02/23/2009]	0.197 (0.000) [02/24/2009-05/03/2012]
$\mu_F$ : HCM-SIG	0.090 (0.000) [10/09/2006-05/03/2012]	0.090 (0.000) [10/09/2006-10/26/2008]	0.090 (0.000) [10/27/2008--02/23/2009]	0.090 (0.000) [02/24/2009-05/03/2012]

**Note:** The test is simply a test that under the null hypothesis of no correlation  $H_0 : \mu = 0$ , which is distributed as  $t$  under the null. [.] is the sample periods.

**Source:** Authors' estimations.

According to the test results of  $\mu_A$  (HCM-SH) and  $\mu_B$  (HCM-SZ) shown in Panel A of Table 7, the  $t$ -test finds no contagion effects between the Vietnamese and Chinese stock markets at the points of structural changes. For the Vietnamese and US stock markets, there are negative contagion effects at the points of structural changes of  $\mu_C$  (HCM-SP500) on 11/21/2008 and  $\mu_D$  (HCM-US) on 02/24/2009, whereas there are positive contagion effects at the points of  $\mu_C$  (HCM-SP500) on 02/24/2009 and  $\mu_D$  (HCM-US) on 07/27/2009. The test results for  $\mu_E$  (HCM-JAP) and  $\mu_F$  (HCM-SIG) indicate negative contagion effects on 10/27/2008 as well as positive contagion effects on 02/24/2009. This suggests that there were first negative and then positive contagion effects when the sub-prime mortgage crisis was at its worst. The above test results suggest the existence of contagion effects between Vietnam and the US, Japan, and Singapore, but interdependence effects between Vietnam and China.

bands. However, whether this concept links with the definition of the contagion effect and complies with the tests on the propagation mechanism is not discussed by Pelletier (2006). Forbes and Rigobon (2002) further illustrated contagion effects from a theoretical and an empirical perspective by focusing on comparing the impulses before and after the crisis rather than comparing the probabilities. In other words, the correlation coefficients estimated by Markov switching only indicate the probabilities of event occurrences rather than define real-life structural changes. This approach is not entirely consistent with the definition of contagion. Meanwhile, in addition to validating the existence of the contagion effect, this paper aims to examine which country triggers the greatest contagion risk in Vietnam. Thus, the adoption of the method suggested by Pelletier (2006) cannot resolve these problems. Without any negative effect on forecast accuracy, this paper performs tests using the same method. Tests that are based on the method proposed by Pelletier (2006) could be used for further studies, however.

**Table 7** Dynamic Conditional Correlation Coefficient and Contagion Effect Test

Null hypothesis	$H_0: \mu_1 = \mu_2$	$H_0: \mu_2 = \mu_3$	
Panel A	t-statistic (p-value) [break point]	t-statistic (p-value) [break point]	
$\mu_A$ : HCM-SH	-0.687 (0.245) [01/21/2008]	-0.751 (0.226) [04/24/2009]	
$\mu_B$ : HCM-SZ	-0.736 (0.230) [01/21/2008]	0.006 (0.497) [02/24/2009]	
$\mu_C$ : HCM-SP500	-9.971 (0.000) [11/21/2008]	0.006 (0.000) [02/24/2009]	
$\mu_D$ : HCM-US	-4.044 (0.000) [07/27/2009]	1.384 (0.089) [04/24/2009]	
$\mu_E$ : HCM-JAP	-12.76 (0.000) [10/27/2008]	11.71 (0.000) [02/24/2009]	
$\mu_F$ : HCM-SIG	-4.146 (0.000) [10/27/2008]	2.317 (0.000) [02/24/2009]	
Null hypothesis	Full sample	Period 1 10/9/2006–02/23/2009	Period 2 02/24/2009–05/03/2012
Panel B	t-statistic (p-value)	t-statistic (p-value)	t-statistic (p-value)
$H_0: \mu_A = \mu_B$	30.41 (0.000)	17.11 (0.000)	26.30 (0.000)
$H_0: \mu_A = \mu_C$	15.94 (0.000)	14.85 (0.000)	8.311 (0.000)
$H_0: \mu_A = \mu_D$	47.57 (0.000)	28.98 (0.000)	38.78 (0.000)
$H_0: \mu_A = \mu_E$	-138.9 (0.000)	-82.32 (0.000)	-115.4 (0.000)
$H_0: \mu_A = \mu_F$	-45.22 (0.000)	-26.28 (0.000)	-39.01 (0.000)
$H_0: \mu_B = \mu_C$	-12.75 (0.000)	-3.291 (0.000)	-14.74 (0.000)
$H_0: \mu_B = \mu_D$	5.743 (0.000)	4.743 (0.000)	3.392 (0.000)
$H_0: \mu_B = \mu_E$	-146.7 (0.000)	-88.25 (0.000)	-119.4 (0.000)
$H_0: \mu_B = \mu_F$	-70.79 (0.000)	-42.06 (0.000)	-58.30 (0.000)
$H_0: \mu_C = \mu_D$	21.41 (0.000)	9.587 (0.000)	20.77 (0.000)
$H_0: \mu_C = \mu_E$	-132.9 (0.000)	-92.33 (0.000)	-99.58 (0.000)
$H_0: \mu_C = \mu_F$	-53.02 (0.000)	-43.29 (0.000)	-35.11 (0.000)
$H_0: \mu_D = \mu_E$	-199.0 (0.000)	-126.9 (0.000)	-154.6 (0.000)
$H_0: \mu_D = \mu_F$	-134.1 (0.000)	-91.25 (0.000)	-99.74 (0.000)
$H_0: \mu_E = \mu_F$	148.2 (0.000)	91.17 (0.000)	118.2 (0.000)

**Note:** The test is simply a test that under the null hypothesis of no contagion effect  $H_0: \mu_i = \mu_j$ , which is distributed as  $t$  under the null.

**Source:** Authors' estimations.

After confirming the contagion effects of individual event points, the next step is to examine which stock markets cause the greatest contagion risk in the Vietnamese stock market at the common break point on 02/24/2009. According to the DCC test results for all sample periods (Panel B of Table 7), the null hypotheses of  $H_0: \mu_A = \mu_C$ ,  $H_0: \mu_A = \mu_D$ , and  $H_0: \mu_B = \mu_D$  are rejected and the  $t$ -statistics are positive, implying that the stock market in China causes stronger contagion risk in the Vietnamese stock market compared with the US stock markets. Moreover, the null hypotheses of  $H_0: \mu_A = \mu_E$ ,  $H_0: \mu_B = \mu_E$ ,  $H_0: \mu_C = \mu_E$ ,  $H_0: \mu_D = \mu_E$ , and  $H_0: \mu_E = \mu_F$  are rejected and the  $t$ -statistics are negative, suggesting that the stock market in Japan causes stronger contagion risk in the Vietnamese stock market compared with the stock markets in China, the US, and Singapore. In addition, the null hypotheses of  $H_0: \mu_A = \mu_F$ ,  $H_0: \mu_B = \mu_F$ ,  $H_0: \mu_C = \mu_F$ , and  $H_0: \mu_D = \mu_F$  are rejected and the  $t$ -statistics are negative, suggesting that the stock market in Singapore causes

stronger contagion risk in the Vietnamese stock market compared with the stock markets in China and the US. According to Table 7, Japan causes stronger contagion risk in the Vietnamese stock market than Singapore, China, and the US in that order.

Table 8 reports the results of Dungey et al.'s (2005) contagion test. According to the periods in Table 6, we find that Japan causes stronger contagion risk in the Vietnamese stock market compared with the stock markets in China, the US, and Singapore. These findings are the same as those presented in Table 7.

**Table 8** Dungey et al. Contagion Effect Test

Periods	Full sample	Period 1	Period 2	Period 3
HCM←SH	<b>0.070 (0.002)</b> [10/09/2006–05/03/2012]	0.038 (0.365) [10/09/2006–01/20/2008]	0.064 (0.127) [01/21/2008–02/23/2009]	<b>0.119 (0.001)</b> [02/24/2009–05/03/2012]
HCM←SZ	0.030 (0.160) [10/09/2006–05/03/2012]	0.017 (0.679) [10/09/2006–01/20/2008]	0.025 (0.524) [01/21/2008–02/23/2009]	<b>0.058 (0.066)</b> [02/24/2009–05/03/2012]
HCM←SP500	0.040 (0.136) [10/09/2006–05/03/2012]	0.027 (0.384) [10/09/2006–11/20/2008]	0.042 (0.530) [01/21/2008–02/23/2009]	<b>0.076 (0.055)</b> [02/24/2009–05/03/2012]
HCM←US	<b>0.054 (0.044)</b> [10/09/2006–05/03/2012]	0.033 (0.395) [10/09/2006–07/26/2009]	0.129 (0.216) [02/26/2009–02/23/2009]	0.064 (0.092) [02/24/2009–05/03/2012]
<b>HCM←JAP</b>	<b>0.238 (0.000)</b> [10/09/2006–05/03/2012]	<b>0.259 (0.000)</b> [10/09/2006–10/26/2008]	<b>0.240 (0.000)</b> [10/27/2008–02/23/2009]	<b>0.232 (0.000)</b> [02/24/2009–05/03/2012]
HCM←SIG	<b>0.133 (0.000)</b> [10/09/2006–05/03/2012]	<b>0.119 (0.011)</b> [10/09/2006–10/26/2008]	0.094 (0.213) [10/27/2008–02/23/2009]	<b>0.183 (0.000)</b> [02/24/2009–05/03/2012]

**Note:** The notation  $B \leftarrow A$  implies the A bring Contagion effect to Dungey et al. test is a Wald test using the GMM parameter estimates of  $\gamma_{i,j}$  that under the null hypothesis of no contagion  $H_0 : q_i=0$ , which is distributed asymptotically as  $\chi^2$  under the null. (.) is the p-value.

**Source:** Authors' estimations.

Thus, as seen in Tables 7 and 8, the stock market in Japan causes stronger contagion risk in the Vietnamese stock market compared with the stock markets in Singapore, China, and the US (in order of contagion risk). Further, the China and US stock markets cause a weaker contagion effect in the Vietnamese stock market because there are stronger interdependence effects between these two markets. Our results are similar to those presented by Chang and Su (2010).

This paper thus argues that from a global perspective Vietnam may face a financial crisis due to the constant accumulation of capital inflow. This is evidenced by its booming stock market. Since 2003, a wall of liquidity has been flushed into emerging markets. However, because there are risks associated with reverse capital movements, it remains a challenge to determine at what point to release the capital inflows in these countries. In the process of reforms and integration with other parts of the world, Vietnam has failed to keep up with corresponding changes in its market systems. This reason is why a similar crisis did not occur in Eastern European countries (to which there is also an abundance of capital inflows), but erupted only in Vietnam, an Asian country.

As far as the methodology is concerned, King and Wadhvani (1990) and Forbes and Rigobon (2002) use traditional and variance-adjusted non-conditional

coefficients, respectively, in order to verify contagion effects, whereas Longin and Solnik (1995) indicate that the coefficients of stock markets are variable over time. Suleimann (2003) also argues that coefficients change over time. However, because non-conditional coefficients are not suitable equations for estimating the coefficients of stock market returns, this paper uses DCC equations to estimate conditional coefficients that change over time and thus simulate reality. The validity of the tests of contagion effects should be superior to that of tests in previous studies, as this approach has never been discussed thus far in the literature. This methodological approach is one of the contributions of this paper to the empirical study of contagion effect tests. In addition, we used Dungey et al.'s (2005) test and found similar results.

From the early days (e.g., King and Wadhvani 1990) to recent times (e.g. Forbes and Rigobon 2002), scholars have examined contagion effects in order to assess whether the exogenous impulse of any country (or region) enhances the coefficients in relevant markets. Any exogenous financial impulse can result in the movement of capital in international markets, for instance, from highly risky countries to low-risk countries or even to other regions. The influence of the US on Vietnam is another example.

This paper takes into account the increase or decrease in coefficients in contrast to previous studies based on conventional definitions of contagion effects. By doing so, it finds more evidence of contagion effects than do Forbes and Rigobon (2002). It also provides more information than Farber, Nguyen, and Vuong (2006), and Giang (2008) as far as the Vietnamese stock market is concerned. The presented research findings can thus serve as a guide of asset allocations for investors in the Vietnamese stock market, because they shed light on the correlation between the Vietnamese stock market and the markets in China, Japan, Singapore, and the US.

## 4. Conclusion

Contagion effects explain the influence of the economic or financial exogenous impulses of any country on the co-movements of international or regional markets. Reena Aggarwal, Carla Inclán, and Ricardo P. C. Leal (1999) suggest that the US stock market crash in 1987 triggered an increase in the volatility of global stock markets, whereas the impacts of the Mexican or Asian financial crises were regional. Forbes and Rigobon (2002) further indicate that the Asian financial crisis created only interdependence in regional markets rather than contagion effects. This paper extended recent examinations of contagion effects by empirically validating whether the contagion risk triggered by stock markets in China, the US, Japan, and Singapore has any impact on the Vietnamese stock market when it is confronted with a financial crisis.

Our empirical results can be summarized as follows. First, the test results show that there are contagion effects between the Vietnamese and three other stock markets, namely Japan, Singapore, and the US. Second, we find that the stock market in Japan causes stronger contagion risk in the Vietnamese stock market compared with the effects of China, Singapore, and the US. Finally, the China and US stock markets cause weaker contagion effects in the Vietnamese stock market because there are stronger interdependence effects between these two markets.

This paper tests contagion effects using different methods from those used by previous research. Previous studies have applied co-integration or GARCH models in order to focus on the long-run relationships between markets or on the spillover effects. In other words, they have focused on indirect and implied effects rather than directly assessing contagion effects. Heteroskedasticity twists non-conditional coefficients and leads to biased inferences on contagion effects. This paper, by contrast, applies the DCC model suggested by Engle (2002) to estimate the DCC coefficients of the investigated stock markets in order to test contagion effects, which is a significant improvement on previous approaches. Consequently, it first confirms the existence of contagion effects and then validates the influence of contagion risk. This paper is the first to propose such a methodology.

In summary, the empirical results show that under the integration of global economies, there are co-movements or interdependences between financial markets. Because we have demonstrated that the contagion risk of the sub-prime mortgage crisis has affected Vietnam, it is suggested that investors in the Vietnamese stock market review the performances of Vietnam's neighboring markets and refer to financial exogenous impulses as a decision variable. Ignorance of market information on the economies and financials of neighboring countries will enhance the uncertainties of returns on investments.

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