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Did Vietnam stock market avoid the "contagion risk" from China and the U.S.? The contagion effect test with dynamic correlation coefficients

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Abstract This paper examines the Vietnamese stock market with an extension of the recent investigation of risk contagion effects. Daily data spanning October 9, 2006–June 19, 2009 are sourced for the empirical validation of the risk contagion between the stock markets in Vietnam, China, and the U.S. To facilitate the validation of contagion effects with market related coefficients, this paper constructs a bivariable EGARCH model of dynamic condition correlation coefficients. First, we examine whether there are contagion effects when there is a financial crisis in the Vietnamese stock market. Next, we verify whether the contagion risk triggered by the crisis can affect the Vietnamese market and examine which market influences the Vietnamese market the most. We find that compared to the U.S. stock market, the Chinese stock market brings more contagion risk to the Vietnamese market, and these effects gain more significance after the sub-prime mortgage crisis.

Keywords Vietnam stock market · Contagion risk · EGARCH model · DCC estimation · Sub-prime mortgage crisis

1 Introduction

After the Asian financial crisis in 1997, the Vietnamese government has gradually been shifting the country from communism to capitalism by following in the footsteps of China. However, tight control remains over certain industries such as the financial industry and state enterprises. In 2000, Vietnam and the U.S. entered a bilateral trade agreement that allowed Vietnamese goods to be circulated freely in the U.S. This agreement also attracted a large amount of foreign investment into Vietnam. Since then, Vietnam began to prosper by benefiting from exports based on its agriculture and industries. With cheap labour and operational costs, the export of a large amount of agricultural produce creates abundant foreign reserves. (Vietnam is one of the three largest rice producers in the world.) In 2001, the Vietnamese

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government initiated a 10-year economic reform program to speed up economic development. Vietnam's GDP growth is the fastest (at an average of 7.1%) after that of China. In 2006, Vietnam became a WTO member and formally connected to the world. This accelerated its pace in privatization and liberalization. However, the entrance into the WTO also means that Vietnam is faced with challenges from other parts of the world.

In addition to the significant influence of the U.S., most economists believe that the changes in the economic patterns in Vietnam are very similar to those in China. They have both recently transformed themselves from communist to capitalist countries by attracting foreign direct investment with cheap labour and by creating foreign reserves with exports. Therefore, they are faced with the same problem of excess liquidity due to the ease of capital inflows and the difficulty of capital outflows. This is why both stock markets and real estate markets are booming in China and Vietnam. High inflation results in an increase in labour and operational costs. In addition, since the Vietnamese government adopted the U.S.-peg policy for its currency, the Vietnamese Dong experienced a drastic depreciation due to the sub-prime mortgage crisis in the U.S. and the depreciation of the U.S. dollar under the selling pressure of the U.S. dollar. This put the Vietnamese corporate world in a panic. The VN Index dropped nearly 60% from October 2007 to June 2008.

The following development was a challenge faced by the Vietnamese government. In early 2006, the IMF warned the Vietnamese government of the overheating economy and the government took some measures, such as an interest rate increase, an increase of the deposit reserve ratio for banks, and even limitations on the 1% rise and fall of single stocks in a day. However, none of the measures could stop the massive walls of capital inflows. The beginning of the sub-prime mortgage crisis in the U.S. in 2007 lead to a loss of confidence in exports from Vietnam due to a shrinkage in the purchasing power of the U.S. The 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 triggers major shocks and heavy losses around the globe. In the extreme periods, when risk diversification is needed the most, investors find it impossible to effectively diversify risk in a timely manner; investors in Vietnam are no exception. In fact, financial crises are 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 the concern of investors (retail and institutional) in Vietnam and other parts of the world.

The most noticeable economic phenomenon in Vietnam is its stock markets. There are currently two stock exchanges in Vietnam, the Ho Chi Minh Stock Exchange that began operations on July 28, 2000 and the Hanoi Securities Trading Centre that began operations on March 8, 2005. According to data from the State Securities Commission of Vietnam, the VN Index soared from 100 on July 8, 2000 to 517 on June 25, 2001 (in less than 12 months). It fell back to 183 in 2002 and then fell further to 130 on October 24, 2003. It went back up to 239 at the end of 2004 and after that, it was a great run, climbing to 307 at the end of 2005, to 751 at the end of 2006 and to 1,170 on March 11, 2007, before corrections set in. At the end of 2006, there were a total of 193 listed companies with a combined market capitalization of U.S. $1.4 bn, a 20-fold increase from the end of 2005, accounting for 22.7% of the country's GDP. At the end of May 2007, the market capitalization rose to U.S. $20 bn, i.e. 31% of the country's GDP. Meanwhile, over 500 bonds were listed, accounting for 8.3% of GDP. It is estimated that 23 well-known investment funds managed by HSBC, JP Morgan Chase, and Merrill Lynch held a total of U.S. $2.3 bn of Vietnamese equities and bonds. There are 18 fund companies in Vietnam, and they run 35 funds listed on the two exchanges. In Vietnam,

there are 55 securities firms. By the end of 2006, there were 160,000 stock trading accounts opened by locals and another 1,700 accounts opened by foreign investors (who held 25–30% of total market capitalization). This illustrates the importance of foreign investors in Vietnam, especially those from China and the U.S.

Since stock markets are the window to a country's economy, the Vietnamese equity market is the best showcase of its economic future. As the above description indicates, the Vietnamese equity market is subject to the influence of stock markets in China and the U.S. However, there is little literature that analyses the Vietnamese stock market, let alone any discussion on the correlation between the Vietnamese stock market and stock markets in other countries. This paper performs an empirical test of the transmission of contagion risk between the Vietnamese stock market and stock markets in China and the U.S. from the perspective of the Vietnamese stock market by examining crisis contagion effects.

Firstly, this paper sets out to examine whether there are crisis contagion effects between the Vietnamese stock market and stock markets in China and the U.S. when financial crises occur. Further, this paper investigates whether the China or U.S. stock market reports greater influence in terms of the contagion risk either of them triggers. In terms of research motivations, this paper constructs a bivariate EGARCH model to explore the correlation coefficients under the dynamic conditional correlation (DCC) method. Thereafter, the market correlation coefficients are estimated. If the existence of contagion effects is confirmed, this paper then explores the contagion risk.

The empirical result shows that the sub-prime mortgage crisis results in contagion effects between Vietnam and China/U.S. However, the Chinese stock market brings more crisis contagion risk to the Vietnamese market than the U.S. stock market does. These effects become even more evident after the sub-prime mortgage crisis. This paper examines these issues from the DCC coefficients between markets. The significant changes of the coefficients prove the existence of contagion effects. Hence, this paper examines the strength of contagion risk from China and the U.S. to the Vietnamese stock market. This contagion risk has not been defined in existing literature and is first defined by this paper.

This remainder of this paper is as follows: Sect. 1 presents the introduction; Sect. 2 outlines the literature review of contagion effects; Sect. 3 introduces the empirical methods; Sect. 4 discusses the empirical results; and Sect. 5 presents the conclusion.

2 Literature review

The study of propagation mechanisms shows the beginning of Contagion Theory. Propagation mechanisms explain the characteristics of co-movements between different markets in different countries. An exogenous impulse in one market travels to another country. If there already are routes for connections before the impulse, the transmission process in contagion effects are independent effects. This is the non-crisis-contingent hypothesis. This is because the transmission of any impulse is an extension of connection routes that are already in place. Forbes and Rigobon (2002) explain the interdependent effects from four routes, namely, trade, policy coordination, re-evaluation, and random aggregate shocks. Meanwhile, the transmission of contagion effects may strengthen or weaken previous connection routes, or may be triggered by other routes resulting from exogenous impulses. This is 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 empirical literature are market correlation coefficients, the GARCH model, co-integration tests, and the probability of specific events. King and Wadhwani (1990) and Lee and Kim (1993) apply correlation coefficients for stock market returns to examine the influence of the market crash in the U.S. in 1987 on the stock markets in Japan and the U.K. If there is a significant increase in correlation coefficients, there are contagion effects. The empirical results show that the U.S. stock market crash significantly increases the correlation coefficients between multiple markets. Therefore, the Contagion Effect Hypothesis is supported. Calvo and Reinhart (1995) find that during the 1994 currency crisis in Mexico, there were contagion effects, as evidenced by a significant increase of correlation coefficients for the stock and bond markets.

Forbes and Rigobon (2002) indicate that the correlation coefficients are overestimated as a result of market heterogeneity variances, and therefore, the result tends to support contagion effects. They suggest that heteroskedasticity bias tests should be used. By using these adjusted correlation coefficients, they find that during the 1997 Asian financial crisis, the 1994 Mexico crisis and the 1987 U.S. stock market crisis, there were no contagion effects (as evidenced by significant changes in correlation coefficients) in a total of 29 countries sampled; the countries were nine countries in South East Asia, four countries in Latin America, 12 OECD countries and other four emerging market countries. There are only interdependent effects. However, Baig and 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 returns on stocks in Thailand, Malaysia, Indonesia, South Korea, and the Philippines.

Hamao et al. (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 U.S. The result shows that among the stock markets in New York, London, and Tokyo, there were spill-over effects from New York to London and Tokyo and from London to Tokyo. 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 the government bond markets. Edwards and Susmel (2001) take system changes, apply the bivariable switching ARCH model and find that there is a significant correlation between multiple stock markets in Latin America during periods of high market volatility. The finding proves the contagion effects of stock market volatility.

A co-integration analysis examines whether crisis impulses alter long-term equilibrium relationships, causal relationships, impulse responses, and variance decompositions in markets, so as to determine contagion effects. Sheng and Tu (2000) examine 12 countries in the Pacific region, such as the U.S. and Taiwan, and find that there was no co-integration relationship between stock markets before the Asian financial crisis in 1997. However, co-integration relationships emerged during the financial crisis. Variance decomposition indicates that no single country carries exogenous characteristics during a financial crisis period. This proves contagion effects. Meanwhile, causal relationship tests indicate that the U.S. is the leading factor that influences the performances of stock markets in other countries. The VAR model by Nagayasu (2001) examines causal relationships and analyzes impulse responses; it finds that the inflation crisis in Thailand resulted from the contagion effects of the industrial stock index of the Philippines through currency impacts.

Eichengreen et al. (1996) apply a bivariate probit model to examine the contagion effects of currency crises in ERM countries such as France, Germany, and the Netherlands in 1992–1993. If a country reports an exogenous impulse, it will increase the probability of another country suffering an attack of speculation. Forbes (2002) conducts an event study and analyses the responses of the sampled 14,000 companies in 46 countries around the world to

crises in Asia and the Soviet Union. It is also found that different function transmissions through product competition and return on shares in different crises, as well as the strengths, are rather different. Therefore, it is not possible for any single model to capture the effects of all crisis impulses.

Risk diversification is sought after in order to enhance returns on investments. Grubel (1968) applies the Portfolio Theory from the capital market in one country to international capital markets. It is the first study that indicates that low correlation in international capital markets can bring about diversification benefits for international investors. Most previous studies on international market correlation also confirm the contribution of low correlation to the diversification effects of investment portfolio risks. The issues surrounding investment portfolio diversification attract considerable attention, such as Levy and Sarnat (1970), Solnik (1974), Lessard (1976), Watson (1978), and Meric and Meric (1989). International investors can diversify risks with international diversifications and can achieve potential profits. However, the internationalization and liberalization of capital markets under the waves of globalization have accelerated the frequency of international economic activities and brought the financial markets of different countries closer and closer.

Masih and Masih (1997) examine the correlation between the sampled eight stock markets, that is, those of the U.S., the U.K., Germany, Japan, Taiwan, Korea, HK, and Singapore in 1982–1994. They find that there is a strong correlation between one country and another. King and Wadhwani (1990) and Liu et al. (1998) explore the influence of the stock market crash in the U.S. in 1987 on international stock markets. Their empirical studies all show that the interdependence of the stock markets of different countries significantly increases after the market crash. Aggarwal et al. (1999) investigate whether global or local events result in greater volatility of the stock markets of emerging markets. They examine emerging markets in Asia and Latin America. The results show that the events that bring about dramatic volatility in the stock markets are mostly local events. The only major event that resulted in a correlation of the stock markets around the world was the U.S. stock market crash in 1987. Also, the same paper indicates that the volatility of emerging markets is greater than that of developed countries. Sheng and Tu (2000) also confirm, with empirical results, that after the Asian financial crisis, the interdependence of stock markets in Asia increased significantly. Hon et al. (2004) sample the returns on equity price indices of 25 countries and the correlation of global financial markets. They find that responses to European stock markets increased after the September 11 attack on the U.S. The empirical results indicate that the impulse of extreme events increases the correlation of global markets, and further co-integrates global stock markets. As a result, the benefits of investment risk diversification decline dramatically.

After the potential benefits of international diversification declined, the focus gradually shifted to emerging markets, which previously were ignored. Divecha et al. (1992); Harvey (1995), and Goetzmann and Jorion (1999) all report that the correlation between emerging markets and other markets is low and that there may exist potential benefits associated with investment diversification. They suggest that international investors or fund managers incorporate the emerging markets with high volatility and high returns into their portfolios in order to diversify risk and enhance diversification benefits. Turgutlu and Ucer (2008) also explore the correlation between emerging markets and developed markets. These studies raise the question of whether international diversification still is suitable in modern times. These issues are even more important for situations such as the sub-prime mortgage crisis.

For research on the Vietnam stock market (VSM), Vuong et al. (2006) provide empirical evidence of the following. (1) Anomalies of HSTC stock returns through clusters of limit-hits, limit-hit sequences. (2) A strong herd effect toward extreme positive returns of the market portfolio. (3) The specification of ARMA-GARCH, which helps capture fairly well

issues such as serial correlations and fat-tails for the stabilized period. By using more information and policy dummy variables, it is justifiable that policy decisions on technicalities of trading can have an influential impact on the move of risk level, through the conditional variance behaviour of HSTC stock returns. (4) Policies on trading and disclosure practices that have had profound impacts on the VSM. The over-use of policy tools can harm the market and investment mentality. Price limits become increasingly irrelevant and prevent the market from self-adjustment to equilibrium. Giang (2008) summarizes the major aspects of the emerging market from its opening to now, so as to provide an intuitive and essential overview of its constituents, regulations and performance. Specifically, he examines the benefits and risks associated with the promising market by looking into changes in the level and volatility of the VN-Index return during the period. He finds that predictive power and signs of heteroskedasticity are evident.

According to the above discussion, there is no relevant research on the correlation between the Vietnamese stock market and other stock markets. This paper validates contagion risk from the multiple perspectives identified in various articles of literature. The approach it takes can materially improve the verification validity for contagion risk.

(1) 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. This definition ignores impulses and positive influences; there may also be negative influence resulting 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 the capital 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 exist in regional markets. This paper validates the contagion effect of returns on stocks and allows the use of correlation coefficients to express an increase or decrease of 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.

(2) A test of the contagion effects of correlation coefficients requires the definitions of the samples before and after the crisis. Correlation coefficients of market variables of different samples are estimated in order to facilitate variance tests. The use of unconditional correlation coefficients in empirical literature implies the assumption that correlation coefficients are fixed during the sample periods. Forbes and Rigobon (2002) consider heterogeneous variances and adjust correlation coefficients. Longin and Solnik (1995) indicate that from the 1960s to the 1990s (covering 30 years), the correlation coefficients of market returns of the seven OECD countries sampled (including the U.S.) increase significantly. Suleimann (2003) argues that the correlation coefficients of the five major stock markets (e.g. the U.S. and Germany) change over time. Therefore, unconditional correlation coefficients are not the correct estimation equations for the correlation coefficients of stock markets. Rather, since economic and financial environments are dynamic, it is difficult to differentiate the constancy of correlation coefficients of different market variables over time. Engle (2002), Tse and Tsui (2002), and Tsay (2002) prove that dynamic correlation coefficient models demonstrate better estimation efficiencies than fixed correlation models (e.g. Bollerslev 1990). This paper applies the DCC model proposed by Engle (2002) to estimate the correlation coefficients of stock market returns over time. This approach is consistent with the actual economic and

financial environments and materially improves the verification validity for contagion effects. It is better than the use of fixed or adjusted correlation coefficients.

(3) The GARCH model focuses on the spill-over effects of market volatility; whereas a co-integration analysis emphasizes the changes of co-integration vectors that represent the long-run relationships of market variables after an exogenous impulse. Suleimann (2003) suggests that co-integration steps up over time, perhaps due to a permanent shift of market connecting mechanisms, rather than contagion. Namely, a co-integration analysis examines the permanent shifts of market connections, rather than short-run changes. This is why co-integration analysis is deemed unsuitable for the study of contagion effects. This paper applies the DCC model to estimate market coefficients and to validate contagion effects. This approach is different from those seen in literature that applies the GARCH model to examine market volatility and long-run co-integration changes.

(4) This paper makes the following innovations. In terms of research issues, it starts with the Vietnamese stock market and examines the influence of stock markets in the U.S. and China on the Vietnamese market since the sub-prime mortgage crisis. In terms of research methods, in contrast with Giang (2008) and Vuong et al. (2006) on the Vietnamese stock market, this paper makes validations based on the correlation coefficients of market dynamics. Any significant changes in correlation coefficients prove the existence of contagion effects. Then, it examines the strength of the contagion risk from China and the U.S. to the Vietnamese market. This contagion risk has yet to be defined by literature. This paper is the first one to do so.

3 Research method

The method used by this paper to test contagion risk is mainly focused on DCC coefficients, as proposed by Engle (2002). This paper first makes estimates with a univariate EGARCH model, and then applies Engle (2002) DCC model to estimate the DCC coefficients between stock returns. Furthermore, it examines whether there are contagion effects (as evidenced by significant changes of correlation coefficients) between Vietnam and the U.S. and between Vietnam and China. The purpose is to compare which coefficient is greater in order to determine whether it is China or the U.S. that triggers contagion risk to Vietnam.

3.1 The dynamic conditional correlation bivariate EGARCH model

Let the stock return ($r_{i,t}$) be the logarithmic difference between closing stock price ($P_{i,t}$; $P_{i,t-1}$) of the i market in the t period:

$$r_{i,t} = (\log P_{i,t} - \log P_{i,t-1}) \times 100 \tag{1}$$

With the known information of the pervious interval, the conditional correlation coefficients between stock returns ($\rho_{ij,t}$) of the i and j market can be defined as:

$$\rho_{ij,t} = \frac{E_{t-1}\left(r_{i,t} r_{j,t}\right)}{\sqrt{E_{t-1}\left(r_{i,t}^2\right) E_{t-1}\left(r_{j,t}^2\right)}} \tag{2}$$

The return of the i stock market can be presented by conditional deviation $\sqrt{h_{i,t}}$ multiplying standardized disturbance $\varepsilon_{i,t}$:

$$r_{i,t} = \sqrt{h_{i,t}}\varepsilon_{i,t} \tag{3}$$

$\varepsilon_{i,t}$ has mean zero and variance one and the j market is in the same situation, then Eq. 2 can be rewritten as:

$$\rho_{ij,t} = \frac{E_{t-1}\left(\varepsilon_{i,t}\varepsilon_{j,t}\right)}{\sqrt{E_{t-1}\left(\varepsilon_{i,t}^2\right)E_{t-1}\left(\varepsilon_{j,t}^2\right)}} \tag{4}$$

It is seen that the conditional correlation is the covariance of standardized disturbance. During the dynamic time, the stock return variance is constant and undisputable. Thus, the correlation coefficients between any couple markets also vary with time. The estimation of the Engle (2002) DCC model comprises two steps, one is the estimation of univariate GARCH, and the other is the estimation of correlation coefficient.

It is generally agreed that EGARCH(1,1) is sufficient to capture the characteristics of heteroscedasticity of stock and financial variables (Bollerslev et al. 1992). The EGARCH(1,1) in Mean model in Eq. 5 is set to estimate the stock returns and dynamic variances in these five stock markets.

$$\begin{aligned} r_t &= \alpha + \vartheta h_t + \sum_{i=1}^{p} a_i r_{t-i} + \sum_{j=1}^{q} b_j \varepsilon_{t-j} + \varepsilon_t \\ \log(h_t) &= \omega + \delta \log(h_{t-1}) + \aleph \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \gamma \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| \end{aligned} \tag{5}$$

where, in the i market, the mean equation is the process of ARMA (p, q); ε_t is the white noise residual of message set $\Im_{t-1}$ in $t-1$ period and in normal distribution. Its mean is zero, and variance is h_t. We assumed a generalized error distribution (GED) structure for the errors with EGARCH model: $f(v_t) = \frac{\upsilon \exp[-(1/2)|v_t/\lambda|^{\upsilon}]}{\lambda 2^{[(\upsilon+1)/\upsilon]}\Gamma(1/\upsilon)}$. $\Gamma(\cdot)$ is gamma function, and $\lambda = \left\{\frac{2^{(-2/\upsilon)}\Gamma(1/\upsilon)}{\Gamma(3/\upsilon)}\right\}^{1/2}$ is a constant, υ is a positive parameter representing the thickness of the distribution tail. If $\upsilon = 2$ then $\lambda = 1$, equation $f(\cdot)$ measures standard normal distribution; the tail of function distribution is thicker than the tail of normal distribution if $\upsilon < 2$, and flatter if $\upsilon > 2$. ε_t is the absolute expected value: $E|v_t| = \frac{\lambda 2^{(1/\upsilon)}\Gamma(2/\upsilon)}{\Gamma(1/\upsilon)}$. $E|v_t| = \sqrt{2/\pi}$ under normal distribution.

Using the conditional correlation coefficients and variances of the i and j stock returns to parameterize stock return covariance matrix H_t:

$$H_t = D_t R_t D_t \tag{6}$$

where $D_t = \text{diag}\left\{\sqrt{h_{i,t}}, \sqrt{h_{j,t}}\right\}$ is a 2×2 conditional standard deviation diagonal matrix. The conditional correlation coefficient matrix R_t is:

$$R_t = D_t^{-1} H_t D_t^{-1} \tag{7}$$

DCC uses GARCH(1,1) with the standardized disturbance matrix ε_t to estimate correlation coefficient:

$$Q_t = S(1 - \theta_1 - \theta_2) + \theta_1(\varepsilon_{t-1}\varepsilon_{t-1}') + \theta_2 Q_{t-1} \tag{8}$$

where $\varepsilon_t = D_t^{-1} e_t$ is the standardized disturbance matrix, Q_t is the covariance matrix of ε_t, S is an unconditional correlation matrix of ε_t. In Eq. 8, coefficient θ_1 and θ_2 must be

positive and $\theta_1 + \theta_2 < 1$, assuring that Q_t is positive and satisfies the condition of mean reverting. Thus, the correlation coefficient matrix is:

$$R_t = (\text{diag}(Q_t))^{-\frac{1}{2}} Q_t (\text{diag}(Q_t))^{-\frac{1}{2}} \tag{9}$$

If $\theta_1 = \theta_2 = 1$, the model is simplified as the constant conditional correlation model of Bollerslev (1990).

The DCC model encompasses two EGARCH(1,1) processes with stock returns and standardized disturbance. The log-likelihood function also includes the stock return fluctuation and correlation coefficient:

$$L(\Theta, \Phi) = L_v(\Theta) + L_c(\Theta, \Phi) \tag{10}$$

where Θ is the parameter of stock return volatility:

$$L_v(\Theta) = -\frac{1}{2} \sum_t \left(n \log(2\pi) + \log |D_t|^2 + e_t' D_t^{-2} e_t \right) \tag{11}$$

Φ is the parameter of correlation coefficient:

$$L_c(\Theta, \Phi) = -\frac{1}{2} \sum_t \left(\log |R_t| + \varepsilon_t' R_t^{-1} \varepsilon_t - \varepsilon_t' \varepsilon_t \right) \tag{12}$$

Engle's (2002) two-step estimation is proposed to maximize Eq. 10 likelihood function; that is to, in the first step, estimate Eq. 11 to derive the optimal value of market volatility parameter $\widehat{\Theta}$, and bring $\widehat{\Theta}$ in Eq. 12 in the second step to estimate the optimal value of correlation coefficient $\hat{\Phi}$. Engle (2002) proves that the consistency in the first step guarantees the consistency in the second step under standard conditions.

3.2 The contagion effect test with dynamic correlation coefficients

In this paper, the correlation coefficient between stock returns estimated by the DCC model, with the progress of time, varies with market variances. Thus, the conventional contagion effect test that ignores the adjustment of heteroskedasticity can be improved. In order to test whether the U.S. or the Chinese stock market brings more contagion risk to 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 when 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 the U.S. and China before and after the occurrence of structural changes. The result proves that contagion effects do exist between the stock markets in Vietnam, China, and the U.S. Step 2 is to verify the influence of the contagion risk trigged in China and the U.S. on the Vietnamese stock market. There are two empirical procedures for this step: (1) given the complete samples, this paper validates whether the conditional correlation coefficients for Vietnam and China are significantly different from those for Vietnam and the U.S.; (2) this paper further verifies whether the conditional correlation coefficients for Vietnam and China are significantly different from those for Vietnam and the U.S. before and after the structural changes.

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

$$H_0: \mu_i = \mu_j, \quad H_a: \mu_i \neq \mu_j \tag{13}$$

where μ_i and μ_j are the population of means conditional correlation coefficients of two samples. Assuming that the sample sizes are n_1, n_2, population variances σ_1^2, σ_2^2 are different and unknown, and the DCC-estimated time-variant sample correlation coefficient means are $\overline{\rho}_i$ and $\overline{\rho}_j$, and the variances are s_i^2, s_j^2, the statistic t is:

$$t = \frac{\left(\overline{\rho}_i - \overline{\rho}_j\right) - \left(\mu_i - \mu_j\right)}{\sqrt{\frac{s_i^2}{n_i} + \frac{s_j^2}{n_j}}} \tag{14}$$

where $s_i^2 = \frac{1}{n_i - 1}\sum_{n=1}^{n_i}\left(\rho_i - \overline{\rho}_i\right)^2$, $s_j^2 = \frac{1}{n_j - 1}\sum_{n=1}^{n_j}\left(\rho_j - \overline{\rho}_j\right)^2$, the degree of freedom v is:

$$v = \frac{\left(\frac{s_i^2}{n_i} + \frac{s_j^2}{n_j}\right)^2}{\frac{\left(s_i^2/n_i\right)^2}{n_i - 1} + \frac{\left(s_j^2/n_j\right)^2}{n_j - 1}} \tag{15}$$

If t value is significantly greater or smaller than the critical value, H_0 is rejected, suggesting the existence of contagion effect.

4 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, and the American-Amex Composite Index (US) and the S&P 500 Index (SP500) in the U.S.[1] The use of these indices in China and the U.S. is because both China and the U.S. are the main trading partners of Vietnam. In terms of the nature of traded commodities, these indices are better able to reflect the correlations and interactions. In order to understand the crisis contagion effects on the Vietnamese market of the stock markets in China and the U.S. before and after the sub-prime mortgage crisis, this paper samples data from October 9, 2006 to June 19, 2009. The data source is the Taiwan Economic Journal (TEJ) Data Bank: Stock Price Database. In addition, this paper deletes the data of different trading days for an empirical analysis, since these three stocks sometimes trade on different days.

First, we observe the trends of these five stock indices. According to Fig. 1, before March 20, 2007, the first 100 data entries show an upward trend, but the indices began their gradual decline. After the first 300 data entries (as of February 15, 2008), the indices plunged due to the worsening sub-prime mortgage crisis. The rebound only began after 600 data entries (as of June 2, 2009). The Vietnamese index and the two stock indices in the U.S. rebounded in a W shape; whereas the two stock indices in China rebounded in a V shape. Figure 1 shows that the sub-prime mortgage crisis caused all the five stock indices to fall. However, compared to the Vietnamese and Chinese stock markets, the U.S. stock market experienced a more extreme slump (i.e. 450 data entries).

In order to estimate the conditional variance and the conditional correlation coefficient, we need to conduct a preliminary analysis of the descriptive statistics of the sample. Table 1 displays the descriptive statistics for the sample of five markets. The mean return of the three

[1] At present, Vietnam has two stock indexes. Vietnam's first stock exchange, known as the Ho Chi Minh City Securities Trading Center, was established in July 2000. Another is The Hanoi Securities Trading Center opened in March 2005; because of this index data is too small so it is not taken.

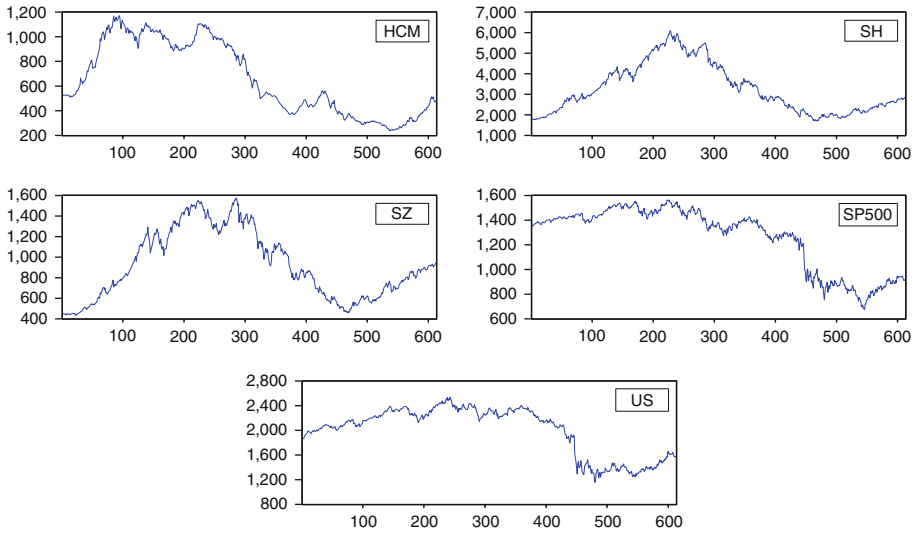

Fig. 1 The trend of five stock indices. The *horizontal axis* denotes observation (date): 100 (3/20/2007), 200 (8/29/2007), 300 (2/15/2008), 400 (7/21/2008), 500 (12/19/2008), 600 (6/2/2009)

Table 1 Basic statistics of stock returns

Index	HCM	SH	SZ	SP500	US
Mean	−0.019	0.078	0.122	−0.062	−0.028
Standard deviation	2.297	2.520	2.684	2.038	1.978
Skewness	0.053	−0.500	−0.661	−0.433	−1.004
Kurtosis	4.327	5.025	4.664	10.76	17.93
J-B	45.19***	130.2***	115.2***	1557.3***	5789.2***
LB(12)	91.69***	18.75*	17.64*	33.79***	24.65**
LB2(12)	97.18***	18.99*	31.83***	449.7***	287.3***
ADF	−9.643(3)***	−10.26(5)***	−10.51(4)***	−14.83(2)***	−14.25(2)***
N	612	612	612	612	612

J-B is the statistic of Jarque-Bera normal distribution test. 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
N sample size
*, **, and *** denotes 10, 5, and 1% significant level, respectively

stock markets in Vietnam, China, and the U.S. is negative; whereas the mean return of the two markets in China is positive. Based on the standard deviations, the two markets in China have higher risk; while the markets in the U.S. have lower risk. The returns and standard deviations show high returns and high risk. This is consistent with market expectations. Meanwhile, information in emerging markets is not transparent or complete, and hence, these markets are more risky. In contrast, the information in developed markets is rapid and complete and hence these markets are less risky. Due to the impact of the sub-prime mortgage crisis in the U.S., returns on the investments of USD-denominated dollars are significantly lower than the returns on the stock markets in China and Vietnam. Investors who want to maximize their

Table 2 The estimation of GED-EGARCH(1,1)-M model

	HCM		SH		SZ		SP500		US	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
α	−0.404	0.002	−3.252	0.260	0.754	0.058	0.064	0.067	0.060	0.098
ϑ	0.374	0.000	1.934	0.225	−0.173	0.437	−0.036	0.293	0.008	0.877
a_1	–	–	–	–	–	–	–	–	–	–
a_3	0.083	0.052	–	–	–	–	–	–	–	–
a_4	0.104	0.009	0.066	0.039	0.069	0.061	–	–	–	–
a_{15}	−0.102	0.005	–	–	–	–	–	–	–	–
b_1	0.340	0.000	–	–	–	–	−0.107	0.005	–	–
ω	−0.232	0.000	2.381	0.000	−0.022	0.630	−0.061	0.028	−0.097	0.001
δ	0.957	0.000	−0.357	0.262	0.955	0.000	0.991	0.000	0.988	0.000
$\aleph$	0.017	0.566	0.043	0.334	−0.041	0.141	−0.122	0.000	−0.089	0.001
γ	0.369	0.000	0.137	0.170	0.139	0.007	0.081	0.036	0.136	0.000
ν	1.808	0.000	1.206	0.000	1.222	0.000	1.253	0.000	1.294	0.000
$Q_{12}(uh^{-1/2})$	9.035	0.108	13.66	0.189	12.05	0.359	15.80	0.148	5.420	0.942
$Q_{12}(u^2h^{-1})$	6.303	0.613	16.26	0.131	5.264	0.918	5.222	0.920	1.274	0.999
SB		0.770		0.990		0.734		0.730		0.351
NSB		0.693		0.526		0.785		0.770		0.489
PSB		0.654		0.864		0.953		0.235		0.618
Joint		0.905		0.845		0.986		0.683		0.590
log L	−1252.08		−1399.6		−1422.9		−1.64.7		−1050.9	

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

profits shift their focus to stock markets in China. The crowd-out effect is also the reason for the sluggishness of the U.S. stock markets.

In terms of coefficients of skewness, only the Vietnamese market shows a left-skewed distribution; all the other four markets have right-skewed distributions. The kurtosis statistics indicate that the returns of all the stock returns are leptokurtic distributions, typical of financial variables. LB(12) and LB2(12) are the tests of the returns on sticks of the 12 lagging periods and the auto-correlation Ljung-Box statistics of the squares. The results show that under 10% levels, the significant LB(12) statistics mean that the returns of all the markets in all countries exhibit a high level of auto-correlation. The significant LB2(10) statistics imply that returns on stocks exhibit heteroskedasticity. The Jarque-Bera (J-B) normal distribution test shows that all returns are not normal distribution.

As the data in Table 1 indicates, the five returns series have conditional heteroskedasticity characteristics. In order to consider the standardized residual distribution as the GED cumulative density function and in order to test for the leverage effect of each market, we first estimate the univariate EGARCH(1,1) model for the return of each market. Next, we estimate the standardized residuals so as to obtain the dynamic conditional coefficients. Table 2 provides the estimation of the univariate EGARCH(1,1) in the mean model for each market. $Q_{12}(uh^{-1/2})$ and $Q_{12}(u^2h^{-1})$ are the 12th order standardized residual $(uh^{-1/2})$ and square standardized residual (u^2h^{-1}) of Ljung-Box statistics. With the 10% significant level, the

Table 3 The parameter estimation of mean-reverting DCC-GARCH(1,1) model

Parameter	HCM-SH	HCM-SZ	HCM-SP500	HCM-US
α_c	0.064 (0.000)	0.044 (0.002)	0.0130 (0.096)	0.077 (0.002)
β_c	0.800 (0.004)	0.795 (0.000)	0.847 (0.500)	0.516 (0.690)
$\overline{\rho}_{ij}$	0.121	0.080	0.079	0.070
LMC	60.56 (0.000)	36.46 (0.000)	4.744 (0.093)	17.83 (0.000)
Log L	−1155.6	−1150.2	−1144.7	−1156.8

Log L is maximum likelihood function, inside $(\cdot)$ is p-value, and the LMC, tests for constant correlation coefficient

autocorrelation of standardized residuals and square standardized residuals do not exist. It is interesting to discover that except for in the SH market, the impact coefficients (δ) of conditional variance are all significant and greater than the coefficient γ in the other four markets. In other words, a strong shock merely causes a small correction of volatility or variance in the future. Due to the significance of coefficient $\aleph$, we can identify the existence of the leverage effect in U.S. markets. The coefficient $\aleph$ of the SP500 and the U.S. markets is smaller than -1, showing that a positive shock decreases the market variance, and that a negative shock increases the market variance.

Moreover, because all ν coefficients are smaller than 2, the tails of the standardized residual function distributions are thicker than the ones of the normal distribution in the five markets. On the other hand, 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 standardized residuals are not autocorrelation, the maximum likelihood method can be used to obtain the mean reverting DCCs. Table 3 reports the estimations of the mean reverting DCCs. We find β_c being greater than α_c, under the restriction that coefficients and $\alpha_c + \beta_c < 1$. The evidence from these results suggests that a big shock causes only a small correction in the oncoming mutual fluctuation (or covariance) between markets. Besides, the results of the LMC tests for constant correlation coefficient show that four couple markets reject the null hypothesis.

Figure 2 depicts α_c, β_c, and $\overline{\rho}_{ij}$—the dynamic correlation coefficients and the conditional covariance parameters of four couple markets. Focusing on dynamic correlation coefficients, we can observe the variation of correlation between two markets. When correlation is positive and close to 1, it indicates the same direction of return. On the other hand, when correlation is negative and its absolute value is close to 1, it indicates the opposite direction of return. Figure 2 displays correlations fluctuating around their mean (see $\overline{\rho}_{ij}$ value in Table 3 for reference).

To validate the contagion effects, this paper compares the dynamic correlation coefficients of the stock markets in Vietnam, China, and the U.S. Figure 3 shows that the trend of the two stock indices in the U.S. is close to the right axis whereas that of the two stock indices in China is close to the left axis. According to Fig. 3, we find that the volatility of the correlation coefficients between Vietnam and China is greater than that of the coefficients between Vietnam and the U.S. This paper finds that in a particular period (July 6, 2007), all the exchanges in Vietnam and China reported the largest negative coefficients. In addition, on October 7, 2008, all the exchanges in Vietnam and the U.S. reported the largest positive coefficients. During the sub-prime mortgage crisis, July 2007 saw the collapse of the hedge

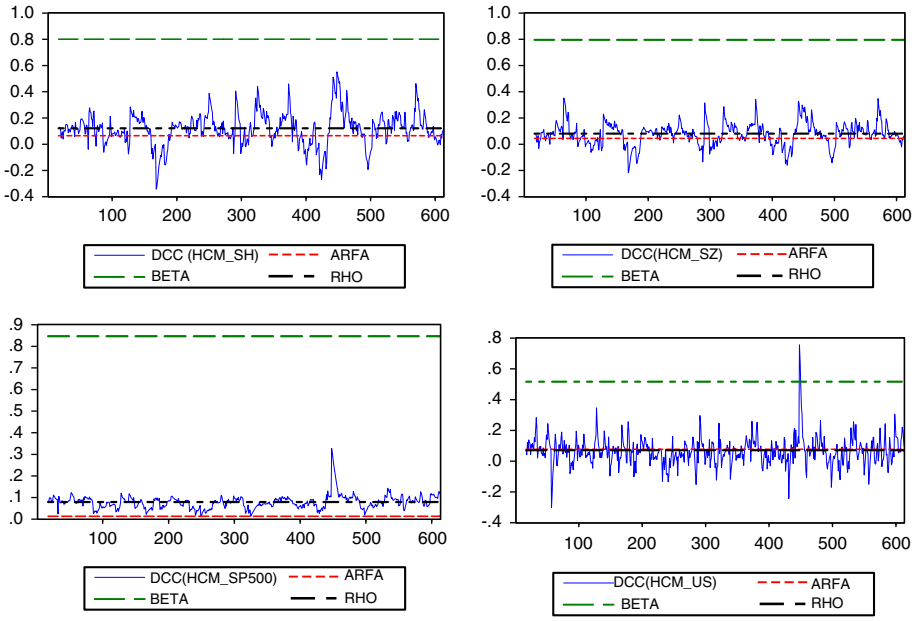

Fig. 2 Dynamic correlation coefficient of return between markets. DCC(i_j) denotes the dynamic correlation coefficient of return between i and j markets, ALPHA, α, BETA, β, and RHO, $\overline{\rho}_{ij}$. The *vertical axis* denotes trend of dynamic correlation coefficient, the *horizontal axis* denotes observations (date): The *horizontal axis* denotes observation (date): 100 (3/20/2007), 200 (8/29/2007), 300 (2/15/2008), 400 (7/21/2008), 500 (12/19/2008), 600 (6/2/2009)

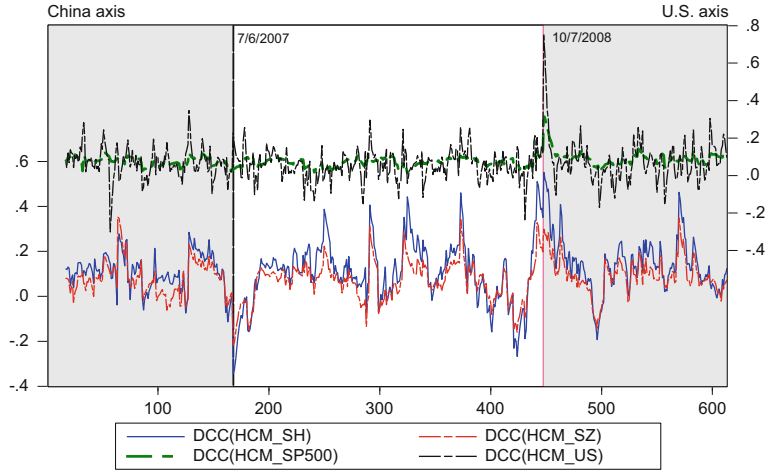

Fig. 3 Structural changes and dynamic correlation coefficient of return between markets. DCC(i_j) denotes the dynamic correlation coefficient of return between i and j markets. The *vertical axis* denotes trend of dynamic correlation coefficient, the *horizontal axis* denotes observations (date): 100 (3/20/2007), 200 (8/29/2007), 300 (2/15/2008), 400 (7/21/2008), 500 (12/19/2008), 600 (6/2/2009)

funds under the umbrella of Bear Sterns. It signalled the beginning of the crisis. The crisis was at its worst from June to October 2008. Fannie Mae and Freddie Mac went under water, Lehman Brothers went bankrupt and Iceland reported the worst financial crisis in its history.

In order to test the contagion effects, Wang and Nguyen Thi (2007) suggested that there are positive and negative effects. Therefore, this paper refers to the two tipping points for structural changes and divides the research period into three sub-periods in order to test whether contagion effects exist in Vietnam, China, and the U.S. The three sub-periods are sub-period 1 (October 9, 2006–July 5, 2007), sub-period 2 (July 6, 2007–October 6, 2008), and sub-period 3 (October 7, 2008–June 19, 2009). This paper uses two methods to validate the existence of contagion effects. The first is to test whether the mean, μ_1, of the DCC coefficients of sub-period 1 is any different from the mean, μ_2, of the DCC coefficients of sub-period 2; the null hypothesis is H_0: $\mu_1 = \mu_2$. The second method is to test whether the mean, μ_2, of the DCC coefficients of sub-period 2 is any different from the mean, μ_3, of the DCC coefficients of sub-period 3; the null hypothesis is H_0: $\mu_2 = \mu_3$.

The test results are summarized in Table 4. This paper finds that of the tests of the four different combinations of the coefficients, only the combination of Vietnam and the U.S. (HCM-SP500, HCM-US) indicate that the mean, μ_1, of the DCC coefficients of sub-period 1 is greater than the mean, μ_2, of the dynamic correlation condition coefficients of sub-period 2. This shows that negative contagion effects exist in Vietnam and the US. However, there are no contagion effects in Vietnam and China. They are in fact interdependent. However, the mean, μ_3, of the DCC coefficients of sub-period 3 is significantly greater than the mean, μ_2, of the DCC coefficients of sub-period 2 for all the four combinations. This indicates that there were positive contagion effects at the time the sub-prime mortgage crisis was at its worst. This was when the U.S. stock markets slumped and the stock markets in Vietnam and China also plummeted (Fig. 1).

Once it has confirmed that there are contagion effects, this paper continues to validate contagion risk. Let μ_A be the mean of the HCM-SH DCC coefficients, μ_B the mean of the HCM-SZ DCC coefficients, μ_C the mean of the HCM-SP500 DCC coefficients and μ_D the mean of the HCM-US DCC coefficients. In order to explore whether it is the U.S. or China that brings more contagion risk to Vietnam, this paper establishes five null hypotheses, i.e. H_0: $\mu_A = \mu_B$, H_0: $\mu_A = \mu_C$, H_0: $\mu_A = \mu_D$, H_0: $\mu_B = \mu_C$, and H_0: $\mu_B = \mu_D$. Meanwhile, this paper examines all the samples and the three sub-periods. The null hypotheses H_0: $\mu_A = \mu_C$, H_0: $\mu_A = \mu_D$, and H_0: $\mu_B = \mu_D$ are rejected. Therefore, it is safe to infer that China (relative to the U.S.) brings more contagion risk to Vietnam, particularly in sub-period 3 and the mean of the HCM-SH correlation coefficients. As stated above, in terms of political and economic systems, these two countries are basically the same. This is why stock markets in China and Vietnam are correlated to a certain degree. The development of the Vietnamese market owes, in part, to retail investors from China. These Chinese retail investors can even be regarded as the pioneers of the Vietnamese stock market. The economy in Vietnam is similar to that of China. Surplus capital is trapped within, due to difficulties in capital outflows. This is why both markets boomed without the support of fundamentals. The impact of the sub-prime mortgage crisis and the economic recession transformed the interdependence of the two stock markets into contagion effects. The changes of the significant correlation are due to the growing contagion risk.

This paper argues that from the global perspective, Vietnam may be faced with a financial crisis due to the constant accumulation of capital inflow. This is evidenced by the booming of its stock market. Since 2003, a wall of liquidity has been flushed into emerging markets. There already are risks associated with reverse capital movements. However, it is a challenge to determine at what point to release the capital inflows in these countries. In the process of

Table 4 DCC coefficient and contagion effect test

	Entire sample	Period 1 10/9/2006–7/5/2007	Period 2 7/6/2007–10/6/2008	Period 3 10/7/2008–6/19/2009	H_0: $\mu_1 = \mu_2$	H_0: $\mu_2 = \mu_3$
μ_A: HCM-SH	0.1175	0.1107	0.1047	0.1452	[0.560]	**[−3.150]*****
μ_B: HCM-SZ	0.0783	0.0804	0.0669	0.0956	[1.609]	**[−3.431]*****
μ_C: HCM-SP500	0.0786	0.0768	0.0696	0.0952	**[3.157]*****	**[−7.074]*****
μ_D: HCM-US	0.0651	0.0689	0.0549	0.0786	[1.762]*	**[−2.339]***
H_0: $\mu_A = \mu_B$	**[6.297]*****	**[3.393]*****	**[3.702]*****	**[4.318]*****		
H_0: $\mu_A = \mu_C$	**[7.360]*****	**[5.102]*****	**[4.046]*****	**[4.915]*****		
H_0: $\mu_A = \mu_D$	**[8.298]*****	**[4.440]*****	**[5.145]*****	**[5.049]*****		
H_0: $\mu_B = \mu_C$	[−0.074]	[0.542]	[−0.486]	[0.050]		
H_0: $\mu_B = \mu_D$	**[2.590]*****	[1.261]	**[1.687]***	[1.539]		

* and *** denote 10% and 1% significant level, respectively

reforms and integrations with other parts of the world, Vietnam fails to keep up with corresponding changes in its market systems. This is why a similar crisis did not occur in Eastern European Countries (to which there also are an abundance of capital inflows), but erupted only in Vietnam, an Asian country.

As far as the methodology is concerned, King and Wadhwani (1990) and Forbes and Rigobon (2002) used traditional and variances-adjusted non-conditional coefficients, respectively, to verify contagion effects. Longin and Solnik (1995) indicated that the coefficients of stock markets are not fixed over time. Suleimann (2003) argued that coefficients change over time. However, non-conditional coefficients are not the proper equations for estimates of coefficients for stock market returns. This paper uses DCC equations to estimate conditional coefficients that change over time and simulate reality. The validity of the tests of contagion effects should be superior to that of tests in previous studies. This approach is never discussed in current research. It is one of the contributions of this paper to the empirical study of contagion effect tests.

From the early days, for example King and Wadhwani (1990), to recent times, for example Forbes and Rigobon (2002), scholars have been examining contagion effects, i.e. 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 U.S. on Vietnam is another instance. In the study of contagion effects, this paper takes into account the increase or decrease of coefficients. This is different from conventional definitions. As shown in Table 4, the coefficients go down from sub-period 1 to sub-period 2, but go up markedly from sub-period 2 to sub-period 3. This paper finds more evidence of contagion effects than do Forbes and Rigobon (2002). It also provides more information than Giang (2008) and Vuong et al. (2006), as far as the Vietnamese stock market is concerned. The research finding can serve as a reference in asset allocations for investors in the Vietnamese stock market because it sheds light on the correlation of the Vietnamese stock market and the stock markets in China and the U.S.

5 Conclusions

The contagion effects explain the influence of the economic or financial exogenous impulse of any country on the co-movements of international or regional markets. Aggarwal et al. (1999) suggested that the crash of the U.S. stock market in 1987 triggered an increase in the volatility of global stock markets. However, the impacts of the Mexican or Asian financial crises were regional. Forbes and Rigobon (2002) indicated that the Asian financial crisis created only interdependence in the regional markets, rather than contagion effects. This paper examines the Vietnamese stock market with an extension of the recent examinations of risk contagion effects. This paper conducts an empirical study to validate whether the contagion risk triggered by stock markets in China and the U.S. has any impact on the Vietnamese stock market when the Vietnamese stock market is confronted with a financial crisis. It also further examines whether the stock markets in China or the U.S. have more influence in terms of the contagion risk they trigger. The empirical research finds that China (compared to the U.S.) brings more crisis contagion risk to the stock market in Vietnam. The effects have become even more pronounced after the sub-prime mortgage crisis.

This paper conducts tests of contagion effects with different methods from those used by existing literature. Past studies use co-integration or GARCH models to focus on long-run relationships between markets or on spill-over effects. In other words, past studies focus on

indirect and implied effects, rather than directly attacking contagion effects. Heteroskedasticity twists non-conditional coefficients and leads to biased interferences on contagion effects. Forbes and Rigobon (2002) used variances-adjusted non-conditional correlation coefficients to test contagion effects. Suleimann (2003) indicated that the coefficients of stock markets are not fixed over time. In addition, non-conditional coefficients are not the proper equations for the estimates of coefficients for stock market returns. This paper applies the DCC model, suggested by Engle (2002), to estimate the DCC coefficients of the stock markets in order to test contagion effects. This approach is a significant improvement on prior approaches, which were based on the tests on non-conditional or adjusted coefficients. This paper first confirms the existence of contagion effects and then validates the influence of contagion risk. This concept has never been mentioned in existing literature and has first been proposed in this paper.

In sum, the empirical results show that under the integration of global economies, there are co-movements or interdependences between financial markets. The contagion risk of the sub-prime mortgage crisis impacts Vietnam. It is suggested that investors in the Vietnamese stock market should review the performances of Vietnam's neighbouring markets and refer to the financial exogenous impulses as a decision variable. Ignorance of market information concerning the economies and financials of neighbouring countries will enhance the uncertainties of returns on investments.

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