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Influences of Quantitative Easing Policy on Volatility and Correlation among Asianfinancial Markets

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Abstract

This paper is to investigate the impacts of the U.S. quantitative easing (QE) policy on the volatility of stock and exchange markets and the dynamic correlation between stock and exchange markets in the Asian countries. Our empirical results show that the U.S. QE policy would ease the fluctuations caused by the 2008 global financial crises by reducing the volatility of stock and exchange markets in the Asian countries, especially during the QE1 period. Using the DCC GARCH model, we explore whether the QE policy made significant changes of the structure between stock and exchange markets. We find that the dynamic correlation coefficients of stock and exchange markets in Hong Kong, Malaysia, Taiwan and Thailand show a dramatic change during the period of financial crisis and QE policy. In particular, the stock indices rise more and the currencies appreciate more during the QE1.

Keywords: Quantitative Easing; Volatility; DCC-GARCH; Asian Markets; Dynamic Correlation
JEL classification: F31; G01

1. Introduction

Financial crisis in 2008 were caused byrapid growth of innovative financial products in the stock market, such as Collateralized Debt Obligation(CDO), Credit Default Swap(CDS) and Real Estate Investment trust(REIT), which were reorganized and sold through re-securitization packages. Such securities are characterized by diversification of assets, dispersed risks and higher returns than ordinary bonds, which were therefore favored by the general public. Under complicated layers of packaging, people were not aware of the risks behind the curtain.Among that time, the low interest rate policy and inflow of foreign capitals created a loosecredit condition. Also, the encouragement of consuming by financing, leading banks to make loans on someone who hadpoor credit ratings to earn higher interest spread. When these customers with bad credits couldn't afford payments, banks would auction their properties and reformbad debts into a new package, the most famous one was called Real Estate Investment Trust. As the time passed by, more and more bad debts dragged down the markets and triggered series of financial crisis, liked subprime mortgage crisis and bankruptcy of Lehman brothers, spreading to the global markets.

The financial crisis drove serious systematic risks, having weaken the whole industries, causing large outflow of capitals from the U.S. markets and made the interest rates continue to decline, eventually leading the economy into a severe liquidity trap. In order to rescue U.S economy, the Federal Reserve System launched a nonconventional monetary policy called "Quantitative Easing", targeting on continuously reducing interest rate and strengthening the liquidity of funds in the market.

The U.S.government announced the implementation of the first stage of QE (QE1) on November 25, 2008 and would last to March 2010 by purchasing $ 1.25 trillion of Mortgage Backed Securities, $ 300 billions of U.S. treasury bonds and $ 200 billions of institutional securities. Total amount was $ 1.75 trillion. The main purpose of first quantitative easing was to support and restore the current financial markets. After implementing QE1, major emerging economies in Asia started to recover from downturn, but the result was not as good as expected. As a result, the Fed announced the implementation of QE2 on November 3, 2010 and ended in June 2011, by injecting $600 billion in purchasing long-term bonds at a pace of about $100 billion per month.In order to increase exports and stimulate the employment rate, the QE2 focused on depressing the U.S. long-term interest rate and depreciatingthe U.S. dollar. However, this policy did not work as well, instead, rising in the oil price caused the world toface the pressure of inflation.

Although the economy had improved slightly after the implementation of QE2 in the United States, the unemployment rate was still 7.8%. There was still room for improvement in the overall economy. In September 2011, the Fed introduced a new policy called "Operation Twist", mainly to sell short-term bonds and buy long-term bonds at about $667 billion. Then in September 2012, the Fed announced QE3 which was set for indefinite period, with a monthly purchase of $40 billion in collateralized mortgages (MBS). Under quantitative easing policy, the economy began to climb up from the low tide, but the most concerning part was the unemployment rate which had been above 6.5%. To stimulate the market, the U.S. Fed announced on December 13, 2012 that it would extend the implementation of QE3. The Fed stated that it would purchase $45 billion of U.S. Treasury bonds each month additionally and aim at long-term high unemployment rate, housing markets and addition of bank lending. It was widely believed that the purpose of the United States in extending the QE3 policy was to reduce the impact of tightening fiscal policy. Because of economic recovery, in December 2013, the U.S. Fed announced the termination of QE and the reduction of $10 billion purchased each month, starting from next year 2014, which meant the ending of QE.

The United States as the world's largest economic entity, the successive implementation of QE had considerably impact on global markets. International monetary mechanism used the "dollar-standard" as the main body, implementing a nonconventional monetary policy would make depreciation of the U.S. dollar and the appreciation of the foreign currency, causing hot money to flow form U.S to international financial markets and brought large impacts on the stock and foreign exchange markets in various countries. The flooding funds were too difficult to control that the bubbles in housing and stock markets had been boosted. The prices of oil, gold and bulk goods had also risen, resulting in rising global inflationary pressures.

In this paper, we would like to examine the impact of QE policy on the Asian financial markets. Many Asian countries belong to export-oriented countries, andthe United States and Japan are their main trading partners. The large number of funds flew into the Asian markets after the implementation of QE policy would increase pressures on the appreciation of Asian countries' currencies.Too much inflow of capitals in a short period would rise the risk of internally inflation. Moreover, appreciation of the Asian currencies would inevitably affect their countries' export which was one of most important tools for economic growth.Hence, the QE policy of the United States did have a significant impact on the Asian economy.

Among all prices in financial markets, the stock price and foreign exchangerates can exhibit the information most efficiently. Therefore, this study focuses on discussing the impact of QE1, QE2, OT and QE3 on the stock and exchange markets in the Asian countries, including Hong Kong, South Korea, Malaysia, the Philippines, Singapore, Taiwan, Thailand, China, India and Indonesia.

We first examine the changes of volatility in the stock and foreign exchange markets before and after the QE periods. Did the QE policy announcement ease the fluctuation of 2008 global financial crisis or increase the volatility of financial markets in the Asian countries? Are there any significant changes in the structure of stock and exchange marketsupon the announcement of QE policy? Which country is the most influenced one facing the U.S. QE policy? In this paper, we would try to answer the above questions.

The main structures are as follows: section 2 reviews literatures. Section 3 describesresearch methods. Section 4addresses the data and empirical analysis to observe the changing volatility and linkage of stock markets between financial crisis and quantitative easing using DCC GARCH model. Sample countries include Hong Kong, South Korea, Malaysia, the Philippines, Singapore, Taiwan, Thailand, China, India and Indonesia. Section 5 concludes.

2. Literature Review

One strand of research focused on the impact of QE policy on asset prices. Wright (2012) used structural VAR model to examine the impacts of U.S.QEpolicy on the long term yields. Bekaert et al. (2013) indicates loosing monetary policy would reduce the risk aversion and uncertainty. Bauer and Neely (2014) found that the impacts of the U.S. QE on the international financial markets yields are indifferent from those of conventional monetary policies. Hausman and Wongwan (2011) examined the impacts of U.S. FOMC announcements on the financial markets in the 49 countries. They found the varying impacts can be attributed to the different exchange rate regimes adopted by countries. Stock indexes and interest rates in countries with less flexible exchange regimes respond more to U.S. monetary policy surprises. Their paper also finds the variation to be strongly related to each country's stock market capitalization relative to its GDP.

Recent studies have focused on the impact of the QE policy on the stock markets in advanced industrialized countries (Ueda, 2012a, 2012b, 2012c; Kontonikas, MacDonald, Saggu,2013; Ricci,2014).As the capital flows influence the global financial markets, studies have examined the effect of QE on the stock prices in developing markets. For example, Tillmann (2013, 2016) indicated that QE had significant effects on the financial conditions of emerging market economies and played a crucial role in explaining capital inflows and equity prices. Djigbenou, Park (2016) investigated the impacts of global liquidity on global imbalances in both advanced and emerging markets. Bali, Hajhoj, Basher, Ghassan (2015)used spillover models to show the volatility from US, Japan and EU to the emerging markets during 2000 and 2013. However, these studies do not produce uniform results on whether the QE policy would induce stock price inflation in emerging markets.

In this studies, we examine the QE impacts from the perspective of market volatility. Engle(1982) proposed an econometric model"Autoregressive Conditional Heteroskedasticity Model, ARCH Model" which depicted fluctuation characteristics of time series data. Since then, many models expanded the concept and investigated in volatilities, conditional co-variances and conditional correlations. For example, from ARCH Model to General ARCH, GARCH Model and from Multivariate GARCH, MGARCH Model to Multivariate Conditional Correlation Coefficients Matrix Model. This paper uses Dynamic Conditional Correlation Model (DCC) which is one of the Multivariate Conditional Correlation Coefficient Models.

3. Model

In this section, we first introduce the univariate ARCH model, then GARCH model, next moving to multivariate GARCH model. Finally, we would address DCC (dynamic conditional correlation) structure.

ARCH Model

Engle (1982) propose the ARCH (q) model, we will briefly introduce the situation when q = 1 and consider a stationary sequence as follows:

$$y_t = \mu + \varepsilon_t$$

$$h_t = a_0 + a_1 \varepsilon_{t-1}^2$$

$$\varepsilon_t | F_{t-1} \sim N(0, \sigma_t^2)$$

The first equation is mean equation and the second equation is variance equation.
$h_t = \sigma_t^2 = var(y_t | F_{t-1})$is conditional variance.
$F_{t-1} = \{y_{t-1}, y_{t-2}, \dots\}$ is the available information dataset for time t-1.

In order to meet the property of variation that is always greater than or equal to zero, we limit $a_0 > 0$ and $0 < a_1 < 1$, which means σ_t^2 will follow residual ε_{t-1} pattern of previous period, then we can predict fluctuations of time series. Comply with the above restrictions, the following qualities will be qualified at the same time:

- ARCH model is comprised by mean equation and variance equation.
- Conditional variance changes overtime.
- Volatility Clustering effect exists.
- Kurtosis of distribution is larger than 3.

We expect to explain the empirical nature of time series data through ARCH (1) model. If the ARCH (1) model fails to explain the correlation between ε_t^2, we need to expand the model to an ARCH (q) model as follows:

$$h_t = E[\varepsilon_t^2 | F_{t-1}] = a_0 + a_1 \varepsilon_{t-1}^2 + \cdots + a_q \varepsilon_{t-q}^2$$

s.t $a_0 > 0$and$0 < a_i < 1, \forall i \in [1, q]$

GARCH Model

Although ARCH model is simple, the order q needs to be large enough to fit well in practice, which easily leads to insufficient degree of freedom in estimation. Bollerslev (1985) used the ARMA concept to extend the ARCH model into Generalized Autoregressive Conditional Heteroskedasticity Model (GARCH).The most commonly used GARCH (1,1) model is as follows:

$$y_t = \mu + \varepsilon_t$$

$$h_t = a_0 + a_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$$

$$\varepsilon_t | F_{t-1} \sim N(0, \sigma_t^2)$$

Compare with ARCH (q) model, it only uses squared error prior to q period to estimate the current conditional variance. GARCH model considers squared error of each period in the past, by adding h_{t-1} into the equation to solvelagged terms of ARCH (q) model. While limiting all parameters to be positive and $a_1 + \beta_1 < 1$, the characteristics of dynamic fluctuations, clustering effects and thick-tailed properties can still be depicted. Although GARCH (1,1) is adequate for most time-series data, it is able to extend GARCH (1,1) to a higher order, that is GARCH (p, q), where p and q are the lagged terms. Following is the equation for h_t:

$$h_t = a_0 + \sum_{i=1}^{p} a_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j}$$

Multivariate GARCH Model

Correlation coefficients, variance and co-variance are good indicators in financial analysis, and we can understand the volatility, risk and correlation of assets' return by using these indices. But what kind of estimation is accurate? For example, if we calculate the unconditional variance from sample, we obtain average of volatility. In order to demonstrate rapid change in the real world, we can add dynamics into GARCH model. Besides, we can use Multivariate GARCH model to understand and interpret the real world interactions among cross-market commodities.

According to Silvennoinen et al. (2008), it classifies MGARCH model into four categories:

- Conditional Covariance Matrix Models such as VEC Model, Diagonal VEC Model and BKK Model
- Factor Models
- Conditional Variance and Correlation Models like Constant Conditional Correlation(CCC Model) and Dynamic Conditional Correlation (DCC Model)
- MGARCH models with nonparametric or semi-parametric method

This article focuses on the DCC model, we will describe it in detail at below.

Dynamic Conditional Correlation Model

CCC model of Bollerslev (1990) consider dynamic, but for the sake of simplicity, it assumes that the correlation coefficient is fixed. DCC model of Tse and Tsui (2002), Engle and Sheppard (2001) both correct the assumption in CCC that the correlation coefficients have to be constant. More further, Engle and Sheppard (2001) simplify estimation into two steps, while Engle (2002) generalize the DCC model. The model is set up as follows:

$$r_t|F_{t-1} \sim Multivariance\ Normal(0, H_t)$$

$$H_t \equiv D_t R_t D_t$$

DCC model assumes that the Filtered time series $r_t|F_{t-1}$of N assets obey multivariate normal distributions of $H_t$with mean zero and variant-covariant matrix. At the same time, the correlation coefficient matrix $R_t$is set to change with time, considering the dynamics of the correlation coefficient matrix.

- Step 1: Conditional variance estimation

Take univariate GARCH(1,1) for example, by estimating the conditional standard deviation $\sqrt{h_{it}}, \forall i \in [1, N]$of all markets, then we can obtain the conditional standard deviation of the main diagonal matrix model D_t. Details are as follows:

$$D_t = \begin{pmatrix} \sqrt{h_{1t}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{Nt}} \end{pmatrix}$$

Where $h_{it} = \alpha_{i0} + \alpha_{i1} \varepsilon_{t-1}^2 + \beta_{i1} h_{i,t-1}$

Because h_{it} are part of conditional variance, it must comply Stationary non-negativity constraints, that is, $a_{i1} + \beta_{i1} < 1$ and $h_{it} \geq 0$。

- Step 2: Correlation coefficient matrix estimation

Estimation of dynamic correlation coefficient matrix$R_t$by MGARCH model as follows:

$$Q_t = (1 - \lambda_1 - \lambda_2)\ \bar{Q} + \lambda_1 \epsilon_{t-1} \epsilon_{t-1}^T + \lambda_2 Q_{t-1}$$

$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$

$\epsilon_t = D_t^{-1} r_t$ is Standardized Residual

$\bar{Q} = T^{-1} \sum_{t=1}^{T} \epsilon_t \epsilon_t'$ is unconditional covariance of Standardized Residual, calculated by ϵ_t

Because $\epsilon_t \sim N(0, R_t)$, so $\bar{Q}$ is correlation coefficient matrix of r_t.

Q_t^* is demonstrated below:

$$Q_t^* = \begin{pmatrix} \sqrt{q_{11}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{q_{NN}} \end{pmatrix}$$

Diagonal elements of the correlation coefficient matrix need to be 1, but the matrix Q_t, calculated by MGARCH (N, M), is not necessarily equal to 1. After multiplying both sides of Q_t by Q_t^{*-1} to get R_t with diagonal elements equal to 1. Q_t is the weighted average of positive definite $\bar{Q}$, positive semidefinite $\epsilon_t \epsilon_t'$ and positive definite Q_{t-1}, thence Q_t and R_t must be positive definite. The correlation coefficient matrix is defined as a real, symmetric, semi-positive definite matrix with diagonal elementsequal to 1. Since the elements $\rho_{ijt=} q_{ijt} / \sqrt{p_{ii} q_{jj}}$ of matrix R_t, estimated through the second phase, satisfyingthe definition of the correlation coefficient matrix, we can visualize the matrix R_t as a dynamic correlation coefficient matrix.

4. Data and Empirical Analysis

4.1 Data

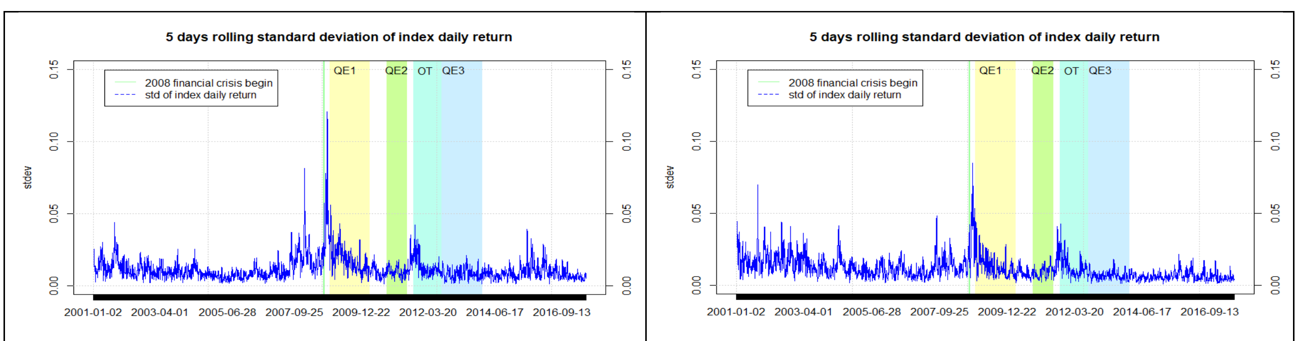
The sample countries analyzed in this study are mainly the Asian countries, include Hong Kong, South Korea, Malaysia, the Philippines, Singapore, Taiwan, Thailand, China, India and Indonesia. Data types contain closing price of major indices in each country and the foreign exchange rates. We use both daily and monthly data in our models between 2001/01/02 to 2017/06/30 from Data Stream.

4.2 Empirical Analysis

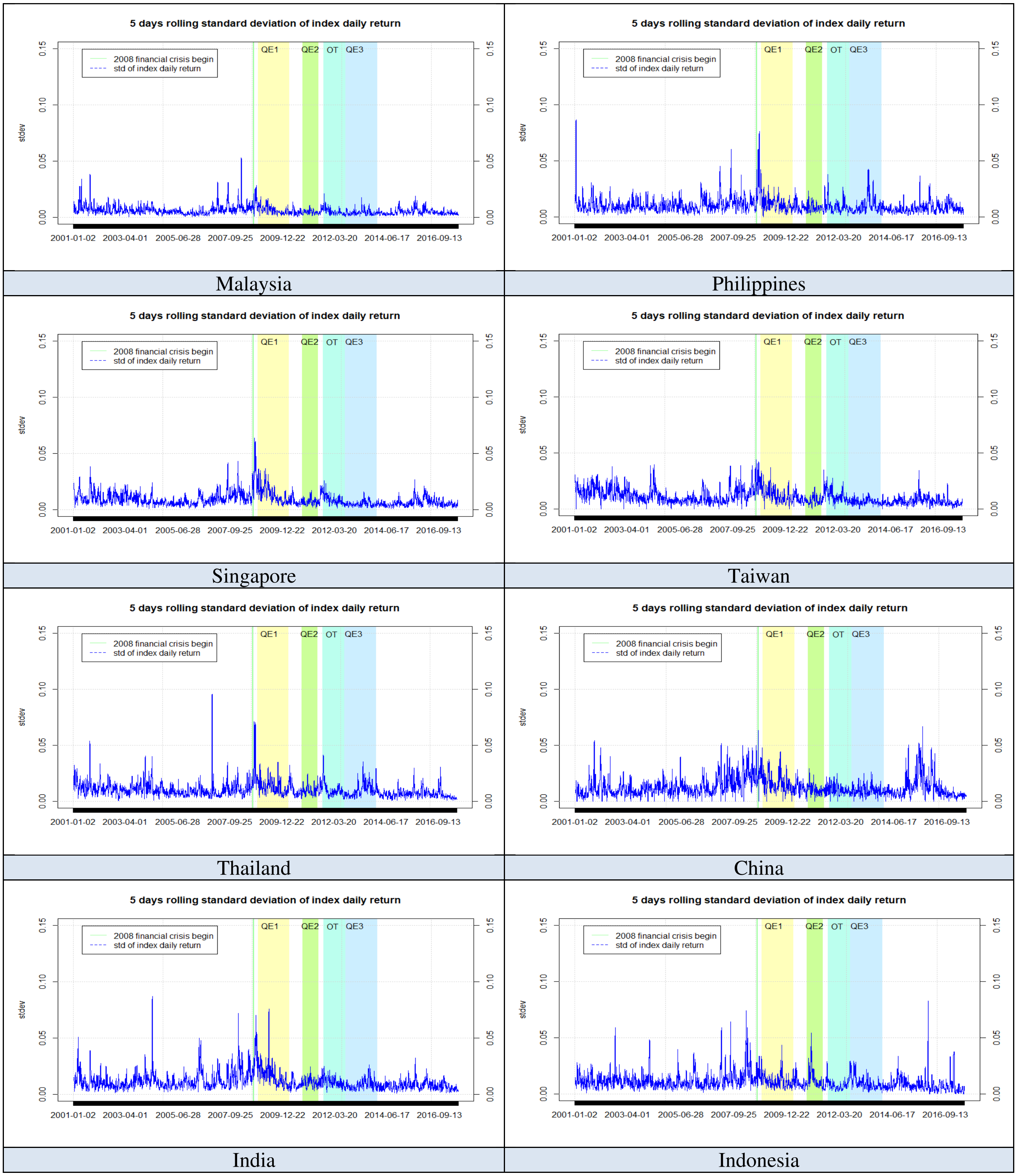
4.2.1 The Volatility of Stock Market Returns in the Asian Countries

Figure 1 shows the rolling volatility of the stock returns in Hong Kong, South Korea, Malaysia, the Philippines, Singapore, Taiwan, Thailand, China, India and Indonesia. The sample period is from 2001/01/02 to 2017/06/30 covering the execution of QE1, QE2, OT, and QE3 in the U.S. respectively.

Figure 1: Comparison of the volatility on Asian countries' stock returns



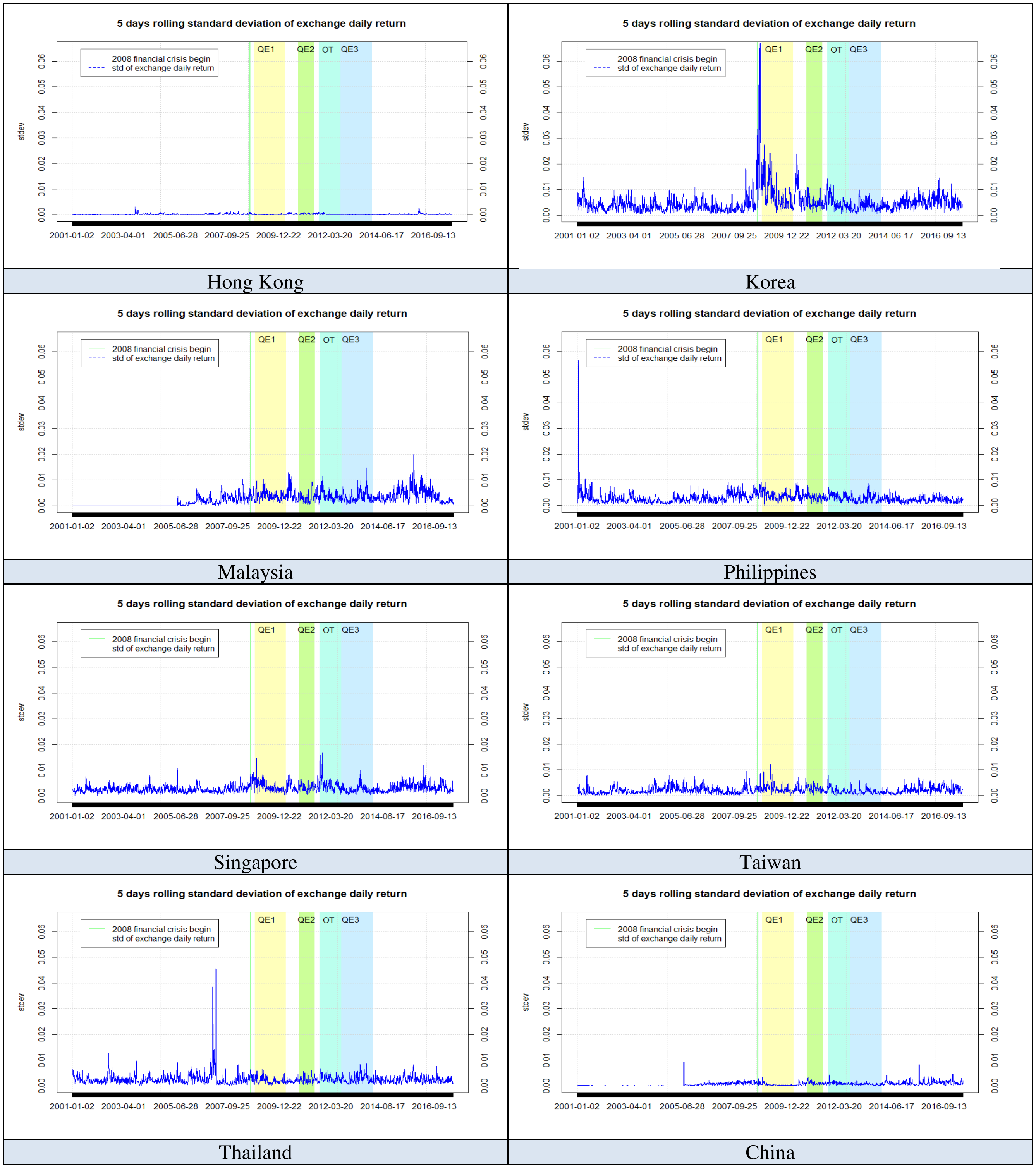
Hong Kong	Korea

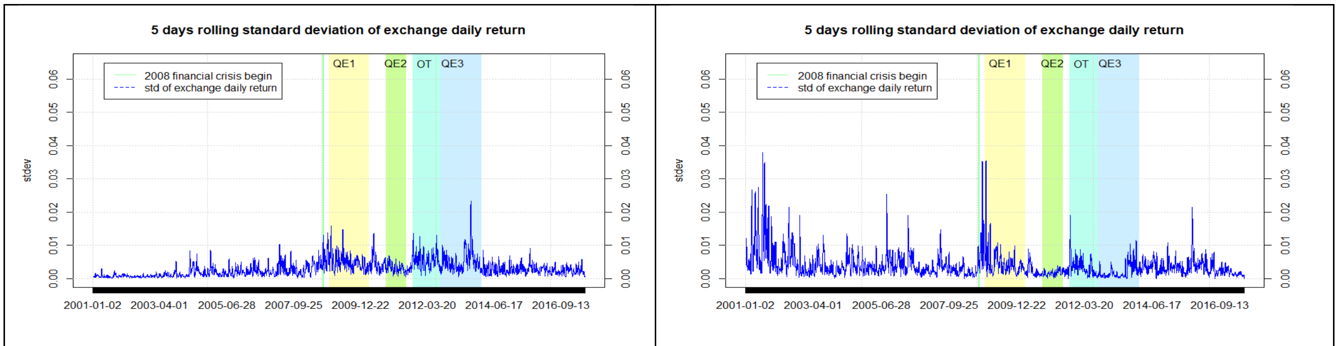


From the figure, we can see that after the bankruptcy of Lehman Brothers, which triggered the global financial crisis, the volatility of stock markets in all countries soared sharply. Hong Kong and South Korea which have the higher linkage with the U.S. stock market, have the most dramatic changes, exhibiting standard deviation of stock returns about 10%. The impact on Taiwan is relatively small comparing with other countries. The standard deviation of the stock return is about 5%. However, since the announcement of quantitative easing, the volatility of stock market in all Asian countries has been declining. The effect is especially significant during the QE1 periods.

4.2.2 The Volatility of Foreign Exchange Market Returns in the Asian Countries

Figure 2: Comparison of the volatility on Asian countries' exchange returns





India	Indonesia

Figure 2 shows the rolling volatility of the exchange rate returns in the Asian markets. From the figure, we can see the fluctuations of exchange rate returns in Hong Kong and China are much smaller than the other countries due to the adopted limited flexibilityexchange rate regime. The most affected country is still South Korea. After the implementation of quantitative easing, the volatility in the currencies of all countries has obviously declined. The same phenomenon occurs in the stock market, and QE1 is particularly evident. The difference between stock market and exchange rate is that the volatility in the stock market is much bigger than in the foreign exchange market in most countries, only South Korea and Indonesia have greater volatility in foreign exchange markets.

4.2.3 Estimated Result of DCC GARCH Model

$$R_{S,A,t} = \alpha_{1,0} + \alpha_{1,1}R_{S,A,t-1} + \beta_{1,1}m_{A,t-1} + \left(\beta_{1,2} + \beta_{1,2}^{d}D_t\right)m_{US,t-1} + \left(\beta_{1,3} + \beta_{1,3}^{d}D_t\right)m_{EU,t-1} + (\beta_{1,4} + \beta_{1,4}^{d}D_t)m_{JP,t-1} + \varepsilon_{\ t,stock} \quad (1)$$

$$R_{E,A,t} = \alpha_{1,0} + \alpha_{1,1}R_{E,A,t-1} + \beta_{1,1}m_{A,t-1} + \left(\beta_{1,2} + \beta_{1,2}^{d}D_t\right)m_{US,t-1} + \left(\beta_{1,3} + \beta_{1,3}^{d}D_t\right)m_{EU,t-1} + (\beta_{1,4} + \beta_{1,4}^{d}D_t)m_{JP,t-1} + \varepsilon_{\ t,stock}$$

We follow the above mean equation to estimate DCC GARCH model.$R_{S,A,t}$ refers to the return of stock index $R_{S,A,t} = \ln\left(R_{S,A,t}\right) - \ln\left(R_{S,A,t-1}\right)$ and $R_{E,A,t}$ refers to the return of exchange rate $R_{E,A,t} = \ln\left(R_{E,A,t}\right) - \ln\left(R_{E,A,t-1}\right)$. $m_{A,t}$ is the growth rate of monetary base in Asian countries ($m_{A,t}$=ln($m_{A,t}$) − ln ($m_{A,t-1}$)),$m_{US,t}$ is the growth rate of monetary base in the United States ($m_{US,t}$ =ln($m_{US,t}$) − ln ($m_{US,t-1}$)), $m_{EU,t}$ and $m_{JP,t}$ each represents the growth rate of monetary base in euro zone and Japan. This model considers the relationship between stock and exchange markets in various countries when the U.S. , European Union and Japan implement their quantitative easing policy, respectively. Hence, we can use this model to capture the dynamic correlation coefficient and volatility clustering effects, to explore the impact of quantitative easing on Asian stock and exchange markets.

Table 1: Mean equation estimation

Stock (RA,t)	$R_{A,t-1}$	$m_{A,t-1}$	$m_{US,t-1}$	$m_{US,t-2}$	$m_{EU,t-1}$	$m_{US,t-1}^{d}$	$m_{EU,t-1}^{d}$	$m_{JP,t-1}^{d}$
Hong Kong	0.1014	0.3517**	-0.4856**	-0.3441	0.2019**	0.4071	0.3197	-0.12147
Korea	0.0142	0.0217	-0.5962**	-0.2974	0.0913	0.5916*	0.2808	0.0063
Malaysia	0.0061	-0.1076	-0.4198*	-0.0718	0.2880**	0.4686*	0.0196	-0.2358*
Philippine	0.0028	-0.0391	-0.6887*	-0.0422	0.2321	0.5882	0.0029	-0.1983
Singapore	0.1551*	-0.103	-0.3475	-0.3128*	0.2184*	0.4258	0.3355	-0.082
Taiwan	-0.0273	0.1132	-0.2925	-0.2888	0.1131	0.2532	0.1218	-0.0808
Thailand	0.0859	0.0554	-0.841**	-0.2166	0.1049	0.9634**	0.1396	-0.1217
China	0.038	0.4096**	-0.3524	-0.0407	-0.1985	0.5659	-0.0415	0.2193
India	0.0166	0.0128	-0.7278**	-0.2147	0.1226	0.7484*	0.2169	-0.1295
Indonesia	0.178	0.0237	-0.7167*	-0.2678	0.3413*	0.562	0.1299	-0.2409
Exchange	$R_{A,t-1}$	$m_{A,t-1}$	$m_{US,t-1}$	$m_{US,t-2}$	$m_{EU,t-1}$	$m_{US,t-1}^{d}$	$m_{EU,t-1}^{d}$	$m_{JP,t-1}^{d}$

Stock (RA,t)	$R_{A,t-1}$	$m_{A,t-1}$	$m_{US,t-1}$	$m_{US,t-2}$	$m_{EU,t-1}$	$m^d_{US,t-1}$	$m^d_{EU,t-1}$	$m^d_{JP,t-1}$
(RA,t)								
Hong Kong	-0.0652	0.0019	-0.0084**	0.0034	-0.0037	0.0054	-0.0034	-0.0014
Korea	-0.0426	0.0086	-0.0485	-0.0597	-0.0001	-0.081	0.0452	-0.0078
Malaysia	0.0606	-0.0044	0.0450*	0.0046	-0.0134*	-0.1221*	0.0408	0.0598
Philippine	0.1072	-0.0188	0.1082**	-0.0122	-0.0688**	-0.1491**	0.011	0.0315
Singapore	-0.0253	0.0116	0.0781	0.0177	-0.0319	-0.0845	0.0328	0.037
Taiwan	0.2034**	-0.0423*	0.029	0.0496	0.0163	-0.0591	-0.0449	-0.0631
Thailand	0.1475*	-0.012	0.1056**	0.031	-0.0199	-0.1118*	0.0113	-0.0076
China	0.4940**	0.0066	0.0009	-0.0028	-0.0025	0.0042	0.0056	-0.0079
India	0.0951	-0.0211	0.0982	-0.0325	-0.0453	-0.0874	0.0637	0.007
Indonesia	0.0211	0.0006	0.3358**	0.0429	-0.0774	-0.4158**	-0.0123	0.0499
*10% significant / ** 5% significant								

We separate the sample into two periods using the announcement date of QE1 on 2008/11/25, to understand the influence of monetary policy before and after the unconventional QE policy. From table 1, we can see the different impacts on stock and exchange markets of Asian countries, also the different sign of coefficients between $m_{US,t-1}$and $m^d_{US,t-1}$.

The table above shows the effect of monetary base growth of the United States, European Union and Japan on Asian stock and exchange markets before and after the announcement of quantitative easing policy. $\beta_{1,2}$ and $\beta^d_{1,2}$ are the coefficients of the U.S.monetary base variable and itsdummy variable. The cutting point of the dummy variable is 2008/11, $D_t = 0$ represents the time before November and the otherwise is $D_t = 1$ which means the time after November. Before the announcement of quantitative easing policy in the United States, in the stock compensation equation, the growth rate of the United States monetary base has a negative impact on the stock price returns of all countries. After the announcement, the coefficients of Malaysia, Singapore, Thailand, China and India turn from negative into positive, in line with the intuition of economy.

In the exchange rate equation, we adopt direct exchange rate. Prior to 2008/11, the U.S. monetary base has positive correlations between Asian countries' exchange rate (The U.S. monetary base increases will cause the depreciation of the Asian currencies). But the correlation turns negative after December (The U.S. monetary base increases will lead to the appreciation of the Asian currency), indicating that Asian countries' currencies appreciate after the announcement. The coefficients of Malaysia, Philippines, Singapore, Taiwan, Thailand and Indonesia turn from negative into positive.

Next, we show the variance equation estimation.

$$h_t = \alpha_0 + \alpha_1 \varepsilon^2_{,t-1} + \beta_1 h_{,t-1} \quad (2)$$

Equation (2) is the variance equation of GARCH (1,1). Table2 shows the estimated coefficients. In the stock market and exchange rate equations, almost all β_1s are 5% significant, implying volatility does have a clustering effect.

Table 2: Variance equationestimation

Stock(RA,t)	α_1	β_1	Exchange(RA,t)	α_1	β_1
Hong Kong	0.1895**	0.6749**	Hong Kong	0.0115	0.9685**
Korea	0.0835**	0.9083**	Korea	0.5938**	0.0637
Malaysia	0.0682	0.8836**	Malaysia	0.2905**	0.7084**
Philippine	0.0518	0.8909**	Philippine	0.0878**	0.8863**
Singapore	0.3539	0.5334	Singapore	0.0997	0.8324**
Taiwan	0.1489**	0.8303**	Taiwan	0	0.9990**
Thailand	0.2131*	0.5804**	Thailand	0.000004	0.9981**
China	0.2352*	0.7048**	China	0.3477*	0.6512**
India	0.0722**	0.9148**	India	0.2152*	0.7264**
Indonesia	0.074	0.9029**	Indonesia	0.4507**	0.3992**
*10% significant / ** 5% significant					

4.2.4 Dynamic Correlation Coefficient between Stock and Exchange Markets in Asian Countries

Next, we estimate DCC model. Below is the equation for the DCC model

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$$
$$Q_t = (1 - \lambda_1 - \lambda_2)\,\bar{Q} + \lambda_1 \epsilon_{t-1} \epsilon_{t-1}^T + \lambda_2 Q_{t-1} \quad (3)$$

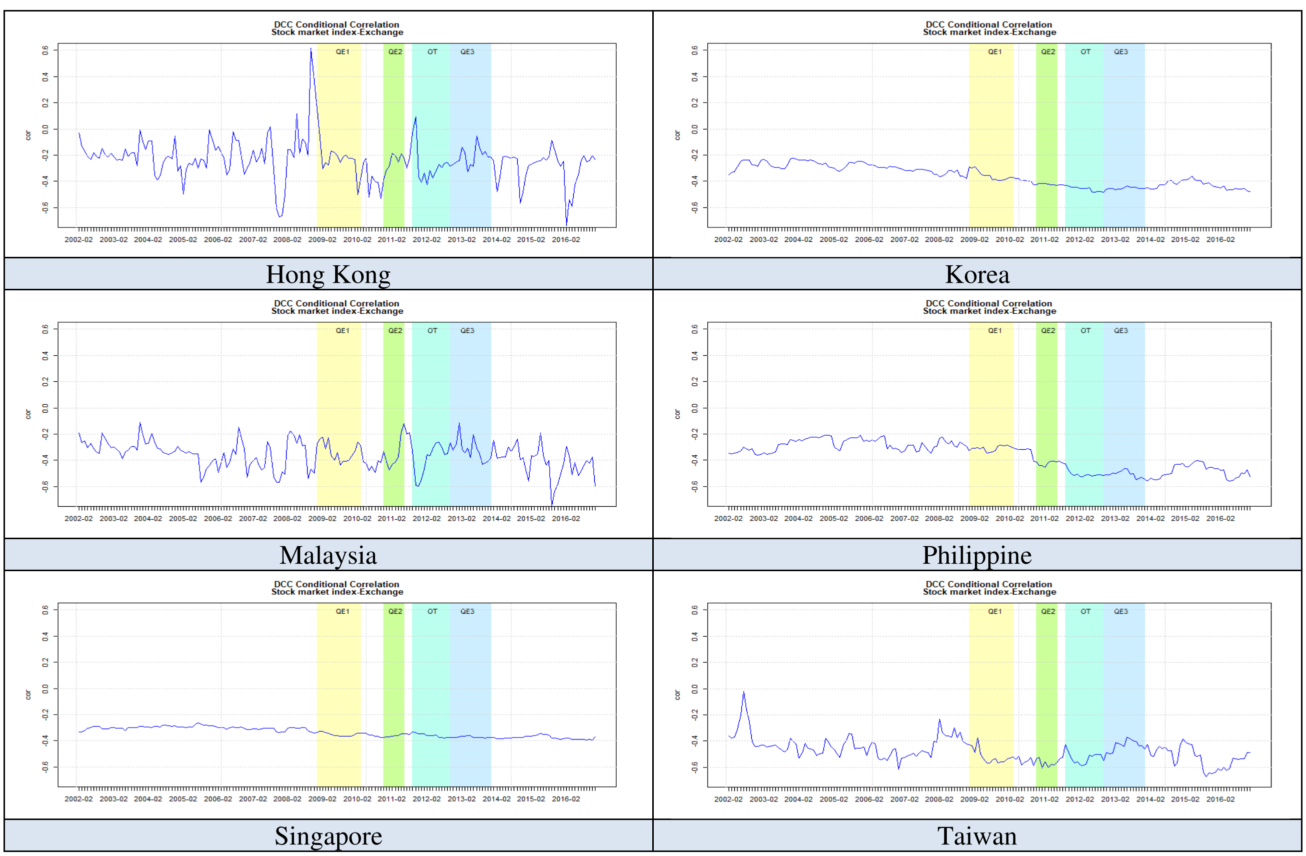
λ_1 and λ_2 are the estimated dynamic correlation coefficient of DCC GARCH model. Table 3 shows the estimated coefficients. Philippines, Thailand and India have 5% significant. All countries have at least one parameter over 5% significant.

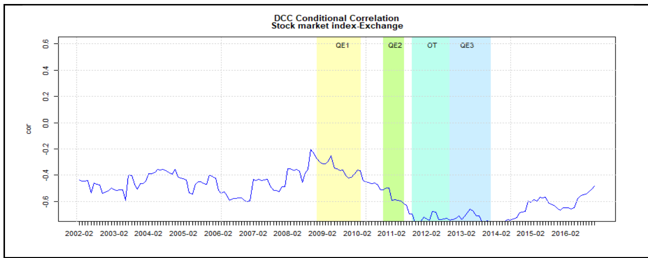
Table 3: Dynamic correlation coefficient estimation

	λ_1	λ_2
Hong Kong	0.177**	0.3706
Korea	0.0201	0.9643**
Malaysia	0.1460**	0.4979*
Philippine	0.0311**	0.9570**
Singapore	0.0093	0.9704**
Taiwan	0.0778*	0.7786**
Thailand	0.0605**	0.9167**
China	0	0.8863**
India	0.0314**	0.9609**
Indonesia	0.0184	0.8820**
*10% significant / ** 5% significant		

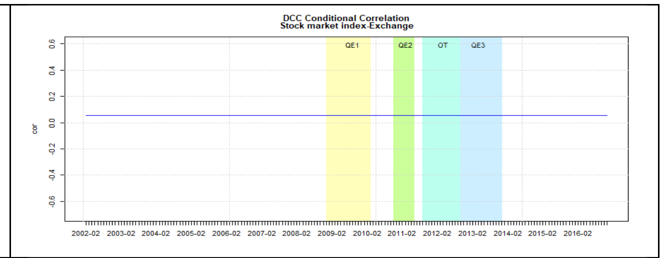
Figure 3 exhibits the estimated dynamic correlation coefficients between stock and exchange rate returns over sample periods by the DCC-GARCH. The study wants to investigate whether the structure of Asian countries' stock and exchange markets have changed after the QE policy.

Figure 3: Dynamic correlation coefficients of Asian countries' stock and exchange markets

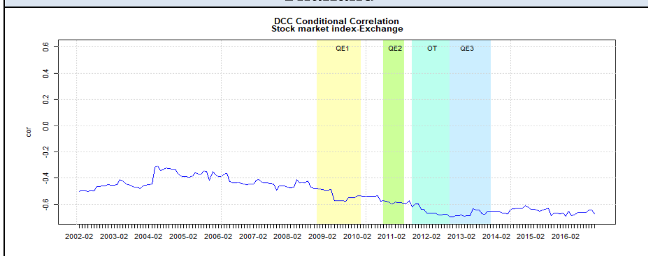




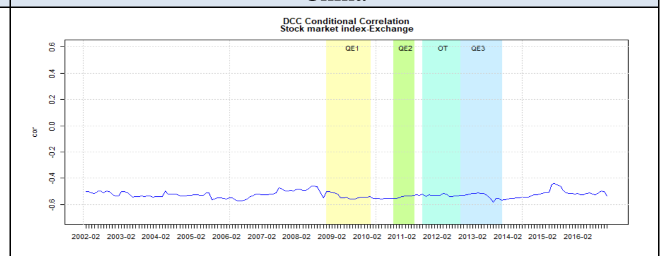
Thailand



China



India



Indonesia

From the figure, we can see that based on the coordinated scale of Hong Kong, the correlation coefficients of Hong Kong, South Korea, Malaysia, Thailand and Taiwan varies greatly. During the 2008 global financial crisis period, the dynamic correlation significantly increases, implying that lower stock returns comes with currency appreciation. Since QE1 implemented, the correlation coefficients between stock returns and exchange changes in almost all countries decrease sharply except for China. The dynamic correlation for China remains the same for all sample periods. The decreasing correlation coefficient indicates that the stock returns move the same direction as the foreign exchange rates (Increases in stock also comply with appreciation of its currency). After QE1, the effects become smaller.

5. Conclusion

The purpose of this study is to investigate whether the four quantitative easing implementations in the United States affect the volatility of stock and exchange markets in the Asian countries and whether it causes the structural changes between stock and exchange markets. According to our empirical results, the U.S. QE policy would ease the fluctuations caused by financial crises by reducing the volatility of stock and exchange markets in the Asian countries, especially during the QE1 period. Using the DCC GARCH model, we explore whether QE policy made significant changes of the structure between stock and exchange markets. We find that the correlation coefficient of stock and exchange markets in Hong Kong, Malaysia, Taiwan and Thailand have a dramatic change during the period of financial crisis and QE policy. In particular, the stock indices rise more and the currencies appreciate more during the QE1.

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