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Spillover Effects among the Main Stock Markets in China's Capital Market Opening Process

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Abstract

With the opening and development of China's capital market, mainland China and the world's stock market is increasingly close. This paper explores the volatility spillover effect between China's stock market and the world's major ones to study the transmission path of stock market risk and provides policy suggestions for promoting development of China's stock market. We selected daily returns of four large indices from December 26, 1996 to March 1, 2016 as the main object to study and analyze Shanghai Composite Index, Hong Kong Hang Seng Index, American Dow Jones Index, and British Financial Times Index. According to the different degree of openness of China's capital market, the samples are divided into five sub-stages. Granger test and DCC-MGARCH model are used to analyze the causal relationship and dynamic correlation of the mainland stock market and the major ones in the world. To avoid the volatility and risks, we found corresponding measures. The empirical results show that the implementation of WTO and the QFII system cannot effectively promote the internationalization of the stock market in China. However, the exchange rate reform of RMB and Shanghai-Hong Kong Stock Connect Program have greatly improved the linkage between Chinese and international stock markets.

JEL Classifications: G15, F30, D00

Keywords: Fluctuation spillover effect; Dynamic correlation; Granger test; DCC-MGARCH model

1. Introduction

Since the establishment of the Shanghai Stock Exchange on December 19, 1990, the Chinese mainland stock market has been developing for almost 27 years. Mainland China's stock market continued to carry

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out institutional construction and institutional reform. The legal system is gradually sound. The supervision efforts continue to strengthen. The stock price movement method established on December 26, 1996 has a significant inhibitory effect on the illegal over-speculation in the market, and prevents the stock market price from violate changes, which has played an effective role in maintaining the market's financial order. Since China's formal accession to WTO on December 11, 2001, China's financial market and foreign mainstream markets have more and more contact. Both the composition of the structure and the future direction of development are slowly in line with the international market. As China's finance is increasingly open and free, China's capital market is gradually liberalized, and the mainland's stock market is also interacting with international capital markets. The first one is the changes of investor structure. On July 8, 2003, QFII was landed in China, expanding the types of investors in China's securities market. The investors vary from mainland China citizens to foreign financial institutions. The original portfolio expands from a simple stock combination of mainland enterprises to enterprise market portfolio of many countries involved in QFII. On July 21, 2005, the reform of RMB exchange rate system made China's capital market and international capital markets closer and closer. This change, while making investors more profitable, increased the risk of investment. In recent years, along with China's "The Belt and Road" policy and the establishment of Asian Infrastructure Investment Bank, China's capital market is more and more opening up. The establishment of Shanghai-Hong Kong Stock Connect Program in 2014 and the access of RMB to SDR in 2016 provide convenience for financial capital circulation at home and abroad. In the increasingly close contact between domestic and international financial market, it has been an urgent problem to deal with the fluctuation of the international financial market in the process of opening up the capital market, and to keep the domestic financial market relatively stable and improve the financial market systemic risk monitoring and financial market risk management.

In the comparison between the domestic and foreign markets, the stock price, as an important indicator of national economic development and resource allocation efficiency, can strongly explain the opening degree of China's capital market to the outside world. Based on the above research, this paper uses the Granger test and DCC-MGARCH model to analyze the returns and volatility correlations of different stock markets from a dynamic perspective, so as to analyze the fluctuation spillover effect of stock market in mainland China and that in Hong Kong, the United States and the UK. From a micro perspective, the results of this paper will help individual investors establish a scientific portfolio, while reminding investors to avoid risks timely in accordance with the international financial market dynamics. At the same time, the research of this paper can promote the government to strengthen the supervision and management of the financial market environment, build a more efficient response mechanism to face different financial shocks, maintain the healthy and reasonable development of financial markets, and ultimately achieve the purpose of protecting investors' rights and interests. In addition, this paper provides a theoretical reference for the research on the linkage between mainland China stock market and international stock market.

2. Literature Review

From the perspective of the international securities market, with the deepening of global economic integration and financial liberalization, the world's major stock markets have shown a growing trend of common change (Jeon & Von Furstenberg, 1990). Because of the combined effects of geographical environment, trade and political connection, different stock markets are usually tightened, showing a strong fluctuation spillover effect.

The capital markets of developed countries opened up relatively early, and the development degree of them is better, so it is the main goal of the related research literature on the stock market spillover effect. In 2007, Terence, Wong and Isabel explored the relationship between Japan's opening price (closing price) for each day from 1992 to 2003 and the closing prices (opening prices) of other G7 countries. They found that when the global stock market was in the uptick, the relationship between Japanese stock market and

other countries' will tend to be close (Chong, Wong & Yan, 2008). Laopodis (2011) studied the relationship between the United States, Britain, France, Germany and Italy through rolling sample co-integration analysis and VAR model. The results show that a country's economic base is of greatest importance of the linkage between stock markets before the establishment of the euro area.

Studies have shown that the financial markets between the United States and most economically developed countries and regions are in a long-term equilibrium, and although the linkage between them is not so obvious, the US still has some impact on financial markets in other countries and regions. Morana and Beltratti (2004) and others, when analyzing the stock market returns of United States, Britain, Germany and Japan from 1973 to 2004, found that there is a clear fluctuation spillover effect in the four stock markets. Employing the GARCH (1, 1) and GARCH-X model, with the objects as the return rates of Dow Jones Industrial Average, the FTSE 100 Index, and the Greek Stock Exchange Composite Index from January 2006 to July 2010, Mulyadi and Anwar (2012) studied the fluctuation spillover effect of the three stock markets. The results show that there is a mean spillover effect of 1% significance during this period.

Due to the gradual opening-up of the financial markets in emerging countries and the development of the globalization process, experts and scholars are interested in the fluctuation spillovers between the emerging stock market and the developed countries' stock markets. Earlier studies have shown that there is no significant fluctuation spillover effect between the emerging stock market and the developed stock market. For example, in 2005, Phylaktis and Ravazzolo (2005) studied the relationship between the stock market in the Pacific region and the US-Japan stock market from 1980 to 1989, and found that the relationship is not so close. Recent studies have shown that the spillover effects of emerging markets and world stock markets have increased significantly. Li and Giles (2015) used the BEKK-GARCH model to analyze the stock markets of the United States, Japan and six developing countries in Asia, and found that the United States had a significant one-way fluctuation spillover effect on Japan and emerging markets in Asia. What's more, during the Asian financial crisis, the US securities market and the Asian securities market have a strong two-way fluctuation spillover effect.

As a member of the emerging markets, China has developed rapidly in stock market, and many experts and scholars have begun to pay attention to the link between China and the international stock market. Early research shows that the linkage between China's stock market and the world stock market is weak. The first study of Bailey (Bailey, 1994) on China's stock market found that although some international market indicators can illustrate the characteristics of ups and downs of Shanghai and Shenzhen stock markets. But in the early 1990s, the fluctuation effects of Shanghai and Shenzhen stock markets and the world stock market are not significant. Huang, Yang and Hu (2000) explored the relationship of representative stock indexes among the US, Japanese and China through the Johansen Maximum Likelihood Estimation, showing the linkage among the US, Japanese stock market and the China stock market is not obvious. Wang and Di Iorio (2007) showed that the fluctuation spillover effect between China's A-share Index and MSCI World Index was not significant from 1994 to 2003.

With the implementation of China's opening-up policy and the continuous development of the internationalization process, the linkage between the Chinese market and the international market has also increased significantly. Mohammadi and Tan (2015) used the VAR model and three kinds of MGARCH models to study the fluctuation spillover effect between China's Shanghai and Shenzhen stock markets and the US and Hong Kong stock markets from January 2, 2001 to February 8, 2013. The result shows that after the financial crisis in 2007, linkage of the two stock markets of china mainland and Hong Kong and the US stock market have strengthened significantly. Liang, Li and Hao (2015) studied the linkage among the global seventeen national stock markets from the perspective of multi-dimensional information spillovers through the methods of directed acyclic graph and spillover index, then they found that after 2005, the degree of international integration of China's stock market has been gradually improving, as well as the degree of China's open and financial liberalization. And the international influence is more powerful on more terms. But Nishimura, Tsutsui and Hirayama (2016) used the 5-min high frequency data of the Nikkei 225 index and the Shanghai Composite Index from January 4, 2013 to March 31, 2014, as well as

the GARCH family model, to study the linkage of stock market between China and Japan. They found that the Chinese stock market did not respond significantly to the volatility on the Japanese stock market.

According to the relevant literatures both at home and abroad, different experts and scholars have different conclusions from different perspectives in different economic backgrounds, and have obtained fruitful research results. But there are still many shortcomings. For example, the selected data range is narrow; the frequency is too low; the statistical method is too simple. Therefore, some research results do not have theoretical value. One of the most important points is that one important factor, that is, changes of institutional mechanisms in the China stock market, is not considered by the majority of the literature. Ten years ago, China's financial policy was still relatively conservative, and China implemented the capital control for the market. In the age of Asian financial crisis, the A-share market didn't have any fluctuation spillover effect towards the world's major stock markets, so we have avoided some difficulty. But now, as the process of globalization of financial markets accelerates, we must study and explore deeply for the fluctuation spillover effects of stock market both at home and abroad.

This paper attempts to break through the researches of the previous literature. Specifically, this article combines with the actual situation of China's capital market development. According to China's accession to WTO, the introduction of QFII system into mainland stock market, the RMB exchange rate reform, and Shanghai-Hong Kong Connect Program, we divide the sample period into five sub-phases. In this paper, Granger test is used to describe the long-term common trend and guidance relationship of different stock markets from static perspective. The fluctuation spillover effects of the four stock markets are analyzed from the dynamic perspective through DCC-MGARCH model to reveal the substantial impact of the changes of China's capital market open policy on the linkage of stock markets both at home and abroad.

3. Method

We often use the GARCH model to establish the model of the volatility of a single asset return. When a single asset is extended to multiple assets, we need to consider the volatility of each asset and the correlation between them. Then we need to extend the univariate GARCH model to the multivariate GARCH model. For the univariate GARCH model, we consider the GARCH (1, 1) model proposed by Bollerslev (1986). For the multivariate GARCH model, we consider the DCC-MGARCH model proposed by Engle (2002). The advantage of this model is that it not only retains the main features of the standard GARCH model, but also overcomes the complexity of the traditional multivariate GARCH model estimation. In addition, it can capture the dynamic variance, covariance and correlation coefficient. The methods of the GARCH (1, 1) model and the DCC-MGARCH model are described below.

3.1. GARCH (1, 1) Model

Bollerslev (1986) proposed the GARCH (1, 1) model, which partly explains the "spikes and thick tail" characteristic of the yield of assets, starting from the characteristics of the volatility aggregation of the asset yield. The GARCH (1, 1) model can be expressed as:

$$y_t = x_t\gamma + u_t,\ t = 1,2,\cdots,T \tag{1}$$

$$\sigma_t^2 = \omega + \alpha u_{t-1}^2 + \beta\sigma_{t-1}^2 \tag{2}$$

Among them, x_t is the $1\times(k+1)$ dimension exogenous variable vector. γ is $(k+1)\times 1$ dimension coefficient vector. To ensure the stability of the GARCH (1, 1) model, we need to make sure $\alpha+\beta<1$. The mean equation given in formula (1) is a function of an exogenous variable with an error term. Formula (2) is also called the conditional variance equation, because σ_t^2 is a forward forecast variance based on the previous information, which is called the conditional variance.

The conditional variance given in formula (2) has three components: the constant term ω, the information u_{t-1}^2 of the volatility obtained from the previous period (ARCH term) after the square of the residual of the mean equation and the previous forecast variance (GARCH).

3.2. DCC-MGARCH Model

The DCC-MGARCH model proposed by Engle (2002) is further developed on the basis of the constant conditional correlation model (CCC) proposed by Bollerslev (1990). The CCC model can be expressed as:

Suppose that r_1, r_2 are the random variables with the mean 0, which meets the condition:

$$r_t = (r_{1,t}, r_{2,t})' \mid I_{t-1} \sim N(0, H_t) \tag{3}$$

The conditional covariance matrix H_t above can be expressed as:

$$H_t = D_t R D_t \tag{4}$$

In the above matrix, $D_t = \begin{bmatrix} \sqrt{h_{1,t}} & 0 \\ 0 & \sqrt{h_{2,t}} \end{bmatrix}$, $R = \begin{bmatrix} 1 & \rho_{12} \\ \rho_{21} & 1 \end{bmatrix}$. Since we have set $\rho_{12} = \rho_{21}$ as a constant that does not change with time, so R is a constant conditional correlation coefficient. $h_{i,t}$ is the conditional variance estimated by the univariate equation:

$$h_{i,t} = \omega_i + \sum_{p=1}^{\rho_i} \alpha_{ip} \varepsilon_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{it-q} \tag{5}$$

Where the residuals of the GARCH model mean equation, the normalized residual vector is:

$$\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t})' = D^{-1} r_t \tag{6}$$

$$E_{t-1}(\varepsilon_t, \varepsilon_t') = E_{t-1}(D_t^{-1} r_t r_t D_t^{-1}) = D_t^{-1} H_t D_t^{-1} = R \tag{7}$$

Dynamic conditional correlation model (DCC model) is based on the constant correlation coefficient model. It allows R to change with time, and R has variability of time. H_t is changed as:

$$H_t = D_t R_t D_t \tag{8}$$

In the above equation, $D_t = diag\{\sqrt{h_{i,t}}\}$ is still the 2×2 order diagonal time-varying standard deviation matrix obtained from the univariate GARCH model. $R_t = \{\rho_{ij}\}$, $i, j = 1, 2,$ is a dynamic conditional correlation coefficient matrix. Engle suggested that the dynamic structure is:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{9}$$

$$Q_t = (1\text{-}\alpha\text{-}\beta)\ Q + \alpha(\varepsilon_{1,t-1}\varepsilon_{2,t-1}') + \beta Q_{t-1} \tag{10}$$

Among them, $Q_t = \begin{bmatrix} q_{11,t} & q_{12,t} \\ q_{21,t} & q_{22,t} \end{bmatrix}$, $Q_t^* = \begin{bmatrix} \sqrt{q_{11,t}} & 0 \\ 0 & \sqrt{q_{22,t}} \end{bmatrix}$. Q is the unconditional variance matrix for the standard residual. When Q is positive definite or semi-positive definite, R_t must be positive definite. α and β are called the coefficient of the DCC model. $\rho_{12,t}$ in the matrix R_t raises our interest:

$$\rho_{12,t} = \frac{q_{12,t}}{\sqrt{q_{11,t} q_{22,t}}} \tag{11}$$

In the DCC-MGARCH (1, 1) model,

$$q_{ij,t} = (1-\alpha-\beta)\rho_{ij} + \alpha\varepsilon_{i,t-1}\varepsilon_{j,t-1} + \beta q_{ij,t-1} \tag{12}$$

ρ_{ij} is the unconditional correlation coefficient for the normalized residual ε_t. α reflects the effect of the standardized residual product on the dynamic correlation coefficient, which reflects the persistence characteristic of the correlation.

Set the parameter to be estimated as θ. DCC model can be estimated by two steps. Firstly, we estimate the univariate GARCH process of each asset, and then use the obtained conditional variance $h_{i,t}$ to remove the residual $r_{i,t}$ to get the normalized residual $\varepsilon_{i,t}$. Then we use the maximum likelihood method to estimate the parameters of the dynamic correlation structure. Parameter θ can be divided into two parts:

$(\phi_1, \phi_2, \cdots, \phi_k, \psi) = (\phi, \psi)$, $\phi_i = (\omega, \alpha_{1i}, \cdots, \alpha_{pi}, \beta_{1i}, \cdots, \beta_{qi})$ is the parameter of the univariate GARCH process for the yield curve sequence of the i th market. Since the first stage of the parameter estimation is irrelevant to R_t, we use a $k \times k$ unit matrix I_k in the likelihood function to replace R_t. The likelihood function of the first stage can be expressed as:

$$QL_1(\phi \mid r_t) = -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi) + \log(|I_k|) + 2\log(|D_t|) + r_t' D_t^{-1} I_k D_t^{-1} r_t) \tag{13}$$

$$= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi) + 2\log(|D_t|) + r_t' D_t^{-2} r_t)$$

$$= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi) + \sum_{n=1}^{k}(\log(h_{it}) + \frac{r_{it}^2}{h_{it}}))$$

$$= -\frac{1}{2}\sum_{t=1}^{T}(T\log(2\pi) + \sum_{n=1}^{k}(\log(h_{it}) + \frac{r_{it}^2}{h_{it}}))$$

After the first stage estimation is completed, the likelihood function of the second stage can be expressed as follows:

$$QL_2(\psi \mid \hat{\phi}, r_t) = -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi) + 2\log(|D_k|) + \log(|R_t|) + r_t' D_t^{-1} R_k D_t^{-1} r_t) \tag{14}$$

$$= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi) + 2\log(|D_t|) + \log(|R_t|) + \varepsilon_t' R_t^{-1} \varepsilon_t)$$

Because of the condition $\hat{\phi}$, only $\log(|R_t|) + \varepsilon_t' R_t^{-1} \varepsilon_t$ will affect the likelihood function part of the parameter selection. Therefore, by maximizing the likelihood function, the parameters of the DCC model can be estimated as follows:

$$QL_2^*(\psi \mid \hat{\phi}, r_t) = -\frac{1}{2}\sum_{t=1}^{T}(\log(|R_t|) + r_t' D_t^{-1} R_k D_t^{-1} r_t) \tag{15}$$

4. Empirical Study

4.1. Selection of Samples and Data Processing

This article selected the daily closing price of nearly 20 years from December 26, 1996 to March 1, 2016 of the Shanghai Stock Exchange as the domestic stock market indicator data. As for the United Kingdom, the United States, Hong Kong, we use the British FTSE 100 (FTSE), the Dow Jones Industrial Average (DJI) and the Hang Seng Index (HSI) of same sample period as the sample data. The above data are

selected from the Cathay Pacific database. On December 26, 1996, China's securities regulatory authorities began to implement the Price Limits Mechanism of 10% rate to curb the stock market speculation and money laundering and other acts. Studies have shown that the price limit system on the stock market price fluctuations caused a large degree of impact, so this article selected December 26, 1996 as the starting point of the sample period. Shanghai stock market and Shenzhen stock market jointly formed the mainland stock market. The economic environment and the system they are in are of no difference, so a high degree of relevance exists. In addition, compared with Shenzhen stock market, the Shanghai stock market starts early and is of high market value and better sensitivity, so this paper uses the Shanghai Composite Index to represent China's mainland stock market. In view of the economic relationship between Hong Kong and the mainland and its special geographical location, we also put the Hang Seng Index as the object of study. New York and London are world financial centers, so trading there is very active. Coupled with its special geographical location, their opening and closing time can be achieved in sequence. So we also select the British FTSE 100 Index and the Dow Jones Industrial Average.

Since the main purpose of this paper is to analyze the dynamic correlation of China's capital market, the Hong Kong market, the US stock market and the British stock market during the capital market opening-up development of China, this article select four events with significant impact on mainland stock market as the basis for division. They can be shown as China's accession to WTO, the first single QFII release, the RMB exchange rate reform, the implementation of Shanghai-Hong Kong Connect Program. These four events divide the sample period into five sub-stages. These four events divide the entire sample period into five sub-stages. The first sub-stage is from December 26, 1996 to December 10, 2001, with China's formal accession to the WTO as a cutting point; the second sub-stage is from December 11, 2001 to July 8, 2003, during which China made the first QFII into Union Bank of Switzerland after joining WTO, and QFII is a major turning point in China's stock market, marking the mainland China has taken a key step in the stock market in the internationalization process; the third sub-stage is from July 9, 2003 to July 20, 2005, during which China began to implement the RMB exchange rate reform and improved the liquidity between the mainland China and international capital markets; the fourth sub-stage is from July 20, 2005 to November 17, 2014, with the formal implementation of Shanghai-Hong Kong Connect Program as the split point, which accelerates the process of internationalization of China's capital market. The fifth sub-stage is from November 18, 2014 to March 1, 2016, during which China's financial market has been adjusted to the international financial environment for a period of time, so the stock index data of this period should be able to better response to the internationalization of China's capital market. In the first and fourth sub-stages, China has experienced the Asian financial crisis and the US subprime mortgage crisis triggered by the global financial crisis. This paper will take the financial crisis into account, and study Chinese and foreign markets' fluctuation spillover effect when the financial environment has drastic changes.

As the national policy, holidays and other factors of countries in the world are different, the stock trading day will be different. For example, the Chinese stock market closed on the National's Day and the Spring Festival, while the US market operates normal trading. Similarly, the US market is not trading in the Christmas, and China's stock market operates normal transactions, so that the date of a same day may be missing. In order not to artificially introduce data and maintain the comparability of the data, this article will delete the transaction data of a few trading days not overlapping, and we get the data of 4340 trading days. This article chooses Eviews 8.0 for data processing and analysis. The daily return *Rt* on the stock market is defined as $R_t = 100\% \times \ln(P_t / P_{t-1})$. P_t is the daily gain of the stock index. R_t is similar to the overall daily return on the stock market when the stock price change is not very huge. In this paper, RSH, RHSI, RDJI, RFTSE respectively demonstrate the daily return rate sequence of Shanghai Composite Index, the Hang Seng Index, the Dow Jones index, and the UK FTSE 100 index.

4.2. Data Inspection

In order to avoid false regression, the data must be operated heteroskedasticity test, sequence

autocorrelation test and stationarity test before the parameters of Granger test and DCC-MGARCH model are estimated.

4.2.1. Heteroscedasticity and Sequence Autocorrelation Test

The yield series of each market is shown in Figure 1 to Figure 4, and each sequence has a number of abnormal peaks, indicating that the volatility of the yield has a certain burst and significance. At the same time, the anomalous fluctuation in the sequence has obvious agglomeration, which indicates that the volatility of the yield series of each market has the conditional heteroscedasticity. The disturbance in these sequences is not white noise.

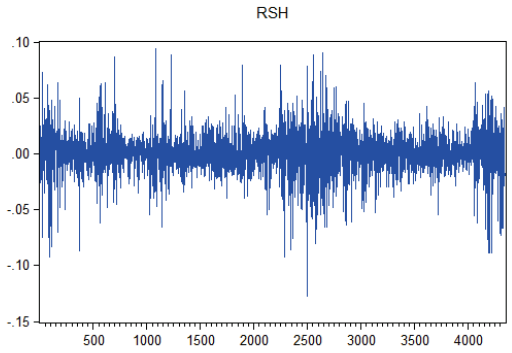

Figure 1. Yield Sequence of Shanghai Composite Index

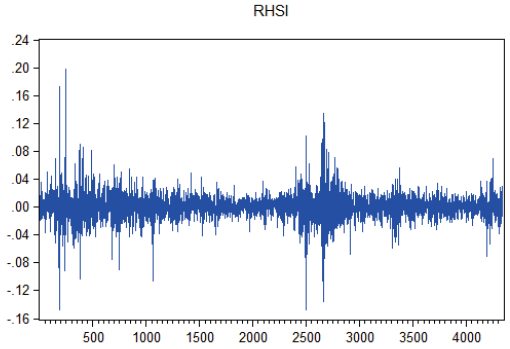

Figure 2. Yield Sequence of Hang Seng Index

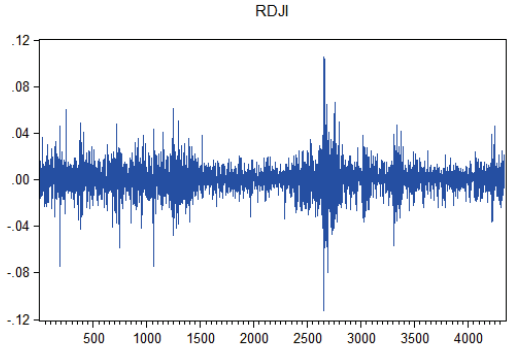

Figure 3. Yield Sequence of Dow Jones index

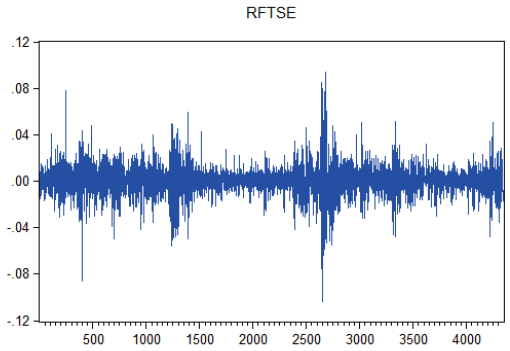

Figure 4. Yield Sequence of UK FTSE 100 index

Table 1. Descriptive statistics on yield sequence of domestic and foreign stock markets

	RSZ	RHSI	RDJI	RFTSE
Mean	0.000256	9.20E-05	0.000219	8.97E-05
Median	0.000556	0.000282	0.000418	0.000413
Maximum	0.094009	0.197978	0.105083	0.093843
Minimum	-0.12764	-0.14735	-0.1127	-0.10327
Std. Dev	0.017577	0.017897	0.012401	0.012764
Skewness	-0.40267	0.201587	-0.18093	-0.16065
Kurtosis	7.661615	15.76206	10.98329	9.272169
Jarque-Bera	4045.977***	29474.96***	11546.04***	7131.027***
Q(6)	19.616**	15.645*	20.899**	32.267***
ARCH(6)	56.373***	111.765***	186.896***	189.747***

Note: ***, ** and * denote statistical significance at 1, 5 and 10-percent level, respectively.

It can be seen from Table 1 that the average daily rate of return on the Shanghai Composite Index is significantly higher than that of Hang Seng Index, the Dow Jones Index and the FTSE 100 Index, while the standard deviations of the Dow Jones Index and the UK FTSE 100 Index are lower than the Shanghai index and the Hang Seng Index. We can see that the emerging capital market still has the "high risk and high yield" characteristic. The daily returns of the four financial markets are close to 0. The skewness of the Shanghai Composite Index, the Dow Jones index and the UK FTSE 100 index is negative. The yields rate sequence skewness of the four markets is different from zero, and the kurtosis is greater than 3, showing a clear "spike thick tail" phenomenon. According to JB statistics, at 1% of the significant level, all the market yields are different from the normal distribution.

In addition, Q (6) statistics show that there is an autocorrelation in the stock market returns of China, the United States and the United Kingdom at the 5% significance level. The yield series of Hong Kong stock market has an autocorrelation phenomenon at the significance level of 10%. According to the ARCH (6) statistics, the four stock markets' returns have a distinct ARCH effect at the 1% significance level, consistent with the result obtained from the analysis in Figure 1.

4.2.2. Stationarity Test

In this paper, ADF test and PP test are used to test the stability of the yield sequence. Among them, the lag is determined based on the minimum criteria of SC (Pauler, 1998). The specific results are shown in Table 2. It can be seen from the test results that the ADF and PP statistics of the four stock markets' returns are

below the critical value of 1% significant level. It can be seen that at the 99% confidence level, the yield rate sequences of the four stock markets are tested by unit root. They have the smoothness, avoiding the false regression.

Table 2. Unit root test results

Yield Rate Sequence	RSH	RHSI	RDJI	RFTSE
ADF Statistic	-66.0553	-67.2378	-49.8376	-50.0114
PP Statistic	-66.09835	-67.2378	-68.5000	-67.4065
1% Critical Value	-2.5655	-2.5655	-2.5655	-2.5655
5% Critical Value	-1.9409	-1.9409	-1.9409	-1.9409
10% Critical Value	-1.6166	-1.6167	-1.6167	-1.6167
P-value	0.0001	0.0001	0.0001	0.0001

4.3. Granger Test

Granger test can fully reflect the information communication status between the two markets. It is worth mentioning that the test method is particularly sensitive to the selection of the lag, and the difference in the lag may cause the results to differ. Using the EViews 8.0 to Granger test the four-stage yield sequence of stock index in four markets, with reference to the AIC minimum principle, we can make a conclusion that the optimal lag order of the first stage is 2, the second stage is 1, the third stage is 1, the fourth Stage and fifth stage are both 4. The Granger test results of the four-stage in four stock markets are in Table 3.

The original assumption of the Granger test is that there is no causal relationship between the variables. If the P value is more than 0.05, then the original hypothesis is rejected, and it is considered that there is a Granger causal relation between the two stock markets. If the P value is less than 0.05, the original hypothesis is accepted, that is to say, there is no Granger casual relation between the two stock markets. It can be seen from the test results that only the mainland stock market did not lead or be led, while there is always a guide or guided relationship for the other three stock markets in the sample period, especially the US stock market, which has always been a leading role on the British stock market and the Hong Kong stock market.

Table 3. Results of granger test about four markets' stock indicators

Null Hypothesis	1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage
	F Statistic	F Statistic	F Statistic	F Statistic	F Statistic
RFTSE does not Granger Cause RDJI	1.7357	0.0026	0.0106	1.6846	2.3664*
RDJI does not Granger Cause RFTSE	47.5957***	50.6143***	34.0847***	64.7948***	6.6878***
RHSI does not Granger Cause RDJI	0.6960	0.3294	0.0455	0.8271	1.2425
RDJI does not Granger Cause RHSI	78.1139***	72.5747***	47.1907***	114.7000***	11.5173***
RSH does not Granger Cause RDJI	1.7405	0.8540	1.3373	1.5480	0.3192
RDJI does not Granger Cause RSH	1.0714	0.1236	0.8187	13.9417***	3.2284**
RHSI does not Granger Cause RFTSE	0.6032	0.3248	0.6567	3.9098***	1.0685
RFTSE does not Granger Cause RHSI	29.2009***	24.2487***	3.5560*	67.5245***	7.1519***
RSH does not Granger Cause RFTSE	1.5194	0.3872	0.3046	3.2882**	1.4358
RFTSE does not Granger Cause RSH	0.3489	1.9236	0.2117	12.0094***	2.9431**
RSH does not Granger Cause RHSI	4.2444**	0.6305	1.1444	3.4570***	4.1103***
RHSI does not Granger Cause RSH	1.5290	0.0565	0.8403	0.5323	1.1896

Note: ***, ** and * denote statistical significance at 1, 5 and 10-percent level, respectively.

As we can see from Table 3, in the first stage, there is causality from China mainland stock market, US stock market and British stock market to Hong Kong stock market; at the same time, the logarithmic return series of US stock market doesn't Granger cause the logarithmic return series of British stock market. At this time, Mainland stock market was in the initial stage, so it had stronger closure, not sensitive to external market information. That is why China mainland stock market was not influenced greatly by the United States, Britain, Hong Kong stock markets in a short time. In the age of Asian financial crisis, China insisted that the RMB did not devalue, while actively expanding domestic demand, so as to maintain healthy and stable growth of the domestic economy. At this stage, China's adherence to and protection for Hong Kong's linked exchange rate system in a wide range of financial crises can explain why there is a causal relationship from China mainland stock market to Hong Kong stock market.

In the second stage, the China mainland stock market was basically isolated, and the other three stock markets had not a guided or guided relationship. While there is causality from US stock market and British stock market to Hong Kong stock market and the null hypothesis that RDJI does not Granger cause RFTSE is rejected. At this stage, China officially joined the WTO, and the domestic capital market began to open to the world capital market gradually, so that it had more contact with world capital market. But in fact, at this time, many investors paid more attention to the capital market reform of various systems and government macroeconomic policy news, so the changes of international economic situation did not have a great impact on the domestic stock market, and with the downturn of domestic stock market, its leading role for Hong Kong stock market also disappeared.

In the third stage, there was still no Granger causality between the China mainland stock market and the other three stock markets. There is causal relationship from US stock market and to British stock market and Hong Kong stock market. Although China introduced QFII in July, 2003, due to restrictions on other aspects of QFII abroad and the lack of familiarity with foreign financial institutions in the Chinese mainland market, the QFII entered the Mainland stock market in different ways but not inflow with large scale in the short term. QFII entered the Mainland stock market with small scale in the early stage, so it had no significant impact on the stock market volatility. Take the Taiwan stock market for an example, not until five years or so after the introduction of QFII, a large-scale external capital had flow into the Taiwan market; likewise, although the Mainland stock market began to introduce QFII, the closure of stock market would not have great changes in short-term.

In the fourth stage, after a long period of development and a series of reforms, the Mainland stock market closed with the international market increasingly, the degree of openness was also increasing. At this stage, unidirectional causality from China mainland stock market to Hong Kong stock market is found to be statistically insignificant. RDJI and RFTSE are the cause of RSH. RDJI is the cause of the other indicators. There is causality from British stock market to China mainland stock market and Hong Kong stock market. At this stage, the impact of QFII on the capital market gradually emerged, the free float of the RMB exchange rate had aroused the interest of many international investors. With a large number of foreign hot money into the mainland stock market, there is a great impact on the domestic stock market.

In the fifth stage, the situation is similar to the fourth stage, but the impact of the China mainland stock market and the Hong Kong stock market on the UK stock market has been weakened. With the increasing of opening and the rapidly developing of market economy, China has more influences in the international affairs, making the Mainland stock market have more and more impact on the global stock market, especially for neighboring countries and countries that trade frequently.

4.4. Dynamic Correlation Test

4.4.1. Estimation and Verification of DCC-MGARCH Model

Before estimating the DCC-MGARCH model, the univariate GARCH process for each market yield is estimated first. As can be seen from the data in 4.2, the four sequences are sequence-dependent. Therefore, this paper uses the ARMA model of the equation structure, with Eviews8.0 software to carry out estimation and comparison, to compare the AIC, BIC and HQ criteria at the same time, then we select the

one with the smallest number of information. Finally, the following results can be considered: RSH: ARMA (4, 0); RHSI: ARMA (4, 0); RDJI: ARMA (1, 1); RFTSE: ARMA (3, 3). The mean equation is shown as follows:

$$RSH_t = -0.0038RSH_{t-1} - 0.0025RSH_{t-2} + 0.0205RSH_{t-3} + 0.0491RSH_{t-4} + \varepsilon_t$$

$$RHSI_t = -0.0193RHSI_{t-1} - 0.0163RHSI_{t-2} + 0.0325RHSI_{t-3} - 0.0373RHSI_{t-4} + \varepsilon_t$$

$$RDJI_t = 0.6540RDJI_{t-1} + \varepsilon_t - 0.6998\varepsilon_{t-1}$$

$$RFTSE_t = 0.5069RFTSE_{t-2} - 0.5795RFTSE_{t-2} + 0.7402RFTSE_{t-3} + \varepsilon_t - 0.5198\varepsilon_{t-1} + 0.5276\varepsilon_{t-2} - 0.7514\varepsilon_{t-3}$$

The Q-statistic test is carried out on the residual sequence of the above mean equation, and the original hypothesis is accepted. The equation does not exist autocorrelation. The residual sequence of the mean equation is verified by the ARCH-LM test. The value of P is 0, and the original hypothesis is rejected, indicating that there are significant ARCH effects in the model residual sequence, and the GARCH model can be further analyzed. According to the above equation, the GARCH (1, 1) model is used to estimate the return rate sequence of each market. We adopt the logarithmic maximum likelihood estimation as the estimation method. The results are shown in Table 4.

Table 4. GARCH (1, 1) parameter estimation results

Parameter	ω	α	β	$\alpha+\beta$
RSH	3.42E-06	0.0750	0.9167	0.9916
RHSI	2.42E-06	0.0807	0.9132	0.9939
RDJI	2.10E-06	0.1020	0.8861	0.9881
RFTSE	2.01E-06	0.0905	0.8982	0.9887

The Q-statistic tests were performed on the residual sequence of the GARCH (1.1) model established in Table 4. It was found that the residual sequence had no autocorrelation and ARCH effects. α is the coefficient of the residual square lag, which indicates the influencing degree of the existing information on the later fluctuation, that is, the influence of the external shock on the market fluctuation. β is the coefficient of the conditional variance itself, which reflects the influence of the memory of the market itself on the fluctuation. $\alpha+\beta$ is the attenuation coefficient, indicating the persistence characteristic of market volatility. The α value of US, UK and Hong Kong stock markets is larger, indicating that the markets of the three regions are more sensitive to information. The α value of China's mainland stock market is relatively small, indicating that the market is relatively closed. The β value of all the stock market is greater than the α value, indicating that the market itself has very strong memory. The value of $\alpha+\beta$ is less than 1, indicating that the time-varying variance of the four stock markets' return rate sequence meets the stability requirements. Meanwhile, the value of $\alpha+\beta$ is close to 1, indicating that the market trend in the future will continue to fluctuate for a long time.

The DCC coefficients of the whole model are $\lambda_1 = 0.0258$, $\lambda_2 = 0.1411$. The test results show that = 34.87, p = 0.0000, indicating that there is a significant dynamic correlation coefficient among the stock markets.

4.4.2. Dynamic Correlation Coefficient Chart

After the DCC-MGARCH model is estimated, the conditional variance and the conditional covariance are

predicted, and the dynamic conditional correlation coefficient between the stock indexes can be calculated and drawn. The higher the dynamic conditional correlation coefficient is, the higher the degree of market trend and the degree of market integration are. Figure 5 to Figure 10 depict the dynamic correlation of the four stock indexes. Stg1, Stg2, Stg3, Stg4, Stg5 respectively represent the first, the second, the third, the fourth and the fifth stages. The period between the red solid straight lines is the 2008 US financial crisis, of which the specific time period is from April 2007 to September 2008.

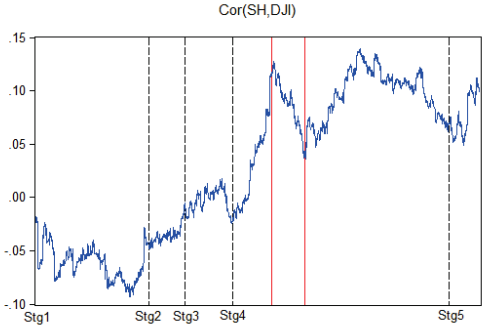

Figure 5. Dynamic correlation coefficient between RSH and RDJI

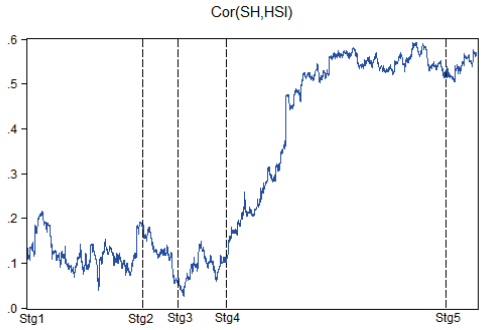

Figure 6. Dynamic correlation coefficient between RSH and RHSI

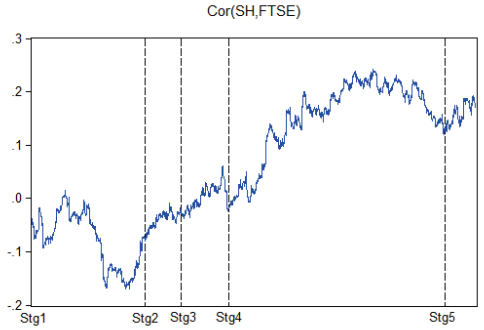

Figure 7. Dynamic correlation coefficient between RSH and RFTSE

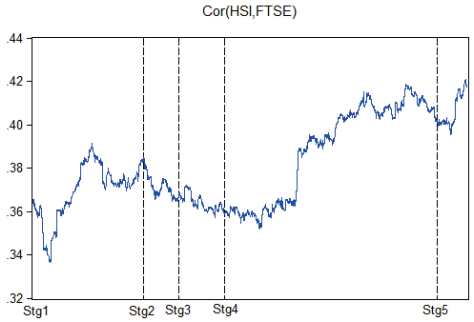

Figure 8. Dynamic correlation coefficient between RHSI and RFTSE

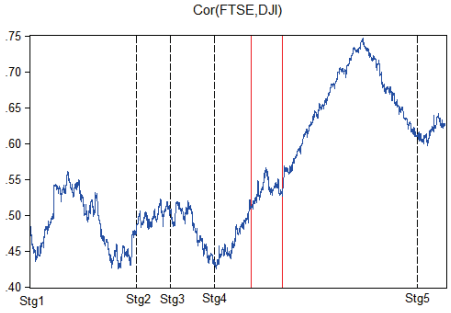

Figure 9. Dynamic correlation coefficient between RFTSE and RDJI

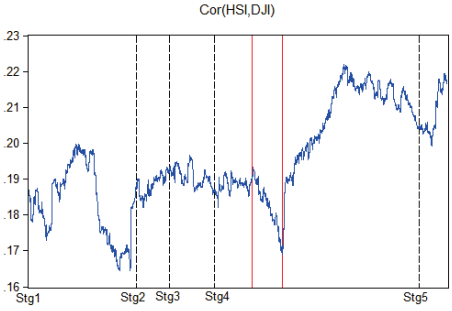

Figure 10. Dynamic correlation coefficient between RHSI and RDJI

From December 26, 1996 to March 1, 2016, the dynamic correlation coefficient has been constantly changing over time in the past 20 years, and the dynamic correlation test and the Granger test are basically the same. According to the analysis of the dynamic correlation coefficient, it can be seen in the previous three stages, the correlation between China mainland stock market and the other three stock markets has been low. The correlation coefficients between the Mainland stock market and the Hong Kong stock market, the US stock market, the UK stock market fluctuated among the three regions respectively: (0,0.2), (0,0.2) and (- 0.18, 0.01), far below the correlation coefficient among the three stock markets. Figure 5 to Figure 10 shows that there is no great fluctuation of correlation coefficient between China stock market and other three stock markets before the reform of RMB exchange rate, and always in a low steady state; after the implementation of QFII, the correlation between the Mainland stock market and the other three

stock markets has risen to a certain extent, but not significant. After joining the WTO, the process of globalization of the China market speeds up, but the domestic stock market is still in a relatively closed state.

The fourth stage, when the RMB exchange rate reform began, the correlation between China mainland market and the Hong Kong market improved significantly, and continuously increased all the way, as well as the correlation coefficient with the US and the British stock markets. In April 2007, with the US sub-prime mortgage crisis broke out, the growth of US economic slowed down or even stagnated, so the US authorities not only introduced a series of provisions which have strong protection for their own trade, but also launched a "double reverse" investigation and special safeguard measures. Therefore, during the US financial crisis, the correlation coefficient between the US stock market and the China mainland stock market declined sharply. The implementation of the Shanghai-Hong Kong Stock Connect system in the fifth phase has further strengthened the linkage between the China mainland market and the worldwide major stock markets, but the correlation coefficient is still very low. In addition to the China mainland stock market, the correlation coefficients among the other four stock markets are at a relatively high level.

5. Conclusions and Recommendations

In this paper, Granger test and DCC-MVGARCH model are used to analyze the degree of correlation between China's stock market and Hong Kong, US and British stock markets. The following conclusions are drawn:

Firstly, the accession to WTO and the implementation of the QFII system cannot effectively promote the internationalization of China's stock market process. Chinese mainland stock market in the first three stages is basically in isolation. In the fourth stage, with the implementation of the RMB exchange rate reform and the implementation of Shanghai-Hong Kong Connect Program, the linkage between Chinese and foreign stock markets has improved, but there is still a certain distance from the integration.

Secondly, with the deepening of the economic and financial integration between Hong Kong and the mainland, especially in the stock market, many large blue chips return from the H shares to the A-share market and become included in the index. The linkage between mainland market and the Hong Kong market rapidly improves.

Thirdly, although the linkage between China's mainland stock market and the United States, the British stock markets has improved, the improvement is not much. China's mainland market is still relatively closed. The subprime mortgage crisis does not influence the mainland China's stock market in a direct way, but through the risk of Hong Kong stock market and indirectly transfers the risk of subprime mortgage crisis to the China’s mainland market.

Fourthly, the increase in the linkage between the stock markets makes the risk of the two markets closely linked. The main purpose of diversified investment in different stock markets is to use the non-relevance of risks in different markets to reduce the total market risk of the portfolio. Thus, this close relation between the stock markets clearly reduces the efficiency of reducing the risk by diversifying investments between two places.

With China's accession to WTO, the opening of financial markets and the implementation of relevant systems, Chinese mainland's stock market and the world's major stock markets will be more closely linked. In view of the above-mentioned international stock market fluctuation spillover phenomenon and the risks, China's stock market should take the following strategies towards fluctuation spillover in the opening-up process of stock market:

Firstly, strengthen the awareness of risk management, and maintain the security of the financial system. With the emergence of financial innovation products, new financial risks are also emerging. At present, China's securities companies are more focused on business development and the expansion of the scale. They have certain understanding of risk management, but they haven’t pay enough attention to it. The

establishment of a scientific and mature risk management philosophy is the primary task of financial institutions to strengthen risk management. The government can establish a sound risk management organization structure within the financial institutions, and set up a special risk management department to control operational risk. The departments should ensure the smooth flow of information and the sensitivity of the reaction mechanism, which can timely and effectively make a quick response to external shocks and risk factors.

Secondly, strengthen the guidance and monitoring of foreign investment. After the opening of the capital market, the biggest risk factor is the inflow of foreign capital. Since the international capital has developed circulation channels and profitability, without the corresponding monitoring and guidance, it would be easy to run a great impact on the market. As for the stock market, it should be based on foreign exchange links to form an effective monitoring and guidance system. As for the market access, it is necessary to ensure that the foreign investment entity is not a hedge fund that specializes in speculative interests. As for the source of foreign investment, the choice of long-term investment funds should be made. As for the use and investment of funds, we give the necessary monitoring and guidance to foreign investment on the basis of full respect for the laws of the market, to promote the efficiency of market allocation of resources and the balanced development of the economy. As for the outflow of funds, we should ensure the effective risk prevention through real-time monitoring system on the basis of legal free outflow, thereby reducing the vibration of the large-scale outflow of funds on the market.

Thirdly, expand international cooperation in financial regulation. In the current trend of global financial integration, the international transmission of financial risk will be faster and faster, and the influenced area will be also more and more wide. Practice has proved that in order to effectively prevent and control financial risks internationally, there is a need for effective bilateral and multilateral cooperation between financial regulatory authorities of countries, to carry out extensive regulatory information exchanges. China's financial industry is gradually integrated into the world market, thus strengthening international cooperation and exchanges is an inevitable requirement to prevent financial risks.

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References

[1] Bailey, W. (1994). Risk and return on China's new stock markets: Some preliminary evidence. *Pacific-Basin Finance Journal*, *2*(2-3), 243-260. https://doi.org/10.1016/0927-538X(94)90019-1

[2] Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, *31*(3), 307-327. https://doi.org/10.1016/0304-4076(86)90063-1

[3] Bollerslev, T. (1990). Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH model. *The Review of Economics and Statistics*, *72*(3), 498-505. http://dx.doi.org/10.2307/2109358

[4] Chong, T. T. L., Wong, Y. C., & Yan, I. K. M. (2008). International linkages of the Japanese stock market. *Japan and the World Economy*, *20*(4), 601-621. https://doi.org/10.1016/j.japwor.2007.06.004

[5] Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate generalized

autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics*, *20*(3), 339-350.

[6] Huang, B. N., Yang, C. W., & Hu, J. W. S. (2000). Causality and cointegration of stock markets among the United States, Japan and the South China Growth Triangle. *International Review of Financial Analysis*, *9*(3), 281-297. https://doi.org/10.1016/S1057-5219(00)00031-4

[7] Jeon, B. N., & Von Furstenberg, G. M. (1990). Growing international co-movement in stock price indexes. *Quarterly Review of Economics & Business*, *30*(3), 15-30.

[8] Laopodis, N. T. (2011). Equity prices and macroeconomic fundamentals: International evidence. *Journal of International Financial Markets*, *Institutions and Money*, *21*(2), 247-276. https://doi.org/10.1016/j.intfin.2010.10.006

[9] Li, Y., & Giles, D. E. (2015). Modelling volatility spillover effects between developed stock markets and Asian emerging stock markets. *International Journal of Finance & Economics*, *20*(2), 155-177. http://dx.doi.org/10.1002/ijfe.1506

[10] Liang, Q., Li, Z., & Hao, X.-C. (2015). The internationalization of Chinese stock market: Based on information spillover. *Economic Research Journal*, *50*(4), 150-164.

[11] Mohammadi, H., & Tan, Y. (2015). Return and volatility spillovers across equity markets in mainland China, Hong Kong and the United States. *Econometrics*, *3*(2), 215-232. http://dx.doi.org/10.3390/econometrics3020215

[12] Morana, C., & Beltratti, A. (2004). Structural change and long-range dependence in volatility of exchange rates: Either, neither or both?. *Journal of Empirical Finance*, *11*(5), 629-658. https://doi.org/10.1016/j.jempfin.2003.03.002

[13] Mulyadi, M. S., & Anwar, Y. (2012). Return and volatility spillover across USA and Europe (study of American and EU crisis period). *African Journal of Business Management*, *6*(19), 5916-5926. http://dx.doi.org/10.5897/AJBM11.420

[14] Nishimura, Y., Tsutsui, Y., & Hirayama, K. (2016). The Chinese stock market does not react to the Japanese market: Using intraday data to analyse return and volatility spillover effects. *The Japanese Economic Review*, *67*(3), 280-294. http://dx.doi.org/10.1111/jere.12086

[15] Pauler, D. K. (1998). The Schwarz criterion and related methods for normal linear models. *Biometrika*, *85*(1), 13-27. https://doi.org/10.1093/biomet/85.1.13

[16] Phylaktis, K., & Ravazzolo, F. (2005). Stock market linkages in emerging markets: Implications for international portfolio diversification. *Journal of International Financial Markets*, *Institutions and Money*, *15*(2), 91-106. https://doi.org/10.1016/j.intfin.2004.03.001

[17] Wang, Y., & Di Iorio, A. (2007). Are the China-related stock markets segmented with both world and regional stock markets?. *Journal of International Financial Markets*, *Institutions and Money*, *17*(3), 277-290. https://doi.org/10.1016/j.intfin.2005.12.001