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Dynamic Correlation Analysis of Asian Stock Markets

Jae-Kwang Hwang

Abstract This paper examines the stock market linkages within the Asia-Pacific region and between Asian markets and the U.S. market over the period of January 2000 to June 2010, employing the dynamic conditional correlation GARCH model. Our results show that there exist very high correlations among the stock markets during the 2008 financial crisis. Therefore, consistent with the finding in literature, there are no diversification benefits during the financial crisis. However, our results show that there are still substantial opportunities for global investors to improve the risk-return performance between China and other markets during the sample period. In addition, we find evidence that the U.S. market significantly affects the stock markets in the Asia-Pacific region. Using T-GARCH model, there is a strong evidence of an asymmetric effect on conditional variance except stock markets in China and Malaysia.

Keywords Stock market correlation · DCC model · T-GARCH · The 2008 financial crisis

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Introduction

There are many empirical studies on the linkages and direction of information flow among the stock markets around the globe (Forbes and Rigobon 2002; Syriopoulos 2007; Gilmore et al. 2008; Bekaert et al. 2009; You and Daigler 2010). It is well documented that there are stronger financial co-movements among the stock markets around the world. That is mainly due to the globalization process, abolishment of the restrictions in capital movements, and the improvement of telecommunications skills.

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Capital market integration or contagion has been one of the important issues in international finance that interest both international investors and policymakers. In fact, knowing the level of market integration allows investors to improve their portfolio performance through diversification with less correlated assets, and helps the policymakers to plan adequate policies for internal capital markets in the event of global economic and financial crisis.

Turgutlu and Ucer (2010) reported that most of the emerging markets have a significant dependence with the U.S. stock markets and international stock markets are significantly interdependent, which leaves a smaller chance to benefit from international portfolio diversification. Gklezakou and Mylonakis (2010) examined ten global stock markets to figure out the effect of economic crisis on the stock markets. They showed the empirical findings that the recent economic crisis increased their correlation, thus tightening the existing links. Arouri and Nguyen (2009) studied the time-varying features of stock market correlations in the Gulf area. There is an insignificant correlation between the Gulf stock markets and the world market, thus there is still room for international investors to get the benefit from international diversification in Gulf markets. Huang (2007) studied the country-level evidence of global pricing for nine developed countries from 1980 to 2004. He showed that large-cap stocks have significant co-movements across countries, but small-cap stocks do not have significant correlations.

This study investigates whether linkages exist among stock markets of Australia, China, Hong-Kong, Japan, Korea, Malaysia, New Zealand, Singapore, Taiwan, and the U.S. by using weekly data. The U.S. market is selected because it has long been seen as the leader of the global financial markets. This study covers the most recent period of January 2000 to June 2010 using weekly data and investigates the following hypotheses. First, is there co-movement between Asian markets and U.S. markets? Are stock market correlations time-varying? Second, how do the returns of the U.S. market influence over the returns of the Asian markets? Third, do good news and bad news have different impacts on predicting future volatility? This paper employs simple correlation coefficients, the DCC model, and the GARCH model to answer the questions.

Major findings can be summarized as follows. First, we find strong co-movements among stock markets between Asian markets and U.S. market during the 2008 financial crisis period. However, Chinese market appears to be only weakly correlated to the rest of the markets over the sample period. Second, we find evidence that the U.S. market significantly affects the stock markets in Asia-Pacific region. Third, there is a strong evidence of an asymmetric effect on conditional variance in all of the stock markets except Chinese and Malaysian markets.

The remainder of this paper proceeds as follows. The next section discusses the data and statistics of stock returns. The section following that describes methodologies and empirical findings. Conclusions and suggestions for further research are given in the final section.

Data and Preliminary Analysis

The data used in this study are weekly observations from Yahoo Finance stock market index data for Asian-Pacific and U.S. markets. The observation period ranges from

January 2000 to June 2010. We choose to work with weekly data to alleviate problems associated with non-synchronous trading resulting from the fact that not all markets are open during the same hours of the day. The missing data arising from holidays and special events are assumed to be the average of the recorded previous price and the next price. The specific markets are Australia (ASX All Ordinaries), China (Shanghai Composite), Hong-Kong (Hang Seng), Japan (Nikkei 225), Korea (KOSPI), Malaysia (Kuala Lumpur Composite), New Zealand (NZ All share), Singapore (Straits Times), Taiwan (SE weighted), and the U.S. (S&P 500). Figure 1 plots the stock returns for each market over the sample period. Weekly stock returns are obtained by taking the logarithmic difference of the weekly stock index. That is, $r_t=(\log P_t-\log P_{t-1})$. As we expected, most of the stock markets have lost more than 20% in returns during the 2008 financial crisis except for Taiwan and Malaysian markets.

Table 1 shows sample statistics of the stock returns. We find that seven of ten markets have positive weekly mean returns during the sample period. The U.S., Japan, and Taiwan have negative weekly mean returns. The average returns range from −0.118% (Japan) to 0.101% (Korea). Standard deviations range from 1.910% (New Zealand) to 3.980% (Korea). In terms of relative risk-return trade, the highest Sharpe ratio is for Malaysia, followed by Australia and China.

The skewness and kurtosis measures imply that the rate of return is not likely drawn from a normal distribution. As reported in the table, the excess kurtosis signifies that the distribution has fat tails, and all markets show evidence of fat tails. Also, the Jarque-Bera test strongly rejects the normality of the stock returns series.

Table 2 provides the correlations among the returns. Although the returns from the ten countries in the sample are correlated, China stands out in that its returns appear to be only weakly correlated to the rest. The highest correlation is between Singapore and Hong-Kong (0.7527) followed by Australia and New Zealand (0.7178) and then Australia and Singapore (0.6981). The lowest correlation is between China and the U.S. (0.0417), China and Japan (0.1622), and China and Korea (0.1712). China has very low correlations with all of the markets, thereby providing the opportunity for diversification benefits. The U.S. and Japanese markets have high correlations with rest of the markets except China, Malaysia, and Taiwan.

Empirical Methodology and Results

DCC-GARCH Model

This section employs the DCC-GARCH model (Engle 2002) to measure time-varying conditional correlations among various stock markets. This model provides a useful way to describe the dynamic evolution of a large correlation matrix over time, which allows us to detect dynamic investor behavior in response to news and innovations. In addition, the DCC-GARCH model is appropriate to examine possible contagion effects due to herding behavior in emerging markets during financial crisis. The stock market returns are assumed as the following demanded process:

$$\begin{aligned} r_t &= \mu + \varepsilon_t, \\ \varepsilon_t/\Omega_{t-1} &\sim N(0, H_t) \end{aligned} \tag{1}$$

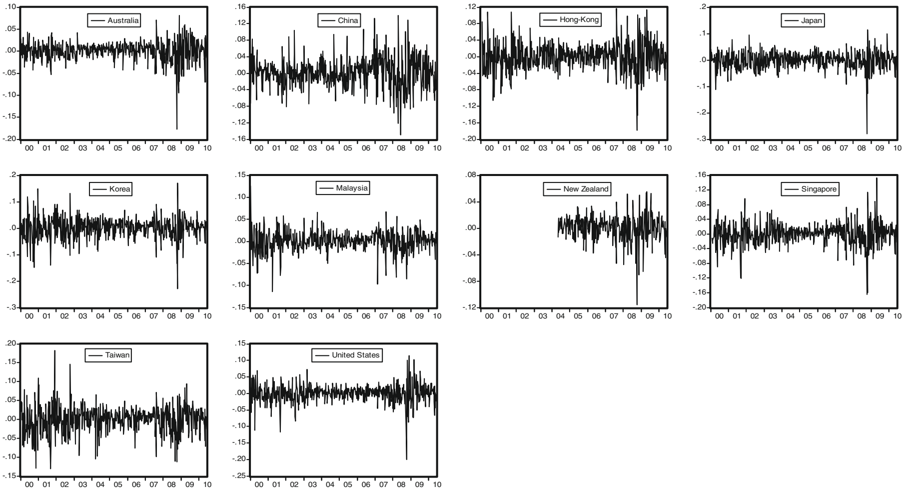

Fig. 1 Stock returns. Notes: Weekly stock returns (January 2000–June 2010). All stock returns are the first differences of natural logarithms of the stock indices

where r_t is a n×1 vector of stock return index and ε_t is a n×1 vector of zero-mean residuals conditional on the information at time period t-1, with N multivariate normal distribution. The multivariate conditional variance is specified as:

$$H_t = D_t R_t D_t \tag{2}$$

Where D_t is (n×n) diagonal matrix of time-varying standard deviations obtained from univariate GARCH (1,1) specification with $\sqrt{h_{ii,t}}$ on the ith diagonal, i=1,2,3, …,n. R_t is the n×n time-varying correlation matrix. Thus,

$$R_t = (\mathrm{diag}(Q_t))^{-1/2} Q_t (\mathrm{diag}(Q_t))^{-1/2} \tag{3}$$

Where $(\mathrm{diag}(Q_t)^{-1/2} = \mathrm{diag}\left(1/\sqrt{q_{11,t}}, \ldots, 1/\sqrt{q_{nn,t}}\right)$.

The DCC specification is given as:

$$\begin{gathered} h_{ij,t} = \rho_{ij,t}\sqrt{h_{ii,t}}\sqrt{h_{jj,t}} \\ \rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}}\sqrt{q_{jj,t}}} \text{ and} \\ q_{ij,t} = \overline{\rho}_{ij}(1-a-b) + bq_{ij,t-1} + a\eta_{i,t-1}\eta_{j,t-1} \\ i, j = 1, 2, \ldots, n, \text{ and } i \neq j. \end{gathered} \tag{4}$$

where $q_{ij,t}$ (Q_t) is the n×n time-varying covariance matrix of the standardized residuals $\eta_{i,t} = \varepsilon_t/\sqrt{h_{ii,t}}, \overline{\rho}_{ij}$ is the unconditional correlations of $\eta_{i,t}\eta_{j,t}$ and a, b are nonnegative scalar parameters satisfying a+b<1.

As proposed by Engle (2002), the log-likelihood of the estimators can be written as:

$$L(\theta) = -\frac{1}{2}\sum_{t=1}^{T}\left[\left(n\log(2\pi) + \log|D_t|^2 + \varepsilon_t' D_t D_t \varepsilon_t\right) + \left(\log|R_t| + \eta_t' R_t \eta_t - \eta_t' \eta_t\right)\right] \tag{5}$$

Where n is the number of equations, T is the number of observations and θ is the vector of parameters to be estimated. The first part of the likelihood function is the

Table 1 Summary statistics

	AU	CH	HK	JP	KR	MA	NZ	SG	TW	US
Mean	0.00067	0.00092	0.00036	−0.00118	0.00101	0.00083	0.00040	0.00034	−0.00039	−0.00056
Std. Dev.	0.02208	0.03562	0.03425	0.03255	0.03980	0.02297	0.01910	0.02995	0.03559	0.02758
Sharpe ratio	0.03034	0.02582	0.01051	−0.03625	0.02538	0.03613	0.02094	0.01135	−0.01096	−0.02030
Maximum	0.08101	0.13944	0.11718	0.11449	0.17031	0.12590	0.05480	0.15320	0.18318	0.11355
Minimum	−0.17710	−0.14897	−0.17815	−0.27884	−0.22928	−0.11448	−0.11637	−0.16468	−0.13081	−0.20083
Skewness	−1.36242	0.06754	−0.24492	−1.30196	−0.51819	−0.41484	−1.03535	−0.51635	−0.13532	−0.87750
Kurtosis	11.7721	4.59949	5.21737	12.7865	6.49328	6.86448	8.16232	8.04480	5.32256	9.90450
Jarque-Bera	1912.52	58.4035	116.025	2324.61	300.948	354.112	411.209	597.728	123.931	1150.38
Observations	544	544	540	544	544	544	319	541	544	544

AU Australia, *CH* China, *HK* Hong-Kong, *JP* Japan, *KR* Korea, *MA* Malaysia, *NZ* New Zealand, *SG* Singapore, *TW* Taiwan, *US* United States

Table 2 Unconditional correlation matrix

	AU	CH	HK	JP	KR	MA	NZ	SG	TW	US
AU	1.000000	0.183984	0.677982	0.675692	0.566826	0.413416	0.717847	0.698112	0.470903	0.638879
CH	–	1.000000	0.248098	0.162236	0.171294	0.214090	0.213284	0.178635	0.199925	0.041681
HK	–	–	1.000000	0.627013	0.642861	0.464297	0.524060	0.752678	0.543814	0.573373
JP	–	–	–	1.000000	0.622301	0.378842	0.572916	0.647312	0.496029	0.546401
KR	–	–	–	–	1.000000	0.370621	0.451159	0.650606	0.613716	0.516385
MA	–	–	–	–	–	1.000000	0.381195	0.497641	0.414075	0.293507
NZ	–	–	–	–	–	–	1.000000	0.544507	0.439987	0.556809
SG	–	–	–	–	–	–	–	1.000000	0.576720	0.551995
TW	–	–	–	–	–	–	–	–	1.000000	0.376497
US	–	–	–	–	–	–	–	–	–	1.000000

AU Australia, *CH* China, *HK* Hong-Kong, *JP* Japan, *KR* Korea, *MA* Malaysia, *NZ* New Zealand, *SG* Singapore, *TW* Taiwan, *US* United States sum of the individual GARCH likelihoods and can be maximized in the first step over the parameters in D_t. In the second step the correlation coefficients can be estimated given the parameters estimated in the first step from the maximization of the second part of the likelihood function.

Conditional correlations obtained from the DCC-GARCH model between U.S. and Asian markets are plotted in Fig. 2. The correlations between the Asian markets are relatively high, except the correlation with China. The average time-varying correlations are quite similar to the unconditional correlation reported in Table 2. However, the figures show that the pair-wise conditional correlations incremented dramatically for all Asian financial markets during the 2008 financial crisis. The 2008 financial crisis period is defined from failure of Fannie Mae and Freddie Mac (September 7, 2008) through the first repayment of Troubled Asset Relief Program (March 31, 2009).

The correlations rise very quickly and reach their peak during the second half of 2008. Then, the conditional correlations decline and are steady after the peak. As the financial crisis evolved and prices of most risky assets have declined due to the contagion effect spreading through various channels, investors began to rebalance their portfolios from risky to risk-free assets. This financial behavior can cause sudden increases in correlations between international stock market returns. As a result, the analysis of the pattern of the conditional correlations provides evidence in favor of contagion effects due to herding behavior in Asian financial markets during the 2008 financial crisis period.

TAR-GARCH Model

Financial researchers and practitioners have used a GARCH specification for modeling the dynamics of the second moment of stock return distributions over time. The advantage of this specification is its ability to capture persistence in the volatility and

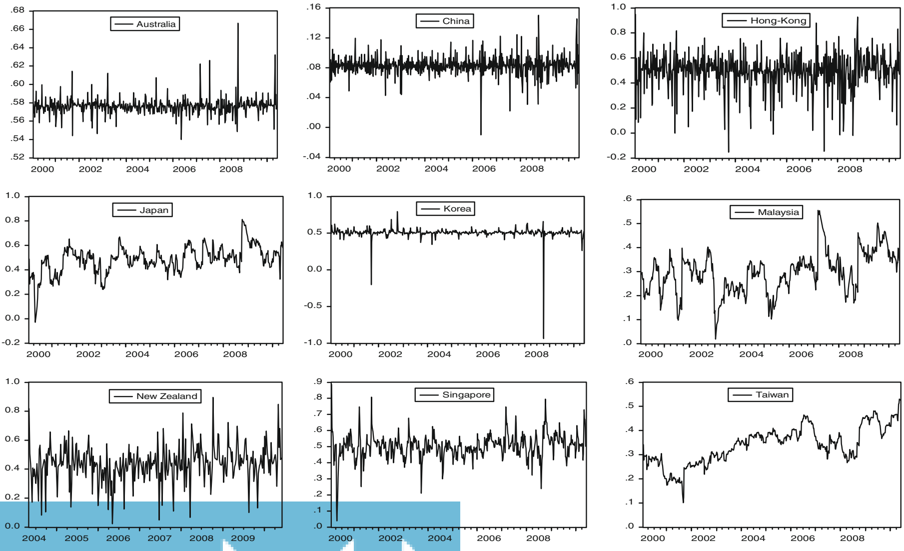

Fig. 2 DCC-GARCH correlations between the stock returns of the United States and Asian-Pacific markets

leptokurtic distribution of stock return series. As the analysis is concerned with the joint behavior of multiple stock returns, a multivariate GARCH model can gauge the patterns of conditional return volatility, correlations and covariance. Many studies have extended a univariate GARCH model (Bollerslev 1986) to multivariate cases. An M-GARCH model can account for the correlation in various stock returns better than univariate GARCH models.

Previous studies indicate that the impact of news may be asymmetric. Good news and bad news may have different impacts on predicting future volatility. The Exponential GARCH (EGARCH) model (Nelson 1991) and the Threshold Autoregressive GARCH (TAR-GRACH) model (Glosten et al. 1993) have been used to investigate the asymmetric effect on conditional variance. The TAR-GARCH model is attractive because fewer parameters need to be estimated.

The model is estimated by TAR-GARCH (1,1) in mean equation as follows.

$$\begin{aligned} &r_{it} = \Gamma_0 + \Gamma_1 r_{t-1} + \Gamma_2 r_{ust-1} + \gamma h_{it}^{1/2} + \varepsilon_{it} \\ &\varepsilon_{it}/\Omega_{t-1} \sim N(0, h_{it}) \end{aligned} \tag{6}$$

$$h_{it} = \omega + (\alpha + \eta d_{t-1})\varepsilon_{i,t-1}^2 + \beta h_{i,t-I} \tag{7}$$

The market return r_{it} is assumed to be related to its autoregressive component, lagged stock returns of the U.S. market, and its own conditional standard deviation $h_{it}^{1/2}$. The innovation ε_{it} is conditional on the information set Ω_{t-1} with zero mean and variance h_{it}. The influence of volatility on stock returns is captured by the estimated coefficient γ. The coefficient γ represents the index of relative risk aversion (time varying risk premium). A significant and positive γ implies that investors will be compensated with higher returns for bearing a higher level of risk, while a significant and negative γ implies that investors will be penalized by bearing risk. The presence of $h_t^{1/2}$ in Eq. (6) implies the explicit trade between risk and expected return.

The conditional variance equation is assumed to be predicted by the previous variance h_{t-I} and the square of the lagged error term ε_{t-1}^2. The size and significance of α in Eq. (7) shows the magnitude of the effect imposed by the lagged error term ε_{t-I} on the conditional variance h_t. The size and significance of β in Eq. (7) implies the existence of GARCH process in the error terms (volatility clustering). If the size of the sum α and β is greater than one, the response function of volatility increases with time.

The difference of variance equation from the traditional GARCH (1, 1) model is that the positive and negative shocks are differentiated by using an indicator variable d_{t-1}. It takes a value of unity when the previous shock is negative and zero otherwise. This will allow us to examine the asymmetry in volatility with respect to ε_{t-1}. A positive η implies that a negative innovation increases conditional volatility. As a result, the asymmetric effect is captured by the hypothesis that $\eta>0$.

We first look at the mean equation. The AR (1) term is significantly negative for Australia, Hong Kong, Japan, Korea, and Singapore. This finding is in agreement with the evidence in the literature in that AR (1) is negative as the presence of positive feedback trading in advanced markets. However, AR (1) is not significant for China, Malaysia, Taiwan, and the United States. The effect of lagged U.S. stock returns on Asian stock returns is highly and consistently significant. Consistent with the finding in literature, we do not find any statistical significance by including a conditional variance term in the return equation. Thus, it is clear that the estimated conditional volatility cannot predict future expected returns.

With respect to the estimates of the variance equation, the evidence shows that all of the GARCH parameters are statistically significant. This is consistent with the volatility clustering phenomenon observed in most financial markets. The hypothesis of no asymmetric effect is strongly rejected in most of stock markets under investigation. It implies that bad news an impact on conditional variance. However, China and Malaysia, which have low correlations with the U.S., provide very little evidence of volatility feedback. The sum of estimated coefficients is closer to unity, meaning that the evolution of volatility occurs in a persistent fashion and that the shocks may persist over a longer period of time.

Table 3 also provides the results of ARCH – LM test that carries out Lagrangian multiplier tests to check whether the standardized residuals exhibit additional ARCH. If the variance equation is correctly specified, there should be no ARCH left in the standardized residuals. The null hypothesis of no ARCH cannot be rejected. In addition, the calculated Ljung-Box values show that the null hypothesis of the absence of autocorrelation up to 12 orders cannot be rejected.

Conclusions

The objective of this paper is to examine the stock market linkages within the Asian region and between Asian markets and the U.S. market from January 2000 to June 2010. In this regard, previous studies have pointed out that diversification benefits would decrease with higher financial integration. Based on the results, the linkages between Asian markets and the U.S. market are significant in all cases except for China. There are no substantial opportunities for global investors to improve their portfolio risk-return performance during the 2008 financial crisis. However, there is still substantial opportunity to improve the risk-return performance between China and other markets. From the unconditional correlations and time-varying correlations, the Asian markets are highly correlated within the region and the U.S. market.

Furthermore, our findings show that the U.S. market significantly affects the markets in Asia-Pacific region. The hypothesis of no asymmetric effect is strongly rejected in most of stock markets. However, Chinese and Malaysian markets provide very little evidence of an asymmetric effect on conditional variance. For further research, one should study how dynamic correlations will be changed in global stock markets before, during, and after the 2008 financial crisis. This might help us understand the application of portfolio diversification strategies as well as the vulnerability of a financial system to financial contagion.

Table 3 Estimates of TAR-GARCH

	AU	CH	HK	JP	KR	MA	NZ	SG	TW	US
A. Return equations										
Γ_0	0.0020 (0.43)	−0.0068 (0.22)	0.0002 (0.95)	−0.0016 (0.81)	0.0009 (0.87)	0.0016 (0.56)	0.0064 (0.15)	0.0009 (0.78)	0.0010 (0.82)	−0.0001 (0.95)
Γ_1	−0.1828** (0.00)	0.0375 (0.41)	−0.1742** (0.00)	−0.1124* (0.05)	−0.1582** (0.00)	0.0190 (0.67)	−0.0373 (0.58)	−0.1402** (0.00)	−0.0780 (0.11)	−0.0311 (0.52)
Γ_2	0.2668** (0.00)	0.1227* (0.05)	0.3913** (0.00)	0.3643** (0.00)	0.3180** (0.00)	0.1625** (0.00)	0.1977** (0.00)	0.3987** (0.00)	0.2815** (0.00)	–
γ	−0.0929 (0.54)	0.2412 (0.21)	−0.0610 (0.91)	0.0130 (0.95)	0.0303 (0.86)	−0.0342 (0.82)	−0.3284 (0.17)	0.0612 (0.68)	−0.0318 (0.82)	0.0096 (0.94)
B. Variance equations										
ω	0.0006** (0.00)	0.0003* (0.05)	0.0003** (0.01)	0.0002** (0.00)	0.0001** (0.00)	0.0000 (0.27)	0.0003** (0.00)	−0.0001** (0.00)	0.0002** (0.00)	0.0002** (0.00)
α	−0.0194 (0.51)	0.0628** (0.00)	0.0348 (0.30)	0.0045 (0.88)	0.0770 (0.08)	0.0759** (0.00)	0.1380 (0.06)	−0.0047 (0.71)	0.0588 (0.11)	0.0091 (0.73)
β	0.9389** (0.00)	0.8966** (0.00)	0.8741** (0.00)	0.6560** (0.00)	0.7660** (0.00)	0.9354** (0.00)	0.6161** (0.00)	0.9175** (0.00)	0.8785** (0.00)	0.8246** (0.00)
η	0.1208** (0.00)	0.0193 (0.37)	0.1249** (0.00)	0.375** (0.00)	0.1854** (0.00)	−0.0300 (0.14)	0.2801** (0.00)	0.1227** (0.00)	0.0795** (0.02)	0.2371** (0.00)
C. Diagnostics on standardized residuals										
ARCH (12)	0.0055 (0.90)	0.0735 (0.11)	−0.0053 (0.90)	−0.0088 (0.84)	0.0026 (0.95)	−0.0317 (0.42)	−0.0487 (0.42)	0.0285 (0.52)	0.0207 (0.63)	−0.0477 (0.28)
Q(12)	4.6785 (0.97)	31.3530 (0.02)**	6.2883 (0.91)	3.0499 (0.99)	12.0071 (0.45)	13.4891 (0.41)	9.8566 (0.63)	10.3591 (0.59)	7.7658 (0.80)	7.5974 (0.81)

AU Australia, *CH* China, *HK* Hong-Kong, *JP* Japan, *KR* Korea, *MA* Malaysia, *NZ* New Zealand, *SG* Singapore, *TW* Taiwan, *US* United States. The estimated equations are:

$$\mathbf{r_{it}} = \Gamma_0 + \Gamma_1 \mathbf{r_{t-1}} + \Gamma_2 \mathbf{r_{ust-1}} + \gamma \mathbf{h_{it}^{1/2}} + \varepsilon_{it}$$

$$\mathbf{h_{it}} = \omega + (\alpha + \eta d_{t-1})\varepsilon_i{}^2{}_{,t-1} + \beta \mathbf{h_{i,t-I}}$$

The values in the parentheses are the *P*-values. ARCH (12) is the ARCH LM test up to 12 weeks, testing the heteroskadasticity of the residuals. Q (12) is the Ljung-Box Q-statistics that tests the joint significance of the autocorrelations of the standardized residuals up to the 12th order. * and ** indicate statistically significant at 5% and 1% levels, respectively

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