2010

Examining the Existence of Long-Run Relationships Between East Asian Economic Integration and ASEAN Tourism Exports

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Financial Market Integration in the Greater China Region: A Multivariate Asymmetric Approach

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Abstract

This paper examines the volatility dynamics of the greater China stock markets (Shanghai A- and B-shares, Shenzhen A- and B-shares, Taiwan, and Hong Kong) by employing a multivariate (tetravariate) framework that incorporates the features of asymmetries, persistence, and time-varying correlations, which are typically observed in stock markets of developed economies. Our results indicate that, unlike the Shenzhen and Shanghai A-shares, Hong Kong and Taiwan markets, the B-share markets do not exhibit significant asymmetric volatility ("leverage effect"), and return volatility in the A-share market is substantially higher than the B-share market before April 1997, but this result is reversed after that. Also, contrary to the stylized fact that emerging markets exhibit greater fluctuations compared with their more advanced counterparts, the mainland Chinese markets are actually less volatile than the Taiwan and Hong Kong stock exchanges in the late 1990s and early 2000s. In addition, there is strong evidence of volatility persistence in all the markets, and this finding is robust to changes in model specification. The greater China stock markets apparently share a common degree of persistence (fractional integration) in volatility. Moreover, the Shenzhen and Shanghai stock exchanges are positively but not perfectly correlated with each other, with the strength of correlation increasing after the late nineties. Their correlations with the Hong Kong and Taiwan markets are much weaker, and they do not display any clear trends. These findings have important implications for hedging and portfolio management and diversification.

1. Introduction

The dynamics of the interrelationships among the financial markets in the greater China area, which comprises mainland China, Taiwan, and Hong Kong, is a noteworthy issue of economic research. This is not only because the financial markets in this region have grown rapidly over the past decade, but also because of the arguably asymmetric integration of the emerging Chinese economy with advanced countries in the real side of the economy and tight control over financial market. These three markets have been Since its estaboishment, the Chinese stock market has The Hong Kong Stock Exchange ranks 9th in the world by market capitalization in 2004 (Hong Kong (*Hong Kong Exchange Fact Book 2004* (2005)). Its total market capitalization achieved the record high of HK$6695.9 billion at the end of that year. The turnover value of the securities market for the whole of 2004 was HK$3974.1 billion, surpassing Hong Kong's historical peak of HK$3789.0 billion in 1997. The total issued capital rose from HK$378,586 million in 2002 to HK$431,926.99 million two years later. The equity funds raised from the Hong Kong Stock Exchange also saw an increase from HK$101,413.28 million in 2002 to HK$276,202.61 million in 2004. In the case of the Taiwan Stock Exchange, a major liberalization took place in May 1988 and the number of listed companies increased rapidly from 199 in 1990 to 669 in 2003 (Taiwan Stock Exchange Fact Book 2005 (2005)). In 1997, the average daily trading value reached a record high of NT$130 billion (US$ 4.54 billion). Total market capitalization of listed shares was NT$12.87 trillion in 2003, up 42% from NT$9.09 trillion in the previous year. There were 7.39 million investors, an increase of 0.14 million from the preceding year. According to the

statistics of the World Federation of Exchanges (WFE), the market capitalization of the Taiwan stock market was US$443 billion (145 per cent of its GDP) as of 2004, ranking it 13[th] in the world. The market was also active in trading – it ranked second in Asia and 10[th] in the world in terms of share trading value in 2004. The annual turnover ratio was high – 162 per cent in 2004, the fourth highest in the world. As for the mainland Chinese stock markets, they have also entered a new stage of development, as manifested by the exponential expansion of market capitalization. By the end of 2004, the Shanghai Stock Exchange had a total of 996 listed securities and 837 listed companies (*Shanghai Stock Exchange Fact Book 2005* (2005)). These companies had a total market capitalization of RMB 2601.434 billion yuan. The number of investors with accounts reached 37.87 million. In 2004 alone, RMB 45.6901 billion was raised through IPO and secondary listings at the Exchange. On the other hand, the Shenzhen stock market is characteristic of the entrepreneurial spirit of the southern coastal city where it locates. A broad spectrum of market participants, including 500 plus listed companies, 35 million institutional and individual investors and 200 or so exchange members, create the market. Since its inception on 1st December 1990, it has blossomed into a market with great competitive edges in mainland China. Over the past 14 years, capital raised here amounted to an equivalence of US$ 807 million trade on the exchange.

The rising importance of the greater China capital markets in the global economy can also be seen from the initial public offerings (IPOs) issued in this region. According to a report by PricewaterhouseCoopers (2005), over the last three years, the capital markets in the greater China region have witnessed a steady increase in the new money raised from

USD13.51 billion in 2002 to USD17.16 billion in 2004. Hong Kong was the exchange with the largest number of initial public offerings (IPOs) in the greater China region, accounting for more than one-third of IPOs by number from 2002 to 2004; the second most active exchange by funds raised and number of IPOs was Shanghai. It is anticipated that the Hong Kong stock market will remain the international fund raising platform for mainland Chinese enterprises whilst her Shanghai counterpart will continue serving as the principal fund-raising platform for the mainland.

Despite the growing importance of the greater China stock markets and their dynamic interactions, there are only a few studies on this issue (see Johansson and Ljungwall, 2006, Groenewold et al. 2004, and Cheng and Glascock, 2005). In particular, Groenewold et al. (2004) investigate the interrelationships between prices on the mainland Chinese share market and those in the neighboring markets of Hong Kong and Taiwan and find a strong contemporaneous relationship between the two mainland markets but that the mainland markets are relatively isolated from the other two markets considered. Also, both Hong Kong and Taiwan have strong contemporaneous relationships, a feature that is more marked after the Asian crisis. The study by Cheng and Glascock (2005) focuses on examining the linkages among three greater China stock markets and two developed markets, Japan and the United States. One main finding is that the three greater China markets are not cointegrated with either U.S. or Japan and the U.S. market has larger influence on the greater China markets than the Japanese market. Recently a few researchers have analyzed the degree of financial integration among the Chinese markets, such as Drysdale, and Huang (2003), Cheung et al. (2006), and Girardin

and Liu (2006). These studies have not analyzed the volatility dynamics of the greater China stock markets in a multivariate framework. To the best of our knowledge, although there are a couple of papers that have examined the time-varying nature of the volatility of the Chinese stock markets, several significant stylized features pertaining to stock market return volatility are not incorporated into the analysis (see Tsui and Yu, 1999 and Yeh and Lee, 2000). Specifically, even though Tsui and Yu (1999) have examined the volatility behavior of the Shanghai and Shenzhen stock markets using a bivariate framework, they have not modeled the feature of volatility asymmetries typical of stock market returns. This creates potential model misspecification and the results obtained can be biased. Furthermore, their paper assumes that the correlation between the Shanghai and Shenzhen markets is invariant over time without any explicit modeling of time-varying correlations, which is an important empirical regularity observed from stock market series. Also, the Hong Kong and Taiwan markets are excluded from the analysis. In the case of Yeh and Lee (2000), albeit they have analyzed the asymmetric reaction of return volatility to good and bad news by utilizing the model of Glosten et al. (1993), they adopt a univariate approach which does not model the potentially changing correlations among the markets over time. Moreover, there is hardly any extensive discussion of the presence of volatility persistence in all the stock markets.

This paper proposes a unified approach to the modeling of volatility dynamics of the greater China area stock markets by adopting a multivariate framework that simultaneously incorporates asymmetries, persistence, and dynamic, time-varying correlations. In particular, we adopt two different classes of the generalized

6

autoregressive conditional heteroscedasticity (GARCH) models that nest many popular versions of the GARCH model as special cases: the asymmetric power ARCH (APARCH) model (Ding et al., 1993), and the quadratic ARCH (QARCH) model (Sentana, 1995). Our multivariate framework also nests the constant correlation GARCH (CC-GARCH) model of Bollerslev (1986), so the appropriateness of the constant correlation hypothesis can be easily tested. More importantly, our framework ensures the positive-definiteness of the conditional variance-covariance matrix once parameter estimates are obtained. Unlike the bivariate ARCH model of Engle et al. (1984), and the vech-representation of Bollerslev et al. (1988), we do not require excessive restrictions on the parameters to guarantee the positive-definiteness of the variance-covariance matrix. Furthermore, our multivariate approach is more parsimonious compared with the Baba-Engle-Kraft-Kroner (BEKK) model of Engle and Kroner (1995) and the factor model of Diebold and Nerlove (1989). Parsimony helps to ensure the tractability of estimating the parameters, especially when many data sets are involved. Also, our approach is more efficient than Engle's (2002) Dynamic Conditional Correlation (DCC) approach, as the parameters for the volatility and correlation equations are concurrently estimated in one step.

We believe that it is important to use the multivariate framework to examine the volatility dynamics of the greater China stock markets, in spite of the potential computational complexities involved. This is partly because many asset returns are subject to similar information or events and it is expected that their volatilities may be correlated conditional on the given information set. Furthermore, measuring and forecasting

financial market volatility is paramount to asset and derivative pricing, asset allocation, and risk management. Volatility is often understood or perceived as a measure of risk available to market participants and observers. Indeed, it is an important input for investment and option pricing. Investors and portfolio managers have some levels of risk threshold at which they could withstand, and a reliable forecast of volatility of asset returns over the investment holding period is a good starting point for evaluating investment risk. Volatility also influences dynamic trading strategies involving options. Specifically, movements of the stock index volatility can influence the value of options, according to the Black-Scholes formula of pricing options. Despite having a correct market expectation of the underlying stock index, an investor can still suffer a loss in the call option if the volatility of the underlying asset moves against his position.

Understanding how volatility evolves over time in the greater China's stock markets is particularly important for the development of robust derivative markets in this region. The promise of mainland China's continued economic expansion offers valuable opportunities to develop its derivatives markets for hedging and risk management of financial exposures. Such derivatives markets are essential adjuncts to fuel China's further economic growth. Access to global interest rate, stock index and foreign currency futures and options contracts will provide Chinese banks, corporations and financial institutions with valuable hedging and risk-management tools necessary to preserve the economic benefits of China's increasingly free and growing market economy. A deeper understanding of the volatility dynamics in the mainland China's stock markets therefore

is instrumental to fostering the growth and development of her derivatives markets like options and futures.

The rest of this paper is organized as follows. Section 2 outlines the econometric methodology used in this paper to examine the volatility dynamics of the greater China stock markets. The next section then provides brief background information of the stock markets, discusses the data sets employed in this paper, and analyzes the estimation results. Section 4 concludes with some remarks on the implications of our findings.

2.   Econometric Methodology

In this section, we first briefly describe the basic features of the multivariate GARCH(1,1) model with time-varying (dynamic) conditional correlations proposed by Tse and Tsui (2002). This relatively simple model is further extended to incorporate the features of asymmetric volatility and long-memory persistence.

2.1 Multivariate GARCH with time-varying correlations

Let $y_t = (y_{1t}, y_{2t}, y_{3t}\dots y_{kt})'$ be the k-variate vector of variables with time-varying variance-covariance matrix H_t, and let $\mu_{it}(\xi_i)$ be the arbitrary conditional mean functions which depend on ξ_i, a column vector of parameters, for i=1,2,…,k.   A typical k-variate GARCH(1,1) model may be specified as follows:

$$y_{it} = \mu_{it}(\xi_i) + \varepsilon_{it}, \qquad i = 1,2,...,k \tag{1}$$

where $(\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t},...., \varepsilon_{kt})' \mid \Phi_{t-1} \sim (O, H_t)$ \hfill (2)

Note that Φ_t is the σ-algebra generated by all the available information up to time t. The random disturbance terms ε_{it} (which are obtained from equation (1)) and the conditional variance equations h_{iit} are modeled as follows:

$$\varepsilon_{it} = \sqrt{h_{iit}}\, e_{it}, \quad \text{where } e_{it} \sim N(0,1) \tag{3}$$

$$h_{iit} = \eta_i + \alpha_i\, \varepsilon_{it-1}^2 + \beta_i h_{iit-1}, \qquad i = 1,...,k \tag{4}$$

where (4) is the popular Bollerslev's (1986) GARCH(1,1) model.

Denoting the ij-th element (i, j = 1, 2,...,k) in H_t by h_{ijt}, the conditional correlation coefficients are given by $\rho_{ijt} = \dfrac{h_{ijt}}{\sqrt{h_{iit} h_{jjt}}}$. Tse and Tsui (2002) assume that the time-varying conditional correlation matrix $\Gamma_t = \{\rho_{ijt}\}$ is generated by the following recursion

$$\Gamma_t = (1 - \pi_1 - \pi_2)\Gamma + \pi_1 \Gamma_{t-1} + \pi_2 \Psi_{t-1} \tag{5}$$

where $\Gamma = \{\rho_{ij}\}$ is a time-invariant (k x k) positive-definite correlation matrix, π_1 and π_2 are assumed to be nonnegative and sum up to less than 1, and Ψ_t is a function of the standardized residuals e_{it}. Thus, Γ_t is a weighted average of Γ, Γ_{t-1}, and Ψ_{t-1}.

Denoting $\Psi_t = \{\psi_{ijt}\}$, the elements of Ψ_{t-1} are specified as

$$\psi_{ij,t-1} = \frac{\sum_{a=1}^{M} e_{i,t-a} e_{j,t-a}}{\sqrt{(\sum_{a=1}^{M} e_{i,t-a}^2)(\sum_{a=1}^{M} e_{j,t-a}^2)}}, \quad 1 \le i < j \le k \tag{6}$$

where M is set equal to k, in accordance with Tse and Tsui (2002).

Assuming conditional normality, the log-likelihood function (which ignores the constant term and is conditional on Φ_{t-1}) of the vector of parameters in equations (1), (4), and (5) $\theta = \left(\xi_1, \xi_2, ..., \xi_k, \eta_1, \eta_2, ..., \eta_k, \alpha_1, ..., \alpha_k, \beta_1, ..., \beta_k, \rho_{ij}, \pi_1, \pi_2\right)$ is specified as

$$l_t(\theta) = -\frac{1}{2} \log |H_t| - \frac{1}{2}(\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, ..., \varepsilon_{kt}) H_t^{-1} (\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, ..., \varepsilon_{kt})' \tag{7}$$

where ε_{it} are the random disturbance terms obtained from equation (1). The conditional variance-covariance matrix H_t can be further defined as

$$H_t = \{h_{ijt}\} \equiv D_t \Gamma_t D_t, \quad D_t = diag\{\sqrt{h_{iit}}\}, \text{ and } \Gamma_t = \{\rho_{ijt}\}$$

Accordingly, the log-likelihood function can be rewritten as

$$l_t(\theta) = -\frac{1}{2} \log |D_t \Gamma_t D_t| - \frac{1}{2}(\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, ..., \varepsilon_{kt}) D_t^{-1} \Gamma_t^{-1} D_t^{-1} (\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, ..., \varepsilon_{kt})' \tag{8}$$

where Γ_t is defined by the recursion in (5). Note that by this formulation, $(\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, ..., \varepsilon_{kt}) D_t^{-1}$ represents the standardized residuals $(e_{1t}, e_{2t} ... e_{kt})$.

Equations (1)-(8) summarize the gist of the varying-correlations GARCH (VC-GARCH) model of Tse and Tsui (2002). In particular, when k = 2, the bivariate VC-GARCH(1,1) model is obtained and equations (5)-(7) can be simplified as follows:

$$\rho_{12t} = (1 - \pi_1 - \pi_2)\rho_{12} + \pi_1 \rho_{12,t-1} + \pi_2 \psi_{12,t-1} \tag{5'}$$

$$\psi_{12,t-1} = \frac{\sum_{a=1}^{2} e_{1,t-a} e_{2,t-a}}{\sqrt{(\sum_{a=1}^{2} e_{1,t-a}^2)(\sum_{a=1}^{2} e_{2,t-a}^2)}} \tag{6'}$$

$$l_t(\theta) = -\frac{1}{2}\sum_{i=1}^{2}\log h_{iit} - \frac{1}{2}\log(1 - \rho_{12t}^2) - \frac{e_{1t}^2 + e_{2t}^2 - 2\rho_{12t}e_{1t}e_{2t}}{2(1 - \rho_{12t}^2)} \tag{7'}$$

As noted by Tse and Tsui (2002), Bollerslev's (1990) constant-correlations GARCH (CC-GARCH) model is nested within the VC-GARCH model under the restrictions $\pi_1 = \pi_2 = 0$. Thus, the likelihood ratio test can be readily applied to compare the performance of these two models.

2.2 Asymmetric Conditional Volatility

In order to incorporate the feature of asymmetric volatility in the VC-GARCH model, we choose the following two well-established structures, namely the quadratic GARCH(1,1) (QGARCH(1,1)) model proposed by Sentana (1995), which is closely associated with Engle's (1990) asymmetric GARCH (1,1) (AGARCH(1,1)) model; and the asymmetric

power ARCH(1,1) (APARCH (1,1)) model of Ding, Granger, and Engle (1993). Their main features are summarized below.

Sentana's (1995) quadratic GARCH(1,1) (QGARCH(1,1)) model is specified as follows:

$$h_t = \eta - \gamma \varepsilon_{t-1} + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \tag{9}$$

where γ is the asymmetric coefficient. When $\gamma = 0$, (9) becomes the GARCH(1,1) model and when $\gamma = \beta = 0$, it becomes the prototype ARCH(1) model. The QGARCH(1,1) model can be shown to be related to Engle's (1990) AGARCH(1,1) model by performing the following rearrangement of the terms in equation (9):

$$h_t = \eta - \frac{\gamma^2}{4\alpha} + \alpha(\varepsilon_{t-1} - \frac{\gamma}{2\alpha})^2 + \beta h_{t-1} \tag{10}$$

If we redefine $\eta^* \equiv \eta - \frac{\gamma^2}{4\alpha}$ and $\gamma^* \equiv \frac{\gamma}{2\alpha}$, then the AGARCH(1,1) model is obtained:

$$h_t = \eta^* + \alpha(\varepsilon_{t-1} - \gamma^*)^2 + \beta h_{t-1} \tag{10'}$$

Ding, Granger, and Engle's (1993) asymmetric power ARCH(1,1) (APARCH (1,1)) model is specified below:

13

$$h_t^{\delta/2} = \eta + \alpha(|\,\varepsilon_{t-1}\,| - \gamma\varepsilon_{t-1})^\delta + \beta h_{t-1}^{\delta/2} \qquad (10)$$

where γ is the asymmetric coefficient. When δ = 2, (14) becomes the leveraged GARCH

(LGARCH(1,1)) model, which nests the GJR model of Glosten et al. (1993). When δ =

1, it becomes the threshold GARCH(1,1) (TGARCH(1,1)) model, which includes an

asymmetric version of the model introduced by Taylor (1986) and Schwert (1989) and

Zakoian's (1994) threshold ARCH (TARCH) model. Ding, Granger, and Engle (1993)

show that when δ approaches 0, the logarithmic GARCH(1,1) (LOGGARCH(1,1))

model, which incorporates an asymmetric version of the model proposed by Geweke

(1986) and Pantula (1986), is obtained. Although the APARCH structure nests 7 models

in total (see Ding, Granger, and Engle (1993) for details), it does not nest the AGARCH

or QGARCH model.

2.3 Long-Memory Dynamics

As regards the modeling of long-memory dynamics in volatility, we suggest generalizing

the conditional variance equations in (9), and (10) such that they are fractionally

integrated.

We derive the fractionally integrated asymmetric GARCH (FIAGARCH) model. Consider the AGARCH(p,q) model:[1]

$$h_t = \eta^* + \alpha(L)(\varepsilon_t - \gamma^*)^2 + \beta(L)h_t \tag{11}$$

By redefining $g(\varepsilon_t) \equiv (\varepsilon_t - \gamma^*)^2$, and $\tau_t \equiv g(\varepsilon_t) - h_t$, the fractionally integrated process can be straightforwardly applied to the AGARCH model by rewriting equation (20) as follows:

$$[1 - \beta(L) - \alpha(L)]g(\varepsilon_t) = \eta^* + (1 - \beta(L))\tau_t \tag{12}$$

After factorizing the lag polynomial $1 - \beta(L) - \alpha(L) = (1 - L)^d \phi(L)$, and rewriting (21) as an infinite ARCH operation applied to $g(\varepsilon_t)$, we obtain

$$h_t = \frac{\eta^*}{1 - \beta(1)} + [1 - (1 - \beta(L))^{-1}\phi(L)(1 - L)^d]g(\varepsilon_t) \tag{13}$$

where $0 \le d \le 1$, and $1 - \beta(L) - \alpha(L) = (1 - L)^d \phi(L)$

For the particular case of FIAGARCH(1,d,1), we have

$$h_t = \frac{\eta^*}{1 - \beta} + \lambda(L)(\varepsilon_t - \gamma^*)^2 \tag{14}$$

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[1] Due to the existence of cross-product terms in the complicated structure of the QGARCH(p,q) model, the fractionally integrated approach is not applied to this model. It can be shown, however, that the FIQGARCH(1,d,1) model is essentially similar to the FIAGARCH(1,d,1) model, since QGARCH(1,1) and AGARCH(1,1) are closely related. Since FIAGARCH(1,d,1) is computationally more tractable in practice, we will focus on this model in the rest of the paper.

where $\lambda(L) = \sum_{a=1}^{\infty} \lambda_a L^a = 1 - (1 - \beta L)^{-1}(1 - \phi L)(1 - L)^d$.

Note that (23) is similar to the FIGARCH(1,d,1) model in (19), except that it allows past return shocks to have asymmetric effects on the conditional volatility.

Similarly, we derive the FIAPARCH(p,d,q) model using the BBM procedure based on an APARCH(p,q) model. To do so, we now define $g(\varepsilon_t) \equiv |\varepsilon_t| - \gamma \varepsilon_t$ and $\tau_t \equiv g(\varepsilon_t)^\delta - h_t^{\delta/2}$:

$$h_t^{\delta/2} = \eta + \alpha(L)(|\varepsilon_t| - \gamma \varepsilon_t)^\delta + \beta(L)h_t^{\delta/2} \tag{15}$$

$$[1 - \beta(L) - \alpha(L)]g(\varepsilon_t)^\delta = \eta + (1 - \beta(L))\tau_t \tag{16}$$

By factorizing $1 - \beta(L) - \alpha(L)$, (25) can be further rewritten as an infinite ARCH operation applied to $g(\varepsilon_t)$. In the final analysis, the FIAPARCH(p,d,q) takes the following form:

$$h_t^{\delta/2} = \frac{\eta}{1 - \beta(1)} + [1 - (1 - \beta(L))^{-1}\phi(L)(1 - L)^d]g(\varepsilon_t)^\delta \tag{17}$$

In particular, the FIAPARCH(1,d,1) model is specified as:

$$h_t^{\delta/2} = \frac{\eta}{1 - \beta} + \lambda(L)(|\varepsilon_t| - \gamma \varepsilon_t)^\delta \tag{18}$$

where $\lambda(L)$ is defined as in (14). Similar to the FIAGARCH(1,d,1) model in (14), (18) allows past shocks to have asymmetric effects on the conditional volatility.

The parameters of the different multivariate fractionally integrated GARCH-type models can be estimated using Bollerslev and Wooldridge's (1992) quasi-maximum likelihood estimation (QMLE) approach. To facilitate convergence in the estimation, we have to make appropriate assumptions for the start-up conditions, including the computation of $\lambda(L)$, the number of lags, and the initial values. In particular, to compute the response coefficients, $\lambda(L) = \sum_{a=1}^{\infty} \lambda_a L^a = 1 - (1 - \beta L)^{-1}(1 - \phi L)(1 - L)^d$, we adopt the following infinite recursions given in Bollerslev and Mikkelsen (1996):

$$\lambda_1 = \phi - \beta + d,$$
$$\lambda_b = \beta \lambda_{b-1} + [(b - 1 - d)/b - \phi]\zeta_{b-1}, \qquad b = 2,...,\infty \tag{19}$$

where $\zeta_b = \zeta_{b-1}(b - 1 - d)/b$, with $\zeta_1 = d$

It can be observed from (19) that since b goes to infinity, an appropriate finite truncation is required during estimation. In our calibration, we have used 1000 and 2000 lags, respectively. We find that the parameter estimates obtained by truncating at 1000 lags are reasonably close to those based on 2000 lags. To save computational time, we truncate $\lambda(L)$ after 1000 lags.

As regards the choice of initial values, we set the presample observations ε_t^2 to the unconditional sample variance for the FIGARCH(1,d,1) model. However, this assumption may be inappropriate for the other models, as the infinite ARCH representation affects $g(\varepsilon_t)$. Therefore, for the multivariate FIAGARCH(1,d,1) model, we equate the presample observations of $g(\varepsilon_t) = (\varepsilon_t - \gamma*)^2$ to the sample mean of $(\hat{\varepsilon}_t - \hat{\gamma}*)^2$, where $\hat{\gamma}*$ is the estimate of $\gamma*$ based on the univariate FIAGARCH(1,d,1) model. As for the multivariate FIAPARCH(1,d,1) model, the presample observations of $g(\varepsilon_t)^\delta = (|\varepsilon_t| - \gamma \varepsilon_t)^\delta$ are equated to the sample mean of $(|\hat{\varepsilon}_t| - \hat{\gamma}\hat{\varepsilon}_t)^{\hat{\delta}}$, where $\hat{\gamma}$ and $\hat{\delta}$ are the estimates of γ and δ based on the univariate FIAPARCH(1,d,1) model. It should be noted that these starting values are not binding. We have experimented with other values and the results obtained are similar to what we report in the next section.

3. Data and Estimation Results

The following data sets are used to examine the volatility dynamics of the greater China markets: the Shanghai Composite Index (SHSCOMP), the Shenzhen Composite Index (SHZCOMP), the Taiwan Weighted Index (TAIWGHT), the Hang Seng Index (HNGKNGI), the Shanghai A-share and B-share Indices (SHSASHR, SHZBSHR), and the Shenzhen A-share and B-share Indices (SHZASHR, SHZBSHR). All four markets commenced trading on different dates: the oldest market is the Hong Kong Stock Exchange Ltd, which was formed in 1947, whereas the youngest market is the Shenzhen market, which started on April 3 1991. The Shanghai market started trading slightly earlier than Shenzhen market on December 19 1990. During the period from December

19 1990 to May 20 1992, the government imposed a daily price limit on the Shanghai market, which restricted changes to the share price within a 5% band. This limit was finally lifted on May 21 1992. As such, our analysis of the greater China stock markets will begin from May 22 1992. Specifically, for the SHSCOMP, SHZCOMP, TAIWGHT, and HNGKNGI indices, the data sets comprise 3225 daily price observations from May 22 1992 to September 30 2004. As for the A-share and B-share indices, instead of May 22 1992, the start date of our analysis is October 5 1992, because this is the very first day of availability for the Shenzhen A-share and B-share indices. All data sets are obtained from DataStream International and the details are provided in the Appendix. A brief description of all the indices used in this paper is provided in Table 2.

[Insert Tables 3 and 4 here]

Tables 3 and 4 display the key descriptive statistics of the daily returns of all the data sets used in this paper. The daily returns are computed on a continuously compounding basis by taking the difference of the logarithms of the daily stock market price indices. As shown in Table 3, excess kurtosis is noted for all markets, and the Shanghai Composite index has the highest kurtosis coefficient. Also, as measured by the standard deviation of the data sets, the Shanghai and the Shenzhen Composite Indices are relatively more volatile. This observation is apparently consistent with papers that highlight the fact that emerging stock markets are generally more volatile than their developed counterparts (see Bekaert and Harvey, 1997, Aggarwal et al., 1999 and Gao, 2002). As specifically noted by Gao (2002), mainland China's stock markets displayed tremendous volatility

19

during the eight years from 1994 through 2001. More importantly, the McLeod-Li, ARCH LM and QARCH LM tests suggest that conditional heteroskedasticity may be present in all the data series. This finding is further corroborated by the BDS test, which is a non-parametric test for the presence of non-linear dependencies. Under the null hypothesis of independence, the BDS test statistic has an asymptotic standard normal distribution.

The figures in Table 4 are fairly consistent with those displayed in Table 3. Again, the standard deviation of the daily returns of the mainland Chinese stock markets is higher compared with those of Taiwan and Hong Kong. Another noteworthy observation is the significant disparity in the kurtosis coefficients between the A-share and B-share markets. For instance, the kurtosis coefficient of the Shanghai A-share market is 27.6047, whereas that of the B-share market is only 8.3140. In addition, the standard deviation figures suggest that the A-share markets are more volatile than their B-share counterparts, but as we will demonstrate later on, this finding is more apparent than real, because there are periods in which the B-share markets exhibit greater fluctuations.

[Insert Tables 5-13 here]

In what follows, we will discuss three main aspects of the volatility dynamics of the greater China stock markets: volatility asymmetries, long-range persistence, and time-varying conditional correlations.

3.1 Volatility Asymmetries

There is significant evidence that corroborates the existence of asymmetries in the volatility of the Taiwan and Hong Kong stock markets. Both markets exhibit the leverage effect, whereby negative shocks have a greater impact on future volatility levels compared with positive shocks of the same magnitude. Apparently, this finding is robust to changes in model specification and time periods. As shown in Tables 5 and 9, the estimated values of the asymmetry parameter γ for the Taiwan Weighted Index are 0.3214 (0.3428) and 0.1557 (0.9832) for the VC-APARCH (VC-FIAPARCH) and the VC-QGARCH (VC-FIAGARCH) models respectively. These values correspond to the time period from May 22 1992 – September 30 2004. When we consider the time period beginning from October 5 1992, the estimated values of the asymmetry parameter do not change very significantly. Our findings for the Taiwan Weighted Index are consistent with Hsin et al (2003), who observe asymmetric effects in volatility for most of their sample firms.

The results for the mainland Chinese markets are a little mixed. The return volatility of the Shenzhen Composite Index displays significant leverage effect for the VC-AGARCH, VC-APARCH, VC-FIAPARCH and VC-FIAPARCH models; this result is reasonably consistent across different time periods. In particular, if we consider the period May 22 1992 – September 30 2004, the estimated values of γ are 0.3314, 0.1313, 0.0432, and 0.1689 for VC-FIAGARCH, VC-FIAPARCH, VC-QGARCH, and VC-APARCH, respectively, and they are significant at least at the 5% level. These estimates do not differ much from those obtained for the period beginning from October 5 1992. Likewise,

for the Shanghai Composite Index, most of the estimated values of γ are significant at the 10% level. It is interesting to note that the return volatility of the A-share markets exhibit some evidence of significant asymmetries, but not in the B-share markets. For instance, the asymmetry parameter of the Shenzhen A-share market is significant at approximately 5% for the VC-FIAGARCH, VC-FIAPARCH, VC-APARCH, and VC-QGARCH models. In the case of the Shanghai A-share market, the parameter γ is significant for the VC-APARCH and VC-QGARCH models. In contrast, the B-share markets do not display statistically significant leverage effects.

A comprehensive in-depth explanation of the volatility asymmetry of the greater China stock markets is beyond the scope of this paper. However, we try to provide some preliminary conjectures. Based on the results obtained from developed stock markets, many existing papers concluded that negative shocks (bad news) engendered higher volatility levels than positive shocks (good news) of the same magnitude, and possible explanations of this finding include: [1] the financial leverage effect (Black, 1972 and Christie, 1982); [2] the volatility feedback effects (French et al. , 1987, Campbell and Hentschel, 1992, and McQueen and Vorkink, 2005); and [3] the presence of investors with heterogeneous expectations in the stock market (Yamamoto, 2005 and Li, 2006). As noted by Yamamoto (2005), asymmetric volatility is observed as investors learn from their own experience. Predictions across investors become more diversified and heterogeneous, and these heterogeneous predictions are important for producing asymmetric volatility in the stock market. Li (2006) also observes that in a stock market setting with investors having heterogeneous beliefs, asymmetric effects can be found in

the volatility of returns. A combination of these three explanations may help us understand why volatility asymmetry occurs in the Chinese A-share, Taiwan, and Hong Kong markets.

What about the statistical insignificance of the asymmetric effect in the B-share markets? Again, a detailed explanation is beyond the scope of this paper, but we conjecture that it may have to do with the differences between the informational environment and institutional characteristics of the A-share and B-share markets. As observed by Abdel-Khalik et al. (1999), the environment of the A-shares appears to be dominated by local regulations and customs at the time of offering or trading. According to them, the informational environment of A-shares appears to be relatively unstructured. Other than the roles played by state officials and appointed managers, external monitoring of A-shares is apparently limited. Independence and social acceptance of auditing appear to be making slow progress, especially when the majority of the domestic Certified Public Accountant (CPA) firms are government-owned. Given the unstructured nature of the informational environment, there could be a higher diversity of predictions in the market and it is possible for greater uncertainty to arise as a result. Furthermore, if investors in the A-share markets are mostly experiential learners who rely on their personal experiences instead of imitating other investors who performed well in the past, the A-share markets will be similar to Yamamoto's (2005) experiential learning market, which is found to exhibit significant volatility asymmetry. It is not unreasonable to assume that experiential learners dominate the A-share market, since most of them (67% as of October 2003) are retail investors who are new to investments in equities. Black (1986)

believes that such investors irrationally act on noise as if it were information that would give them an edge and calls them "noise traders". Indeed, as noted by Yeh and Lee (2000), there is lack of institutional investor trading in the A-share markets, and the trading values of the Shanghai and Shenzhen stock markets are contributed virtually by the individual investors.

In contrast, B-shares are denominated in US or Hong Kong dollars and are sold mainly to foreign investors and their registration requires financial statements to be prepared based on International Accounting Standards (IAS). According to Abdel-Khalik et al. (1999), the IAS is considered to be well-developed compared to most domestic accounting standards in countries with emerging capital markets and it has met a threshold of credibility that satisfies the rigorous demands of a field test. The information environment for Type B shares includes disclosure of financial statements in the documentation of the initial public offering. In addition, the investment funds that own B shares represent sophisticated foreign investors who monitor the issuing firms' activities and decisions. Abdel-Khalik et al. (1999) observed that these shares were relatively insulated from trade manipulation by insiders or state officials. From these features, it is concluded that the informational environment of firms issuing B shares is relatively formalized, and the investors in B-share markets have better access to higher quality news. Diversity of predictions may therefore be smaller compared with the A-share markets, and this in turn explains the lack of asymmetry in the B-share markets.

3.2 Persistence

We consider the issue of volatility persistence in this section. As shown in Tables 5-9, the sum of the GARCH parameters $\alpha + \beta$ for all the stock markets is very close to one, which apparently indicates the presence of strong persistence in volatility (see Bollerslev and Engle, 1993; and Baillie et al., 1996). This finding provides some motivation for us to model the long-range dependence using the approach of fractional integration. Specifically, we measure the persistence of volatility with the fractional differencing (long-memory) parameter d in the VC-FIGARCH, VC-FIAPARCH, and the VC-FIAGARCH models. As noted in Table 14, the estimated values of the fractional differencing parameter d for all the markets range from 0.2 to 0.38, and they are significantly different from zero and one. This suggests that either the usual GARCH or the integrated GARCH (IGARCH) models are inadequate compared with the fractionally integrated version.

The results indicate that the estimated values of d is very sensitive to the model specifications and can vary significantly for the same stock index, especially in the cases of TAIWGHT and HNGKNGI. In the case of HNGKNGI, the value of d seems to be higher for the VC-FIGARCH model than with the VC-FIAPARCH and the VC-FIAGARCH models. Since the latter two models nest the VC-FIGARCH model, this may suggest that ignoring the feature of asymmetry could overestimate the degree of long range persistence in volatility.

The estimated values of d obtained from the different mainland Chinese stock market series are quite similar, and the differences between the A-share and B-share markets are not very substantial.

Judging from the estimated values of the parameter d, there could be a common degree of fractional integration/long memory among some of the markets. . For example, in Group 1, the values of d for the TAIWGHT are 0.2506 and 0.2723 for the VC-FIAGARCH and VC-FIAPARCH models respectively. These values are similar to the corresponding ones for HNGKNGI, which are 0.2957 and 0.3060, respectively. As for the mainland Chinese markets, the estimated values of d are remarkably close. More specifically, the values of d for the Shenzhen (Shanghai) Composite Indices are 0.3684 (0.3559), 0.3515 (0.3456), and 0.3566 (0.3504) for the VC-FIGARCH, VC-FIAGARCH, and VC-FIAPARCH models respectively. The possible presence of co-persistence has important implications for asset pricing relationships and making optimal decisions related to portfolio allocation, and these implications will be discussed in Section 4.

The phenomenon of volatility persistence is a complex issue with no easy explanations. At the risk of over-simplification, the existence of volatility persistence may be explained by the presence of a serially correlated news arrival process (otherwise known as the "information processing hypothesis" and heterogeneous expectations (Engle et al., 1990), the pGarofalo and Sansone, 2005;, Gaunersdorfer and Hommes, 2005), the imitative behavior of investors in the stock market (Yamamoto, 2005), the preferences of risk-averse agents in equilibrium asset pricing models (McQueen and Vorkink, 2004) and the belief systems of traders in a stock market (Brock and LeBaron, 1996). For the latter,

the authors argue that persistent volatility is caused by traders experimenting with different belief systems based upon past profit experience and their estimates of future profit experience. The agents in the model have adaptive beliefs, which induce them to adapt their trading strategies on a time scale that is slower than the time scale on which the trading process takes place. Volatility persistence enters returns through a slower time scale of changes in beliefs. A combination of these explanations may help us understand the existence of volatility persistence in the greater China stock markets.

3.3 Time-Varying Correlations

[Insert Figure 1 here]

Figure 1 presents the main findings for the time-invariant component of the correlation matrix, $\Gamma = \{\rho_{ij}\}$. It can be seen from Figure 1 that the estimated values of the pairwise correlation coefficient for any two indices (the time-invariant component of Γ_t, $\Gamma = \{\rho_{ij}\}$) with different specifications are apparently similar. In particular, the TAIWGHT-HNGKNGI correlation coefficient ranges from 0.3701 to 0.4085. For the correlation between CHSCOMP and CHZCOMP, the estimated value ranges from 0.9872 to 0.9953.

The correlation between the Shanghai and Shenzhen Composite Indices is very high but not perfectly positive. As observed by Gao (2002), what is most "unusual" about China's dual stock exchange system is that the stocks traded on the two exchanges perform quite differently, despite the fact that the two exchanges in China do not have large differences

27

in their sector representation, quotation systems and trading schemes. Xu (2000) notes that one difference between the two markets is that, while most companies listed on the Shanghai market are large and state-owned, those on the Shenzhen market are small joint ventures and export-oriented. Apart from the dissimilar characteristics of the companies listed in these two markets, the relative size of these two exchanges has undergone major changes. Specifically, the Shenzhen exchange, though larger and more active than its Shanghai counterpart in 1992, was outsized by the latter by the end of 1994 due to a shift in government policy. Beginning with a similar size to the SZSE at the end of 1992, the market capitalization of the SHSE has grown to over 4.5 times as large as that of the SZSE at the end of 1994.

It is a bit surprising to note that the correlation between the mainland Chinese markets and the rest of the greater China region is remarkably weak. For example, the correlation between the Shenzhen Composite Index and the Hang Seng Index ranges from 0.0109 to 0.0313, and these figures are insignificant even at the 10% level. As for the correlation between the Taiwan Weighted and the Shanghai Composite Indices, the values are between 0.0604 – 0.0685. This finding seems consistent with Gao (2002) and Groenewold et al. (2004). As noted by Gao (2002), China's stock market is relatively insulated, and this can be attributed to the government's currency shield and the existence of separate share classes for foreign and domestic investors. In comparison with other markets, China displays low correlation with the world's major developed markets. Specifically, none of the three major developed stock markets – Europe, the US and

Japan - displays a correlation coefficient with China higher than 0.05. Groenewold et al. (2004) also show a similar finding.

Although the correlation between the Hong Kong and Taiwan markets is slightly stronger compared with that between the mainland Chinese markets and the rest of the region, it is nonetheless not very high. In fact, the highest value is less than 0.42. If we consider the correlations between the developed stock markets such as the US and Europe, then the correlation between the Taiwan Weighted Index and the Hang Seng Index indeed does not appear very strong. More specifically, it has been noted by some researchers that, for the 15-year period that ended in December 31 2004, the correlation between the US and the European markets is approximately 0.74, and that between the US and the developed markets (excluding the US) is 0.65 (AIM Investments (2005)).

There are several observations worth mentioning for the dynamic component of Γ_t. First, the conditional correlation between any two markets is significantly time-varying. As shown in Tables 5-9, the parameters π_1 and π_2 are individually significant at the 1% level, and the constant-correlation models are rejected by the likelihood ratio tests. The graphs also provide some qualitative support for the existence of varying conditional correlations.

Second, the time-paths of the correlation between the mainland Chinese markets and the Hong Kong and Taiwan markets do not exhibit any distinctive upward or downward trend. No predictable patterns are discernible from the graphs in Figure 1.

Third, there is, however, some qualitative evidence that the correlation between TAIWGHT and HNGKNGI is strengthening over time. In particular, the conditional correlation between the Hong Kong and the Taiwan stock markets seem to increase from 1998 onwards. The reason could be due to increasing financial integration within the Asian region in recent years. As noted by a 2006 IMF study (Cowen et al (2006)), financial integration in Asia is being further enhanced by initiatives aimed at harmonizing financial regulations, developing financial infrastructure, and deepening financial markets. Chi et al. (2006) also observe that the level of financial integration of East Asian equity markets is high and has improved tremendously during 1991 to 2005. Our finding is apparently consistent with research focusing on the financial integration of international equity markets, such as Longin and Solnik (1995, 2001), Chelley-Steeley et al. (1998), Leong and Felmingham (2003), and Cheung et al. (2003).

Last, as seen from Figure 1, the correlation between the CHSCOMP and the CHZCOMP indices has been strengthening over time and the conditional correlations between the two markets have undergone dramatic changes at different points in time. Three different periods are distinguishable: the first period occurs in the early 1990s, during which the correlation coefficient fluctuates between 0.4-0.6. After mid-1993, the correlation coefficient begins to strengthen and it exhibits an upward trend up to 1996. In the third period after 1996, the correlation dips slightly before it rises again gradually and remains at values close to 1.0.

3.4 Graphical Analysis of Volatility Dynamics

[Insert Figure 2 here]

Figure 2 displays the return volatility patterns of the A-share and B-share markets. It can

be seen from Figure 2 that the volatility of the A-share markets is much higher than that

of the B-share markets prior to April 1997. However, the volatility disparity between the

two markets is reversed post 1997, namely, the B-share market appears to be more

volatile than the A-share market. Su and Fleisher (1999) found that the A-share markets

are more volatile compared with the B-share markets. Our results show that conclusion

based on

unconditional standard deviation of the market returns can be misleading. This is

because volatility can change dramatically over time. Our findings underscore the

importance of analyzing conditional instead of unconditional volatility.

Although the issue of volatility disparity is a complex one,

some possible explanations for the volatility disparity between the A-share and B-share

markets may include the differences in the information environment, the market-making

costs and the recent rapid development of the B-share market. First, as discussed earlier,

the environment of the A-shares appears to be dominated by local regulations and

customs at the time of offering or trading. The relatively unstructured informational

environment of the A-share markets may create substantial uncertainty (and therefore

volatility). In contrast, in the B-share market, the informational environment is more

structured. As such, the B-share market appears less volatile. However, after 1996, there were several regulatory changes pertaining to the informational environment instituted by the authorities. According to the Shanghai Stock Exchange (2005), on March 1 1997, information disclosure was made compulsory in stock and fund trading, and on August 5, the A-share market was assigned under the direct supervision of the Central Security Regulation Council (CSRC). These regulatory measures could have improved the information environment in the A-share market in recent years, and thereby reduced market volatility. Then, the differences in the market-making costs between the two markets could also be another possible cause of volatility disparity. He et al. (2003) investigate the bid–ask spreads and estimate the market-making costs (informed trading and noninformed trading costs) for each stock. Their results show that the B-share markets in China contain higher informed trading and other market-making costs than the A-share markets. When informed trading and other cost components are accounted for, the volatility disparity between the A and B shares decreases. Thus, the higher volatility in the B-share market could be attributed to the higher market-making costs faced by B-share traders. Finally, the recent developments in the B-share markets could also have triggered volatility levels that were higher than those in the A-share markets. This could be induced by major events and news affecting the B-share markets, including the speculation of merger between A and B shares and changes in market supervision in the B-share market since 2000. In September 2006, the FTSE Xinhua Index report stated that China's B-shares leapt in price during September amid rumors that the government might allow the A-shares and B-shares to merge.

[Insert Figure 3-5 here]

Figures 3-5 compare the volatility levels of the different pairs of markets. All figures are based on the output extracted from the VC-FIAPARCH model, since the graphs based on other models are qualitatively similar. The first group of graphs (Figure 3) compares the conditional standard deviation of the mainland Chinese Composite Indices with that of Hong Kong and Taiwan. The comparisons with the A-share and B-share markets are displayed in Figures 4 and 5 respectively. These figures further confirm the findings that the Chinese markets may appear to be more volatile than Hong Kong and Taiwan markets if measured by using unconditional standard deviation, and   if we consider the conditional volatility levels of the greater China stock markets, there are significant periods in which the mainland Chinese markets actually exhibit lower volatility than the markets in Taiwan and Hong Kong.

Furthermore, the disparity in volatility level between the Shanghai and Shenzhen markets is not very substantial, especially prior to 2001. The B-share markets, for most of the time, exhibit higher volatility levels compared with the markets in Taiwan and Hong Kong.

3.5 Evaluation of Models

[Insert Table 14 here]

Table 14 reports the results of the likelihood ratio tests of each model in this study. It is noted that models with varying correlations generally outperform those with constant

correlations, based on log-likelihood ratio tests and residual diagnostics. In fact, there are instances in which the estimation of the constant correlation model failed because of non-convergence. For instance, when we tried to estimate the CC-APARCH model for the Group 2 stock indices (TAIWGHT, HNGKNGI, CHSASHR, CHZASHR), no parameter estimates were obtainable. This could also be an indication that the restriction of constant correlation is inappropriate.

The APARCH-class of models yielded more satisfactory results compared with the AGARCH-class, because, in some cases, the estimation of the AGARCH models resulted in negative parameter estimates. These cases can be found in the estimation of VC-FIAGARCH for the TAIWGHT and HNGKNGI indices.[2]

4. Conclusion

In this paper, we have analyzed the volatility dynamics of the stock markets of the greater China region using the daily returns data from 1992 to 2004 and found the existence of volatility persistence and asymmetries. In particular, the results show that only the B-share markets do not exhibit statistically significant asymmetries, and this result is consistent across different model specifications. Also, conditional correlations among the markets are significantly time-varying. There is some evidence that correlations between

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[2] This problem is not new in the literature: see Engle (1982), Lastrapes (1986), Hamao, Masulis, and Ng (1990a, b). We have tried the class of EGARCH models, which admit negative parameter estimates, but there are problems of convergence. A drawback of the EGARCH-class, as noted by Pagan (1996), is that the IEGARCH model is not identifiable by the quasi maximum likelihood, therefore if d tends to 1, the same problem is likely to occur for the FIEGARCH model. Furthermore, unlike the rest of the models in the ARCH family, the volatility level of EGARCH model is based on the standardized innovations rather than the innovations (excess returns) themselves.

some markets are strengthening over time. Judging from the unconditional standard deviation of the returns of the various indices, it appears that the A-share market is more volatile than the B-share market, and that the mainland Chinese markets exhibit greater fluctuations than their counterparts in Hong Kong and Taiwan. However, this claim is misleading when we analyze the conditional volatility of all the markets, since the B-share markets are apparently more volatile than the A-share markets after 1997. Furthermore, there are some periods when the mainland Chinese markets have significantly lower volatility relative to the Hong Kong and Taiwanese markets. This finding suggests that it is not necessarily true that the emerging markets are always more volatile than the developed markets. Equally important, the greater China markets apparently share a common degree of volatility persistence (fractional integration).These findings have various implications for asset allocation and portfolio management. First, volatility asymmetry has implications for the valuation of options and volatility forecasting. Taking asymmetry into account will provide a more realistic measurement of the risk premium associated with a risky portfolio. Second, the dynamic correlations have implications for portfolio management and diversification. Since conditional correlations are found to be significantly time-varying for the greater China stock markets, the weights for a portfolio of assets from these markets have to be adjusted dynamically to achieve optimality in asset allocation. As conditional correlations among the greater China stock markets have strengthened over the years, there could be diminishing benefit from portfolio diversification. Third,volatility persistence and asymmetry can affect the confidence interval associated with the forecast of stock market returns. Long-range persistence can also influence portfolio allocation, because optimal portfolio allocations

may become extremely sensitive to the investment horizon if the volatility of the returns is highly persistent. Similarly, optimal hedging decisions must take into account long-range dependencies in volatility. Forth, the volatility disparity between the A-share and B-share markets also has implications for the potential merger of the two markets. As highlighted in our discussion earlier, the B-share market could have exhibited greater volatility in recent years partly because investors anticipated that the B-share market would merge with the A-share market but this merger failed to materialize. One market analyst has mentioned that "Every year people get excited by the B-share market then the hype just dies down". To mitigate the increased volatility associated with this kind of exuberance, it may be imperative for the government to engineer a clear plan of merger with a specific timeframe. Finally, the observation of a common long-run component in the volatility processes may prove helpful in the construction of long-term forecast intervals and in the calculation of optimal hedge portfolios. Modern asset pricing theories suggest that the price today is a function of the conditional variance of the future asset returns, or the covariance with some benchmark portfolios. If shocks to the conditional variance or covariance have only temporary effects, the risk premium associated with long term contracts will not be affected very much. On the other hand, if the conditional variance is persistent, the pricing of long-term contracts will be a non-trivial function of today's information set. At the same time, if the assets in a portfolio are co-persistent in variance with the co-persistent vector proportional to the vector of asset shares, the risk premium for long term contracts in that portfolio will tend to be time invariant.

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Table 1: Stock Market Highlights

	Shanghai		Shenzhen		Taiwan		Hong Kong	
	1999	2004	1999	2004	1999	2004	1999	2004
Listed securities listed	574	996	540	673	510	709	1205	1971
Listed companies listed	484	837	463	536	462	697	701	892
Market capitalization	1 458 047	2601434	1189070.42	1104122.72	11803524	13,989,100	4,727,527.07	6,629,176.75
Total issued capital	158015	470055	132870.12	200446.79	3056536	5031317	225,577.27	431,926.99
Annual trading volume (million shares)	156042	360774	137200.61	221999.12	678063	987574	1,392,284.36	3,984,706.17

Notes: The figures are extracted from various issues of the *Shanghai Stock Exchange Fact Book* (URL: http://www.sse.com.cn/sseportal/en_us/ps/about/fact.shtml), Shenzhen Stock Exchange Fact Book (URL: http://www.szse.cn/main/en/Catalog_1389.aspx), Taiwan Stock Exchange Corporation (TSEC) Fact Book (URL: http://www.tse.com.tw/en/about/company/factbooks.php), and Hong Kong Exchange (HKEx) Fact Book (URL: http://www.hkex.com.hk/data/factbook/factbook.htm). The market capitalization and total issued capital figures are denoted in Renminbi (RMB) million, New Taiwan dollar (NT$) million, and Hong Kong dollar (HK$) million for the mainland Chinese, Taiwan and Hong Kong markets, respectively. The RMB exchange rate was RMB 8.2783 to US$1 and RMB 8.2765 to US$1 in 1999 and 2004, respectively. The NT$ exchange rate was NT$31.390 to US$1 and NT$31.740 to US$1 in 1999 and 2004, respectively. Finally, the HK$ is pegged at HK$7.80 to US$1.

Table 2: Brief description of greater China stock market indices

Stock Index	Description
Shanghai Composite Index	The Shanghai Composite Index is the earliest index compiled by the Shanghai Stock Exchange, and its constituent stocks are the A-share and the B-share companies listed on the exchange. The index takes December 19 1990 as the base day and the total market capitalization of all listed stocks on that day as the based period. This index has been officially published since July 15 1991 and is calculated by the weighted average of the number of shares of the constituent stocks.
Shenzhen Composite Index	The Shenzhen Composite Index is an actual market-cap weighted index (no free float factor) that tracks the stock performance of all the A-share and B-share lists on Shenzhen Stock Exchange. The index was developed on April 3 1991 with a base-price of 100.
A-share Indices (Shanghai and Shenzhen)	The A-share indices represent shares available to domestic Chinese investors. They are denominated in the Chinese currency and can be further categorized as follows: state shares, legal-person shares, employee shares, and individual shares.
B-share Indices (Shanghai and Shenzhen)	The B-share indices have exactly the same ownership and dividend rights as do A-shares and are purchased by foreign investors, including overseas Chinese. The separation of A-share and B-share markets reflects the central government's policy of restricting the foreign control of vital state-owned enterprises and its desire to prevent manipulation of China's fledgling stock markets from abroad.

Stock Index	Description
	Maintaining a distinct stock market for foreign investors in which they participate using their own currency also helps prevent the devaluation of the RMB from excessive sales.
Taiwan Weighted Index	The Taiwan Weighted Index is the most widely quoted of all the Taiwan Stock Exchange Corporation indices. It covers most of the listed common stocks. It was first published in 1967, and up to December 2003, 636 issues were selected as component stocks from the 669 companies listed on the Exchange.
Hong Kong Hang Seng Index	The Hang Seng Index is a capitalization-weighted stock market index in the Hong Kong Stock Exchange. It is used to record and monitor daily changes of the 33 largest companies of the Hong Kong stock market and as the main indicator of the overall market performance in Hong Kong. These companies represent about 70% of capitalization of the Hong Kong Stock Exchange. The Hang Seng Index was started on November 24, 1969, compiled and maintained by HSI Services Limited, which is a wholly-owned subsidiary of Hang Seng Bank, the second largest bank listed in Hong Kong in terms of market capitalization.

Notes: A-shares are currently available to qualified foreign institutional investors, but the main players are still domestic investors. Domestic investors are now allowed to participate in the B-share markets.

Table 3: Summary Statistics of Stock Index Returns (May 22 1992 – Sep 30 2004)

Variable	CHSCOMP	CHZCOMP	HNGKNGI	TAIWGHT
Mean	0.0000	0.0001	0.0003	0.0001
Median	0.0000	0.0000	0.0000	0.0000
Maximum	0.2886	0.2722	0.1725	0.0852
Minimum	-0.1791	-0.1888	-0.1473	-0.0994
Std. Dev.	0.0255	0.0230	0.0170	0.0165
Skewness	1.4665	0.8666	0.0395	-0.0271
Kurtosis	22.8689	19.4536	12.2503	5.4023
Observations	3224	3224	3224	3224
Ljung-Box Q-statistic				
5 lags	27.0119	26.7411	31.6219	20.6267
10 lags	51.2207	41.8347	39.0681	32.8729
McLeod-Li Test				
5 lags	701.2005	351.2478	961.3332	193.0676
10 lags	864.0146	401.5340	1033.7274	327.3346
ARCH LM Test				
5 lags	451.5436	248.3246	563.4687	134.0914
10 lags	475.7342	254.5937	577.6507	192.3085
QARCH LM Test				
1 lag	83.0659	38.9457	509.7766	52.2148
4 lags	510.7748	380.5109	953.4219	218.7134
BDS Test				
e=1,l=3	24.8321	26.1436	10.1311	6.4830
e=1,l=4	28.5918	30.8695	11.8978	8.7147
e=1,l=5	31.5809	35.1277	13.5199	10.1641
e=1.5,l=3	24.6742	23.1696	12.4218	7.6961
e=1.5,l=4	27.2365	26.0835	14.2512	9.9417
e=1.5,l=5	28.5700	28.3620	15.8442	11.5868
Runs Test				
R_1	-2.2050	-4.3528	-1.9287	-1.6067
R_2	-11.4874	-12.9865	-3.5001	-0.7172
R_3	-14.9279	-14.5654	-4.5451	-2.8163

Notes:
1.   CHSCOMP = Shanghai Composite Index, CHZCOMP = Shenzhen Composite Index, HNGKNGI = Hong Kong Hang Seng Index, TAIWGHT = Taiwan Stock Exchange Weighted Index
2.   QARCH LM test statistic is due to Sentana (1995) and it is distributed as chi-squared with $q(q+3)/2$ degrees of freedom, where q is the number of lags.
3.   For the BDS Test, e represents the embedding dimension whereas l represents the distance between pairs of consecutive observations, measured as a multiple of the standard deviation of the series. Under the null hypothesis of independence, the test statistic is asymptotically distributed as standard normal.
4.   For the Runs Test, Ri for i = 1, 2, 3 denote the runs tests of the series Rt, |Rt|, and Rt2 respectively. Under the null hypothesis that successive observations in the series are independent, the test statistic is asymptotically standard normal.

Table 4: Summary Statistics of Stock Index Returns (Oct 5 1992 – Sep 30 2004)

Variable	TAIWGHT	HNGKNGI	CHSASHR	CHZASHR	CHSBSHR	CHZBSHR
Mean	0.0001	0.0003	0.0002	0.0001	0.0001	0.0002
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.0852	0.1725	0.3085	0.2958	0.1218	0.1380
Minimum	-0.0994	-0.1473	-0.1843	-0.1963	-0.1308	-0.1670
Std. Dev.	0.0166	0.0171	0.0260	0.0237	0.0216	0.0221
Skewness	-0.0185	0.0366	1.7672	1.0443	0.4352	0.3866
Kurtosis	5.4119	12.2018	27.6047	21.9392	8.3140	10.9537
Observations	3128	3128	3128	3128	3128	3128
Ljung-Box Q-statistic						
5 lags	21.4246	30.5702	41.1985	24.5296	94.1293	134.7755
10 lags	33.5546	37.8755	68.3212	39.1099	99.4567	149.9292
McLeod-Li Test						
5 lags	197.7773	929.8222	643.2622	376.1940	1032.8607	1199.3357
10 lags	335.9186	998.9263	808.9107	430.4431	1215.1938	1586.6667
ARCH LM Test						
5 lags	136.8261	546.2968	423.0020	264.7159	514.8476	602.8488
10 lags	197.1381	560.3484	450.8351	271.3087	525.5322	643.5932
QARCH LM Test						
1 lag	55.5093	494.8215	66.4368	37.6952	332.8495	443.2099
4 lags	223.3298	924.9455	463.7085	408.8297	521.6608	731.1548
BDS Test						
e=1,l=3	7.0734	9.6885	24.3788	27.5372	21.3799	24.0239
e=1,l=4	9.3871	11.3791	27.9879	32.4611	25.0160	26.9253
e=1,l=5	10.9437	12.9409	30.8754	36.7603	28.0161	29.1709
e=1.5,l=3	8.3021	12.0532	23.7007	24.1063	18.9418	23.2867
e=1.5,l=4	10.5447	13.8252	26.2032	27.2505	21.1332	25.4289
e=1.5,l=5	12.2154	15.3674	27.5797	29.5085	22.5066	26.4627
Runs Test						
R_1	-1.7246	-1.8426	-1.8355	-4.3756	-6.5077	-8.4941
R_2	-0.9559	-3.5149	-11.6023	-13.0127	-12.0643	-13.4688
R_3	-2.8616	-4.0541	-15.1247	-16.0170	-12.2133	-15.1307

Notes: CHSASHR=Shanghai Stock Exchange A-share Index; CHSBSHR = Shanghai Stock Exchange B-share Index; CHZASHR = Shenzhen Stock Exchange A-share Index; CHZBSHR = Shenzhen Stock Exchange B-share Index

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Table 5: Estimation Results of Group 1 Stock Indices (May 22 1992 – Sep 30 2004)

Variable	η	β	α	γ	δ	μ_0	μ_1	Γ		π_1	π_2	LL (VC)	Corr (CC)		LL (CC)
Panel A: VC-GARCH															
TAIWGHT	0.0817	0.9048	0.0679	-	-	0.0451	0.0289	$\rho_{TH}=$	0.3701	0.9661	0.0242	-9958.9682	$\rho_{TH}=$	0.2414	-11107.55048
	(0.0271)	(0.0181)	(0.0121)			(0.0285)	(0.0171)		(0.0640)	(0.0057)	(0.0036)			(0.0183)	
								$\rho_{TS}=$	0.0633				$\rho_{TS}=$	0.0262	
HNGKNGI	0.0322	0.9163	0.0751	-	-	0.0575	0.0397		(0.0519)					(0.0171)	
	(0.0113)	(0.0126)	(0.0119)			(0.0235)	(0.0179)	$\rho_{TZ}=$	0.0675				$\rho_{TZ}=$	0.0273	
									(0.0526)					(0.0179)	
CHSCOMP	0.0178	0.9390	0.0671	-	-	-0.0287	0.0211	$\rho_{HS}=$	0.0182				$\rho_{HS}=$	0.0431	
	(0.0102)	(0.0134)	(0.0144)			(0.0379)	(0.0155)		(0.0260)					(0.0169)	
								$\rho_{HZ}=$	0.0310				$\rho_{HZ}=$	0.0543	
CHZCOMP	0.0183	0.9389	0.0667	-	-	-0.0458	0.0259		(0.0263)					(0.0169)	
	(0.0115)	(0.0149)	(0.0155)			(0.0404)	(0.0154)	$\rho_{SZ}=$	0.9947				$\rho_{SZ}=$	0.8647	
									(0.0050)					(0.0125)	
Panel B: VC-QGARCH															
TAIWGHT	0.1429	0.8709	0.0796	0.1557	-	0.0003	0.0333	$\rho_{TH}=$	0.3665	0.9661	0.0245	-9893.65	$\rho_{TH}=$	0.2385	-11047.32616
	(0.0500)	(0.0292)	(0.0144)	(0.0431)		(0.0008)	(0.0177)		(0.0651)	(0.0059)	(0.0037)			(0.0179)	
								$\rho_{TS}=$	0.0530				$\rho_{TS}=$	0.0226	
HNGKNGI	0.0490	0.9087	0.0753	0.0891	-	0.0201	0.0486		(0.0740)					(0.0165)	
	(0.0151)	(0.0130)	(0.0108)	(0.0260)		(0.0234)	(0.0183)	$\rho_{TZ}=$	0.0553				$\rho_{TZ}=$	0.0263	
									(0.0750)					(0.0174)	
CHSCOMP	0.0213	0.9390	0.0659	0.0379	-	-0.0613	0.0190	$\rho_{HS}=$	0.0109				$\rho_{HS}=$	0.0395	
	(0.0109)	(0.0131)	(0.0137)	(0.0162)		(0.0641)	(0.0202)		(0.0443)					(0.0193)	
								$\rho_{HZ}=$	0.0205				$\rho_{HZ}=$	0.0511	
CHZCOMP	0.0223	0.9387	0.0660	0.0432	-	-0.0798	0.0235		(0.0454)					(0.0192)	
	(0.0120)	(0.0139)	(0.0142)	(0.0165)		(0.0638)	(0.0191)	$\rho_{SZ}=$	0.9953				$\rho_{SZ}=$	0.8628	
									(0.0051)					(0.0127)	
Panel C: VC-APARCH															
TAIWGHT	0.1031	0.8866	0.0747	0.3214	1.8911	0.0004	0.0361	$\rho_{TH}=$	0.3716	0.9669	0.0240	-9863.37664	$\rho_{TH}=$	0.2386	-10935.42112
	(0.0353)	(0.0240)	(0.0147)	(0.0790)	(0.3014)	(0.0009)	(0.0180)		(0.0652)	(0.0058)	(0.0037)			(0.0179)	
								$\rho_{TS}=$	0.0538				$\rho_{TS}=$	0.0253	

Variable	η	β	α	γ	δ	μ_0	μ_1	Γ		π_1	π_2	LL (VC)	Corr (CC)		LL (CC)
HNGKNGI	0.0328	0.9220	0.0743	0.3703	1.4397	0.0122	0.0499		(0.0562)					(0.0176)	
	(0.0102)	(0.0105)	(0.0101)	(0.0791)	(0.1712)	(0.0285)	(0.0180)	$\rho_{TZ} =$	0.0556				$\rho_{TZ} =$	0.0267	
									(0.0571)					(0.0178)	
CHSCOMP	0.0149	0.9430	0.0720	0.1586	1.5711	-0.0830	0.0198	$\rho_{HS} =$	0.0045				$\rho_{HS} =$	0.0386	
	(0.0078)	(0.0110)	(0.0130)	(0.0548)	(0.1530)	(0.0595)	(0.0181)		(0.0280)					(0.0177)	
								$\rho_{HZ} =$	0.0140				$\rho_{HZ} =$	0.0511	
CHZCOMP	0.0154	0.9414	0.0723	0.1689	1.6379	-0.1015	0.0252		(0.0297)					(0.0177)	
	(0.0089)	(0.0122)	(0.0146)	(0.0515)	(0.1700)	(0.0589)	(0.0178)	$\rho_{SZ} =$	0.9949				$\rho_{SZ} =$	0.8769	
									(0.0053)					(0.0105)	

Notes:
1. All standard errors (in parenthesis) are the heteroskedastic-consistent Bollerslev-Wooldridge standard errors computed based on the Quasi-Maximum Likelihood Estimation (QMLE) technique.
2. Log-likelihood value (VC) and Log-likelihood value (CC) refer to the likelihood values obtained from the VC-GARCH(1,1) and CC-GARCH(1,1) models respectively.
3. Correlations (CC) refer to the conditional correlation coefficient obtained from the constant-correlation models.

Table 6: Estimation Results of Group 2 Stock Indices (Oct 5 1992 – Sep 30 2004)

Variable	η	β	α	γ	δ	μ_0	μ_1	Γ		π_1	π_2	LL (VC)	Corr (CC)		LL (CC)
Panel A: VC-GARCH															
TAIWGHT	0.0796	0.9043	0.0694	-	-	0.0536	0.0288	$\rho_{TH}=$	0.3250	0.9513	0.0321	-9506.8053	$\rho_{TH}=$	0.2447	-10529.84896
	(0.0271)	(0.0185)	(0.0125)			(0.0284)	(0.0174)		(0.0520)	(0.0077)	(0.0043)			(0.0185)	
								$\rho_{TS}=$	0.0696				$\rho_{TS}=$	0.0220	
HNGKNGI	0.0298	0.9196	0.0730	-	-	0.0666	0.0376		(0.0502)					(0.0190)	
	(0.0110)	(0.0126)	(0.0121)			(0.0240)	(0.0179)	$\rho_{TZ}=$	0.0686				$\rho_{TZ}=$	0.0338	
									(0.0509)					(0.0195)	
CHSASHR	0.0120	0.9386	0.0721	-	-	-0.0128	0.0198	$\rho_{HS}=$	0.0159				$\rho_{HS}=$	0.0452	
	(0.0081)	(0.0120)	(0.0142)			(0.0063)	(0.0128)		(0.0323)					(0.0169)	
								$\rho_{HZ}=$	0.0460				$\rho_{HZ}=$	0.0557	
CHZASHR	0.0124	0.9388	0.0710	-	-	-0.0288	0.0309		(0.0326)					(0.0171)	
	(0.0091)	(0.0136)	(0.0154)			(0.0092)	(0.0129)	$\rho_{SZ}=$	0.9856				$\rho_{SZ}=$	0.8851	
									(0.0042)					(0.0108)	
Panel B: VC-QGARCH															
TAIWGHT	0.1355	0.8733	0.0800	0.1518	-	0.0130	0.0323	$\rho_{TH}=$	0.3208	0.9502	0.0330	-9446.12208	$\rho_{TH}=$	0.2413	-10476.36016
	(0.0491)	(0.0290)	(0.0146)	(0.0430)		(0.0223)	(0.0176)		(0.0507)	(0.0077)	(0.0043)			(0.0182)	
								$\rho_{TS}=$	0.0631				$\rho_{TS}=$	0.0191	
HNGKNGI	0.0453	0.9122	0.0734	0.0865	-	0.0321	0.0457		(0.0628)					(0.0169)	
	(0.0147)	(0.0128)	(0.0109)	(0.0267)		(0.0231)	(0.0187)	$\rho_{TZ}=$	0.0618				$\rho_{TZ}=$	0.0328	
									(0.0630)					(0.0176)	
CHSASHR	0.0134	0.9392	0.0706	0.0317	-	-0.0172	0.0236	$\rho_{HS}=$	0.0115				$\rho_{HS}=$	0.0416	
	(0.0076)	(0.0115)	(0.0134)	(0.0158)		(0.0127)	(0.0155)		(0.1039)					(0.0182)	
								$\rho_{HZ}=$	0.0405				$\rho_{HZ}=$	0.0529	
CHZASHR	0.0141	0.9396	0.0692	0.0390	-	-0.0351	0.0334		(0.1006)					(0.0184)	
	(0.0083)	(0.0124)	(0.0139)	(0.0156)		(0.0151)	(0.0152)	$\rho_{SZ}=$	0.9859				$\rho_{SZ}=$	0.8840	
									(0.0041)					(0.0108)	
Panel C: VC-APARCH															
TAIWGHT	0.1006	0.8874	0.0746	0.3073	1.9472	0.0130	0.0352	$\rho_{TH}=$	0.3240	0.9499	0.0330	-9416.844	–		-
	(0.0356)	(0.0239)	(0.0151)	(0.0766)	(0.3217)	(0.0254)	(0.0176)		(0.0501)	(0.0078)	(0.0043)				
								$\rho_{TS}=$	0.0626				–		

Variable	η	β	α	γ	δ	μ_0	μ_1	Γ		π_1	π_2	LL (VC)	Corr (CC)	LL (CC)
HNGKNGI	0.0307 (0.0099)	0.9246 (0.0104)	0.0729 (0.0102)	0.3687 (0.0813)	1.4283 (0.1693)	0.0243 (0.0244)	0.0465 (0.0181)		(0.0498)					
								$\rho_{TZ} =$	0.0610 (0.0506)				–	
CHSASHR	0.0085 (0.0062)	0.9444 (0.0096)	0.0751 (0.0125)	0.1294 (0.0569)	1.5597 (0.1440)	-0.0155 (0.0129)	0.0229 (0.0165)	$\rho_{HS} =$	0.0094 (0.0341)				–	
								$\rho_{HZ} =$	0.0363 (0.0357)				–	
CHZASHR	0.0087 (0.0069)	0.9436 (0.0108)	0.0749 (0.0138)	0.1426 (0.0537)	1.5706 (0.1574)	-0.0335 (0.0156)	0.0322 (0.0170)	$\rho_{SZ} =$	0.9850 (0.0041)				–	

See Notes to Table 5.

Table 7:Estimation Results of Group 3 Indices (Oct 5 1992 – Sep 30 2004)

Variable	η	β	α	γ	δ	μ_0	μ_1	Γ		π_1	π_2	LL (VC)	Corr (CC)		LL (CC)
Panel A: VC-GARCH															
TAIWGHT	0.0791	0.9050	0.0675	-	-	0.0578	0.0182	$\rho_{TH}=$	0.3829	0.9761	0.0185	-11104.7754	$\rho_{TH}=$	0.2459	-11486.14112
	(0.0264)	(0.0180)	(0.0120)			(0.0284)	(0.0179)		(0.0713)	(0.0044)	(0.0028)			(0.0186)	
								$\rho_{TS}=$	0.0015				$\rho_{TS}=$	0.0632	
HNGKNGI	0.0297	0.9236	0.0665	-	-	0.0579	0.0195		(0.0867)					(0.0177)	
	(0.0105)	(0.0117)	(0.0107)			(0.0234)	(0.0175)	$\rho_{TZ}=$	0.0261				$\rho_{TZ}=$	0.0544	
									(0.0781)					(0.0174)	
CHSBSHR	0.2731	0.7377	0.2024	-	-	-0.0614	0.1196	$\rho_{HS}=$	0.1395				$\rho_{HS}=$	0.1769	
	(0.0702)	(0.0423)	(0.0336)			(0.0213)	(0.0192)		(0.0725)					(0.0189)	
								$\rho_{HZ}=$	0.1150				$\rho_{HZ}=$	0.1466	
CHZBSHR	0.3732	0.7040	0.2077	-	-	-0.0706	0.1180		(0.0694)					(0.0190)	
	(0.0930)	(0.0555)	(0.0423)			(0.0231)	(0.0189)	$\rho_{SZ}=$	0.8425				$\rho_{SZ}=$	0.6596	
									(0.0425)					(0.0186)	
Panel B: VC-QGARCH															
TAIWGHT	0.1345	0.8733	0.0782	0.1476	-	0.0182	0.0220	$\rho_{TH}=$	0.3764	0.9764	0.0183	-11055.97856	$\rho_{TH}=$	0.2429	-11434.43528
	(0.0493)	(0.0295)	(0.0143)	(0.0419)		(0.0227)	(0.0175)		(0.0686)	(0.0043)	(0.0027)			(0.0182)	
								$\rho_{TS}=$	-0.0075				$\rho_{TS}=$	0.0594	
HNGKNGI	0.0434	0.9167	0.0671	0.0736	-	0.0272	0.0270		(0.0735)					(0.0177)	
	(0.0137)	(0.0119)	(0.0096)	(0.0237)		(0.0232)	(0.0179)	$\rho_{TZ}=$	0.0185				$\rho_{TZ}=$	0.0525	
									(0.0718)					(0.0174)	
CHSBSHR	0.2711	0.7386	0.2017	-0.0108	-	-0.0584	0.1188	$\rho_{HS}=$	0.1350				$\rho_{HS}=$	0.1741	
	(0.0698)	(0.0427)	(0.0340)	(0.0408)		(0.0213)	(0.0189)		(0.0687)					(0.0186)	
								$\rho_{HZ}=$	0.1078				$\rho_{HZ}=$	0.1462	
CHZBSHR	0.3679	0.7066	0.2057	-0.0621	-	-0.0635	0.1162		(0.0660)					(0.0187)	
	(0.0911)	(0.0554)	(0.0425)	(0.0489)		(0.0229)	(0.0188)	$\rho_{SZ}=$	0.8399				$\rho_{SZ}=$	0.6598	
									(0.0432)					(0.0186)	
Panel C: VC-APARCH															
TAIWGHT	0.1003	0.8876	0.0730	0.3050	1.9338	0.0183	0.0248	$\rho_{TH}=$	0.3772	0.9763	0.0182	-11041.6836	$\rho_{TH}=$	0.2433	-11423.98776
	(0.0354)	(0.0241)	(0.0149)	(0.0776)	(0.03215)	(0.0230)	(0.0174)		(0.0676)	(0.0044)	(0.0027)			(0.0182)	

Variable	η	β	α	γ	δ	μ_0	μ_1	Γ		π_1	π_2	LL (VC)	Corr (CC)		LL (CC)
								$\rho_{TS} =$	-0.0042				$\rho_{TS} =$	0.0604	
HNGKNGI	0.0303	0.9280	0.0679	0.3436	1.4239	0.0182	0.0283		(0.0750)					(0.0180)	
	(0.0093)	(0.0096)	(0.0091)	(0.0785)	(0.1690)	(0.0232)	(0.0180)	$\rho_{TZ} =$	0.0177				$\rho_{TZ} =$	0.0514	
									(0.0749)					(0.0176)	
CHSBSHR	0.2066	0.7644	0.2013	-0.0048	1.4999	-0.0771	0.1126	$\rho_{HS} =$	0.1241				$\rho_{HS} =$	0.1715	
	(0.0573)	(0.0417)	(0.0312)	(0.0479)	(0.1628)	(0.0246)	(0.0192)		(0.0679)					(0.0186)	
								$\rho_{HZ} =$	0.1040				$\rho_{HZ} =$	0.1450	
CHZBSHR	0.3328	0.7196	0.2030	-0.0422	1.8446	-0.0788	0.1127		(0.0655)					(0.0187)	
	(0.0959)	(0.0563)	(0.0437)	(0.0412)	(0.2207)	(0.0268)	(0.0191)	$\rho_{SZ} =$	0.8493				$\rho_{SZ} =$	0.6636	
									(0.0412)					(0.0183)	

See Notes to Table 5.

Table 8: Estimation Results of Group 1 Stock Indices (May 22 1992 – Sep 30 2004)

Variable	η	φ	γ	δ	β	d	μ_0	μ_1	Γ		π_1	π_2	Corr (CC)	
Panel A: VC-FIGARCH														
TAIWGHT	0.3411	-0.0455	-	-	0.2169	0.3000	0.0530	0.0301	$\rho_{TH}=$	0.3965	0.9678	0.0244	$\rho_{TH}=$	0.2391
	(0.1283)	(0.1348)			(0.1592)	(0.0512)	(0.0270)	(0.0176)		(0.0745)	(0.0052)	(0.0036)		(0.0183)
									$\rho_{TS}=$	0.0685			$\rho_{TS}=$	0.0211
HNGKNGI	0.0967	0.2066	-	-	0.5406	0.3963	0.0612	0.0409		(0.0650)				(0.0153)
	(0.0582)	(0.1126)			(0.1683)	(0.1048)	(0.0240)	(0.0175)	$\rho_{TZ}=$	0.0701			$\rho_{TZ}=$	0.0231
										(0.0655)				(0.0164)
CHSCOMP	0.1500	0.1663	-	-	0.3845	0.3559	-0.0388	0.0298	$\rho_{HS}=$	0.0134			$\rho_{HS}=$	0.0444
	(0.0571)	(0.0934)			(0.0898)	(0.0430)	(0.0409)	(0.0176)		(0.0421)				(0.0166)
									$\rho_{HZ}=$	0.0313			$\rho_{HZ}=$	0.0546
CHZCOMP	0.1373	0.1355	-	-	0.3814	0.3684	-0.0541	0.0357		(0.0404)				(0.0164)
	(0.0594)	(0.1017)			(0.1009)	(0.0391)	(0.0436)	(0.0182)	$\rho_{SZ}=$	0.9872			$\rho_{SZ}=$	0.8218
										(0.0066)				(0.0110)
Panel B: VC-FIAGARCH														
TAIWGHT	-0.2218	-0.0911	0.9832	-	0.1053	0.2506	0.0114	0.0328	$\rho_{TH}=$	0.4085	0.9685	0.0242	$\rho_{TH}=$	0.2368
	(0.1850)	(0.0902)	(0.1787)		(0.1085)	(0.0432)	(0.0192)	(0.0173)		(0.0779)	(0.0052)	(0.0036)		(0.0182)
									$\rho_{TS}=$	0.0604			$\rho_{TS}=$	0.0186
HNGKNGI	-0.0500	0.1380	0.6740	-	0.3671	0.2957	0.0277	0.0505		(0.0667)				(0.0185)
	(0.1103)	(0.1690)	(0.1948)		(0.2105)	(0.0703)	(0.0240)	(0.0182)	$\rho_{TZ}=$	0.0607			$\rho_{TZ}=$	0.0219
										(0.0669)				(0.0193)
CHSCOMP	0.1316	0.1569	0.2427	-	0.3652	0.3456	-0.0700	0.0306	$\rho_{HS}=$	0.0026			$\rho_{HS}=$	0.0416
	(0.0621)	(0.0965)	(0.1272)		(0.0939)	(0.0419)	(0.0620)	(0.0185)		(0.0337)				(0.0167)
									$\rho_{HZ}=$	0.0183			$\rho_{HZ}=$	0.0514
CHZCOMP	0.0937	0.1420	0.3314	-	0.3679	0.3515	-0.0870	0.0363		(0.0342)				(0.0165)
	(0.0642)	(0.0979)	(0.1077)		(0.0962)	(0.0348)	(0.0610)	(0.0186)	$\rho_{SZ}=$	0.9870			$\rho_{SZ}=$	0.8214
										(0.0068)				(0.0109)
Panel C: VC-FIAPARCH														
TAIWGHT	0.3912	-0.0905	0.3428	1.8214	0.1367	0.2723	0.0095	0.0367	$\rho_{TH}=$	0.4031	0.9696	0.0234	$\rho_{TH}=$	0.2354
	(0.1307)	(0.1039)	(0.0783)	(0.2183)	(0.1286)	(0.0502)	(0.0236)	(0.0179)		(0.0807)	(0.0053)	(0.0035)		(0.0182)
									$\rho_{TS}=$	0.0606			$\rho_{TS}=$	0.0194

Variable	η	ϕ	γ	δ	β	d	μ_0	μ_1	Γ		π_1	π_2	Corr (CC)	
HNGKNGI	0.1532 (0.0818)	0.1915 (0.1528)	0.3932 (0.1112)	1.7817 (0.1634)	0.4391 (0.2365)	0.3060 (0.1191)	0.0209 (0.0243)	0.0522 (0.0178)	$\rho_{TZ}=$	(0.0737) 0.0604 (0.0716)			$\rho_{TZ}=$	(0.0153) 0.0227 (0.0161)
CHSCOMP	0.1565 (0.0703)	0.1521 (0.0954)	0.0980 (0.0517)	1.9811 (0.1734)	0.3736 (0.0921)	0.3504 (0.0404)	-0.0742 (0.0600)	0.0326 (0.0209)	$\rho_{HS}=$ $\rho_{HZ}=$	-0.0029 (0.1108) 0.0109			$\rho_{HS}=$ $\rho_{HZ}=$	0.0429 (0.0168) 0.0520
CHZCOMP	0.1329 (0.0818)	0.1236 (0.1001)	0.1313 (0.0468)	1.9967 (0.1857)	0.3640 (0.0984)	0.3566 (0.0341)	-0.0914 (0.0591)	0.0386 (0.0209)	$\rho_{SZ}=$	(0.0933) 0.9880 (0.0068)			$\rho_{SZ}=$	(0.0168) 0.8335 (0.0132)

Table 9: Estimation Results of Group 2 Stock Indices (Oct 5 1992 – Sep 30 2004)

Variable	η	ϕ	γ	δ	β	d	μ_0	μ_1	Γ		π_1	π_2	Corr (CC)	
Panel A: VC-FIGARCH														
TAIWGHT	0.3494	-0.0622	-	-	0.1982	0.3015	0.0610	0.0308	ρ_{TH} =	0.3384	0.9525	0.0337	ρ_{TH} =	0.2429
	(0.1499)	(0.1744)			(0.2046)	(0.0537)	(0.0275)	(0.0180)		(0.0594)	(0.0064)	(0.0041)		(0.0186)
									ρ_{TS} =	0.0745			ρ_{TS} =	0.0159
HNGKNGI	0.0890	0.2160	-	-	0.5725	0.4166	0.0712	0.0386		(0.0589)				(0.0146)
	(0.0553)	(0.1045)			(0.1665)	(0.1145)	(0.0247)	(0.0180)	ρ_{TZ} =	0.0717			ρ_{TZ} =	0.0313
										(0.0595)				(0.0153)
CHSASHR	0.1325	0.1565	-	-	0.3863	0.3731	-0.0161	0.0273	ρ_{HS} =	0.0077			ρ_{HS} =	0.0466
	(0.0517)	(0.0937)			(0.0896)	(0.0405)	(0.0125)	(0.0202)		(0.0308)				(0.0158)
									ρ_{HZ} =	0.0495			ρ_{HZ} =	0.0570
CHZASHR	0.1278	0.0924	-	-	0.3367	0.3726	-0.0298	0.0402		(0.0334)				(0.0159)
	(0.0585)	(0.1046)			(0.1056)	(0.0380)	(0.0139)	(0.0190)	ρ_{SZ} =	0.9763			ρ_{SZ} =	0.8491
										(0.0056)				(0.0096)
Panel B: VC-FIAGARCH														
TAIWGHT	-0.2241	-0.1128	0.9775	-	0.0858	0.2544	0.0177	0.0331	ρ_{TH} =	0.3438	0.9527	0.0338	ρ_{TH} =	0.2401
	(0.1899)	(0.1004)	(0.1759)		(0.1213)	(0.0437)	(0.0262)	(0.0170)		(0.0591)	(0.0063)	(0.0041)		(0.0185)
									ρ_{TS} =	0.0667			ρ_{TS} =	0.0140
HNGKNGI	-0.0343	0.1536	0.6286	-	0.4053	0.3146	0.0407	0.0469		(0.0692)				(0.0205)
	(0.0879)	(0.1678)	(0.1731)		(0.2153)	(0.0770)	(0.0242)	(0.0184)	ρ_{TZ} =	0.0627			ρ_{TZ} =	0.0300
										(0.0695)				(0.0208)
CHSASHR	0.1169	0.1597	0.1697	-	0.3766	0.3642	-0.0228	0.0309	ρ_{HS} =	-0.0012			ρ_{HS} =	0.0439
	(0.0557)	(0.1007)	(0.1254)		(0.0959)	(0.0396)	(0.0165)	(0.0179)		(0.1186)				(0.0171)
									ρ_{HZ} =	0.0408			ρ_{HZ} =	0.0547
CHZASHR	0.0809	0.1071	0.2714	-	0.3288	0.3554	-0.0386	0.0428		(0.1162)				(0.0173)
	(0.0631)	(0.1050)	(0.1066)		(0.1036)	(0.0338)	(0.0183)	(0.0173)	ρ_{SZ} =	0.9759			ρ_{SZ} =	0.8486
										(0.0057)				(0.0096)
Panel C: VC-FIAPARCH														
TAIWGHT	0.3917	-0.1239	0.3327	1.8765	0.0982	0.2692	0.0095	0.0367	ρ_{TH} =	0.3352	0.9522	0.0335	ρ_{TH} =	0.2384
	(0.1465)	(0.1198)	(0.0799)	(0.2451)	(0.1451)	(0.0498)	(0.0236)	(0.0179)		(0.0573)	(0.0078)	(0.0043)		(0.0184)
									ρ_{TS} =	0.0653			ρ_{TS} =	0.0149

Variable	η	ϕ	γ	δ	β	d	μ_0	μ_1	Γ		π_1	π_2	Corr (CC)	
HNGKNGI	0.1443 (0.0719)	0.2261 (0.1066)	0.3927 (0.1079)	1.6499 (0.1556)	0.5361 (0.1933)	0.3708 (0.1284)	0.0209 (0.0243)	0.0522 (0.0178)		(0.0574)				(0.0173)
									$\rho_{TZ} =$	0.0628 (0.0582)			$\rho_{TZ} =$	0.0305 (0.0177)
CHSASHR	0.1132 (0.0676)	0.1456 (0.0962)	0.0480 (0.0535)	2.0601 (0.1819)	0.3706 (0.0932)	0.3686 (0.0398)	-0.0742 (0.0600)	0.0326 (0.0209)	$\rho_{HS} =$	0.0003 (0.0342)			$\rho_{HS} =$	0.0453 (0.0175)
									$\rho_{HZ} =$	0.0373 (0.0353)			$\rho_{HZ} =$	0.0552 (0.0177)
CHZASHR	0.0993 (0.0843)	0.0877 (0.1043)	0.0797 (0.0461)	2.0513 (0.1922)	0.3236 (0.1058)	0.3633 (0.0339)	-0.0914 (0.0591)	0.0386 (0.0209)	$\rho_{SZ} =$	0.9770 (0.0060)			$\rho_{SZ} =$	0.8593 (0.0118)

Table 10: Estimation Results of Group 3 Stock Indices (Oct 5 1992 – Sep 30 2004)

Variable	η	φ	γ	δ	β	d	μ₀	μ₁	Γ	π₁	π₂	Corr (CC)
Panel A: VC-FIGARCH												
TAIWGHT	0.3361 (0.1355)	-0.0528 (0.1527)	-	-	0.1981 (0.1783)	0.2928 (0.0504)	0.0623 (0.0285)	0.0205 (0.0180)	$\rho_{TH}=$ 0.3924 (0.0873); $\rho_{TS}=$ 0.0095 (0.4402)	0.9746 (0.0035)	0.0201 (0.0022)	$\rho_{TH}=$ 0.2448 (0.0186); $\rho_{TS}=$ 0.0644 (0.0183)
HNGKNGI	0.0677 (0.0451)	0.2667 (0.0831)	-	-	0.6203 (0.1498)	0.4167 (0.1338)	0.0595 (0.0243)	0.0187 (0.0173)	$\rho_{TZ}=$ 0.0349 (0.3840)			$\rho_{TZ}=$ 0.0575 (0.0180)
CHSBSHR	0.3178 (0.1092)	-0.0513 (0.1149)	-	-	0.0111 (0.1204)	0.3487 (0.0583)	-0.0626 (0.0198)	0.1077 (0.0204)	$\rho_{HS}=$ 0.1569 (0.1610); $\rho_{HZ}=$ 0.1219 (0.1465)			$\rho_{HS}=$ 0.1799 (0.0193); $\rho_{HZ}=$ 0.1465 (0.0192)
CHZBSHR	0.2565 (0.1156)	-0.0206 (0.2067)	-	-	0.0166 (0.1973)	0.2921 (0.0397)	-0.0721 (0.0186)	0.1042 (0.0203)	$\rho_{SZ}=$ 0.8587 (0.0404)			$\rho_{SZ}=$ 0.6473 (0.0174)
Panel B: VC-FIAGARCH												
TAIWGHT	-0.2276 (0.1857)	-0.1013 (0.1474)	-0.9764 (0.1912)	-	0.0878 (0.1800)	0.2454 (0.0490)	0.0200 (0.0518)	0.0234 (0.0171)	$\rho_{TH}=$ 0.3936 (0.0902); $\rho_{TS}=$ 0.0060 (0.6580)	0.9750 (0.0033)	0.0198 (0.0022)	$\rho_{TH}=$ 0.2423 (0.0185); $\rho_{TS}=$ 0.0637 (0.0185)
HNGKNGI	-0.0138 (0.2322)	0.2169 (0.1568)	-0.5805 (0.4378)	-	0.4636 (0.2096)	0.3084 (0.0870)	0.0332 (0.0359)	0.0270 (0.0192)	$\rho_{TZ}=$ 0.0285 (0.4646)			$\rho_{TZ}=$ 0.0570 (0.0185)
CHSBSHR	0.3169 (0.1066)	-0.0508 (0.1470)	0.0013 (0.1234)	-	0.0085 (0.1621)	0.3466 (0.0584)	-0.0634 (0.0208)	0.1074 (0.0203)	$\rho_{HS}=$ 0.1492 (0.2105); $\rho_{HZ}=$ 0.1088 (0.1524)			$\rho_{HS}=$ 0.1789 (0.0193); $\rho_{HZ}=$ 0.1448 (0.0193)
CHZBSHR	0.2214 (0.2747)	0.0123 (1.1281)	0.1279 (0.1308)	-	0.0492 (1.1429)	0.2885 (0.0437)	-0.0689 (0.0183)	0.1031 (0.0204)	$\rho_{SZ}=$ 0.8558 (0.0424)			$\rho_{SZ}=$ 0.6491 (0.0170)
Panel C: VC-FIAPARCH												
TAIWGHT	0.3865 (0.1433)	-0.1088 (0.1122)	0.3358 (0.0819)	1.8504 (0.2419)	0.1065 (0.1358)	0.2630 (0.0480)	0.0167 (0.0235)	0.0277 (0.0172)	$\rho_{TH}=$ 0.3852 (0.0714); $\rho_{TS}=$ 0.0038	0.9754 (0.0032)	0.0194 (0.0022)	$\rho_{TH}=$ 0.2402 (0.0184); $\rho_{TS}=$ 0.0631

Variable	η	ϕ	γ	δ	β	d	μ_0	μ_1	Γ		π_1	π_2	Corr (CC)	
HNGKNGI	0.1236 (0.0652)	0.2667 (0.0725)	0.3562 (0.1081)	1.6074 (0.1562)	0.6073 (0.1836)	0.4031 (0.1682)	0.0219 (0.0242)	0.0296 (0.0179)	$\rho_{TZ} =$	(0.0852) 0.0268 (0.0822)			$\rho_{TZ} =$	(0.0175) 0.0557 (0.0175)
CHSBSHR	0.2863 (0.1700)	0.2260 (0.3558)	0.0112 (0.0453)	1.8130 (0.2185)	0.3195 (0.3842)	0.3698 (0.0654)	-0.0663 (0.0190)	0.1064 (0.0215)	$\rho_{HS} =$ $\rho_{HZ} =$	0.1392 (0.0705) 0.1034			$\rho_{HS} =$ $\rho_{HZ} =$	0.1698 (0.0183) 0.1399
CHZBSHR	0.3407 (0.2693)	-0.9355 (0.0416)	-0.0465 (0.0442)	2.0512 (0.1245)	-0.9445 (0.0383)	0.2654 (0.0333)	-0.0712 (0.0181)	0.1009 (0.0213)	$\rho_{SZ} =$	(0.0666) 0.8624 (0.0362)			$\rho_{SZ} =$	(0.0185) 0.6571 (0.0176)

Table 11: Asymmetry Parameter γ

	VC-FIAGARCH	VC-FIAPARCH	VC-QGARCH	VC-APARCH
Group 1				
TAIWGHT	0.9832 (0.1787)	0.3428 (0.0783)	0.1557 (0.0431)	0.3214 (0.0790)
HNGKNGI	0.6740 (0.1948)	0.3932 (0.1112)	0.0891 (0.0260)	0.3703 (0.0791)
CHSCOMP	0.2427 (0.1272)	0.0980 (0.0517)	0.0379 (0.0162)	0.1586 (0.0548)
CHZCOMP	0.3314 (0.1077)	0.1313 (0.0468)	0.0432 (0.0165)	0.1689 (0.0515)
Group 2				
TAIWGHT	0.9775 (0.1759)	0.3327 (0.0799)	0.1518 (0.0430)	0.3073 (0.0766)
HNGKNGI	0.6286 (0.1731)	0.3927 (0.1079)	0.0865 (0.0267)	0.3687 (0.0813)
CHSASHR	0.1697 (0.1254)	0.0480 (0.0535)	0.0317 (0.0158)	0.1294 (0.0569)
CHZASHR	0.2714 (0.1066)	0.0797 (0.0461)	0.0390 (0.0156)	0.1426 (0.0537)
Group 3				
TAIWGHT	0.9764 (0.1912)	0.3358 (0.0819)	0.1476 (0.0419)	0.3050 (0.0776)
HNGKNGI	0.5805 (0.4378)	0.3562 (0.1081)	0.0736 (0.0237)	0.3436 (0.0785)
CHSBSHR	-0.0013 (0.1234)	0.0112 (0.0453)	-0.0108 (0.0408)	-0.0048 (0.0479)
CHZBSHR	-0.1279 (0.1308)	-0.0465 (0.0442)	-0.0621 (0.0489)	-0.0422 (0.0412)

Notes: The Bollerslev-Wooldridge (1992) standard errors are given in parentheses.

Table 12: Fractional Differencing Parameter d

Group 1	CC-FIGARCH	VC-FIGARCH	CC-FIAGARCH	VC-FIAGARCH	CC-FIAPARCH	VC-FIAPARCH
TAIWGHT	0.2919 (0.0515)	0.3000 (0.0512)	0.2428 (0.0421)	0.2506 (0.0432)	0.2702 (0.0494)	0.2723 (0.0502)
HNGKNGI	0.3698 (0.0973)	0.3963 (0.1048)	0.2785 (0.0657)	0.2957 (0.0703)	0.2965 (0.1185)	0.3060 (0.1191)
CHSCOMP	0.3600 (0.0449)	0.3559 (0.0430)	0.3472 (0.0441)	0.3456 (0.0419)	0.3531 (0.0557)	0.3504 (0.0404)
CHZCOMP	0.3876 (0.0379)	0.3684 (0.0391)	0.3727 (0.0333)	0.3515 (0.0348)	0.3817 (0.0430)	0.3566 (0.0341)
Group 2	CC-FIGARCH	VC-FIGARCH	CC-FIAGARCH	VC-FIAGARCH	CC-FIAPARCH	VC-FIAPARCH
TAIWGHT	0.2910 (0.0522)	0.3015 (0.0537)	0.2440 (0.0423)	0.2544 (0.0437)	0.2656 (0.0494)	0.2692 (0.0498)
HNGKNGI	0.3838 (0.1042)	0.4166 (0.1145)	0.2924 (0.0705)	0.3146 (0.0770)	0.3634 (0.1258)	0.3708 (0.1284)
CHSASHR	0.3722 (0.0395)	0.3731 (0.0405)	0.3662 (0.0403)	0.3642 (0.0396)	0.3652 (0.0462)	0.3686 (0.0398)
CHZASHR	0.3792 (0.0333)	0.3726 (0.0380)	0.3668 (0.0313)	0.3554 (0.0338)	0.3744 (0.0367)	0.3633 (0.0339)
Group 3	CC-FIGARCH	VC-FIGARCH	CC-FIAGARCH	VC-FIAGARCH	CC-FIAPARCH	VC-FIAPARCH
TAIWGHT	0.2897 (0.0519)	0.2928 (0.0504)	0.2438 (0.0421)	0.2454 (0.0490)	0.2653 (0.0491)	0.2630 (0.0480)
HNGKNGI	0.3638 (0.0969)	0.4167 (0.1338)	0.2819 (0.0674)	0.3084 (0.0870)	0.3606 (0.1268)	0.4031 (0.1682)
CHSBSHR	0.3693 (0.0944)	0.3487 (0.0583)	0.3740 (0.0929)	0.3466 (0.0584)	0.3773 (0.0549)	0.3698 (0.0654)
CHZBSHR	0.2056 (0.0474)	0.2921 (0.0397)	0.3093 (0.0620)	0.2885 (0.0437)	0.2902 (0.0421)	0.2654 (0.0333)

Notes: The Bollerslev-Wooldridge (1992) standard errors are given in parentheses.

Table 13: Conditional Correlation Matrix Γ_t

Model	VC-GARCH	VC-QGARCH	VC-APARCH	VC-FIGARCH	VC-FIAGARCH	VC-FIAPARCH
Group 1						
TAIWGHT-HNGKNGI	0.3701 (0.0640)	0.3665 (0.0651)	0.3716 (0.0652)	0.3965 (0.0745)	0.4085 (0.0779)	0.4031 (0.0807)
TAIWGHT-CHSCOMP	0.0633 (0.0519)	0.0530 (0.0740)	0.0538 (0.0562)	0.0685 (0.0650)	0.0604 (0.0667)	0.0606 (0.0737)
TAIWGHT-CHZCOMP	0.0675 (0.0526)	0.0553 (0.0750)	0.0556 (0.0571)	0.0701 (0.0655)	0.0607 (0.0669)	0.0604 (0.0716)
HNGKNGI-CHSCOMP	0.0182 (0.0260)	0.0109 (0.0443)	0.0045 (0.0280)	0.0134 (0.0421)	0.0026 (0.0337)	-0.0029 (0.1108)
HNGKNGI-CHZCOMP	0.0310 (0.0263)	0.0205 (0.0454)	0.0140 (0.0297)	0.0313 (0.0404)	0.0183 (0.0342)	0.0109 (0.0933)
CHSCOMP-CHZCOMP	0.9947 (0.0050)	0.9953 (0.0051)	0.9949 (0.0053)	0.9872 (0.0066)	0.9870 (0.0068)	0.9880 (0.0068)
π_1	0.9661 (0.0057)	0.9661 (0.0059)	0.9669 (0.0058)	0.9678 (0.0052)	0.9685 (0.0052)	0.9696 (0.0053)
π_2	0.0242 (0.0036)	0.0245 (0.0037)	0.0240 (0.0037)	0.0244 (0.0036)	0.0242 (0.0036)	0.0234 (0.0035)
Group 2						
TAIWGHT-HNGKNGI	0.3250 (0.0520)	0.3208 (0.0507)	0.3240 (0.0501)	0.3384 (0.0594)	0.3438 (0.0591)	0.3352 (0.0573)
TAIWGHT-CHSASHR	0.0696 (0.0502)	0.0631 (0.0628)	0.0626 (0.0498)	0.0745 (0.0589)	0.0667 (0.0692)	0.0653 (0.0574)
TAIWGHT-CHZASHR	0.0686 (0.0509)	0.0618 (0.0630)	0.0610 (0.0506)	0.0717 (0.0595)	0.0627 (0.0695)	0.0628 (0.0582)
HNGKNGI-CHSASHR	0.0159 (0.0323)	0.0115 (0.1039)	0.0094 (0.0341)	0.0077 (0.0308)	-0.0012 (0.1186)	0.0003 (0.0342)
HNGKNGI-CHZASHR	0.0460 (0.0326)	0.0405 (0.1006)	0.0363 (0.0357)	0.0495 (0.0334)	0.0408 (0.1162)	0.0373 (0.0353)
CHSASHR-CHZASHR	0.9856 (0.0042)	0.9859 (0.0041)	0.9850 (0.0041)	0.9763 (0.0056)	0.9759 (0.0057)	0.9770 (0.0060)
π_1	0.9513 (0.0077)	0.9502 (0.0077)	0.9499 (0.0078)	0.9525 (0.0064)	0.9527 (0.0063)	0.9522 (0.0078)
π_2	0.0321 (0.0043)	0.0330 (0.0043)	0.0330 (0.0043)	0.0337 (0.0041)	0.0338 (0.0041)	0.0335 (0.0043)
Group 3						
TAIWGHT-HNGKNGI	0.3829 (0.0713)	0.3764 (0.0686)	0.3772 (0.0676)	0.3924 (0.0873)	0.3936 (0.0902)	0.3852 (0.0714)

Model	VC-GARCH	VC-QGARCH	VC-APARCH	VC-FIGARCH	VC-FIAGARCH	VC-FIAPARCH
TAIWGHT-CHSBSHR	0.0015 (0.0867)	-0.0075 (0.0735)	-0.0042 (0.0750)	0.0095 (0.4402)	0.0060 (0.6580)	0.0038 (0.0852)
TAIWGHT-CHZBSHR	0.0261 (0.0781)	0.0185 (0.0718)	0.0177 (0.0749)	0.0349 (0.3840)	0.0285 (0.4646)	0.0268 (0.0822)
HNGKNGI-CHSBSHR	0.1395 (0.0725)	0.1350 (0.0687)	0.1241 (0.0679)	0.1569 (0.1610)	0.1492 (0.2105)	0.1392 (0.0705)
HNGKNGI-CHZBSHR	0.1150 (0.0694)	0.1078 (0.0660)	0.1040 (0.0655)	0.1219 (0.1465)	0.1088 (0.1524)	0.1034 (0.0666)
CHSBSHR-CHZBSHR	0.8425 (0.0425)	0.8399 (0.0432)	0.8493 (0.0412)	0.8587 (0.0404)	0.8558 (0.0424)	0.8624 (0.0362)
π_1	0.9761 (0.0044)	0.9764 (0.0043)	0.9763 (0.0044)	0.9746 (0.0035)	0.9750 (0.0033)	0.9754 (0.0032)
π_2	0.0185 (0.0028)	0.0183 (0.0027)	0.0182 (0.0027)	0.0201 (0.0022)	0.0198 (0.0022)	0.0194 (0.0022)

Notes: The Bollerslev-Wooldridge (1992) standard errors are given in parentheses.

Table 14: Likelihood Ratio Tests

Model	LL	Model	LL	LR
Group 1				
CC-GARCH	-11107.5505	VC-GARCH	-9958.9682	2297.1645
CC-APARCH	-10935.4211	VC-APARCH	-9863.3766	2144.0890
CC-QGARCH	-11047.3262	VC-QGARCH	-9893.6500	2307.3523
CC-FIGARCH	-11008.1868	VC-FIGARCH	-9818.2084	2379.9568
CC-FIAPARCH	-10902.5363	VC-FIAPARCH	-9733.6106	2337.8514
CC-FIAGARCH	-10930.9398	VC-FIAGARCH	-9747.5383	2366.8029
Group 2				
CC-GARCH	-10529.8490	VC-GARCH	-9506.8053	2046.0874
CC-QGARCH	-10476.3602	VC-QGARCH	-9446.1221	2060.4762
CC-FIGARCH	-10428.0326	VC-FIGARCH	-9364.3562	2127.3528
CC-FIAPARCH	-10340.1670	VC-FIAPARCH	-9289.5970	2101.1402
CC-FIAGARCH	-10363.2517	VC-FIAGARCH	-9298.0113	2130.4808
Group 3				
CC-GARCH	-11486.1411	VC-GARCH	-11104.7754	762.7315
CC-APARCH	-11423.9878	VC-APARCH	-11041.6836	764.6083
CC-QGARCH	-11434.4353	VC-QGARCH	-11055.9786	756.9134
CC-FIGARCH	-11406.1269	VC-FIGARCH	-10965.0476	882.1586
CC-FIAPARCH	-11328.1771	VC-FIAPARCH	-10899.9539	856.4464
CC-FIAGARCH	-11353.8893	VC-FIAGARCH	-10912.2470	883.2846

Notes: LL stands for log-likelihood value. LR is the likelihood ratio statistic.

Figure 1: Conditional Correlations (VC-FIAPARCH)
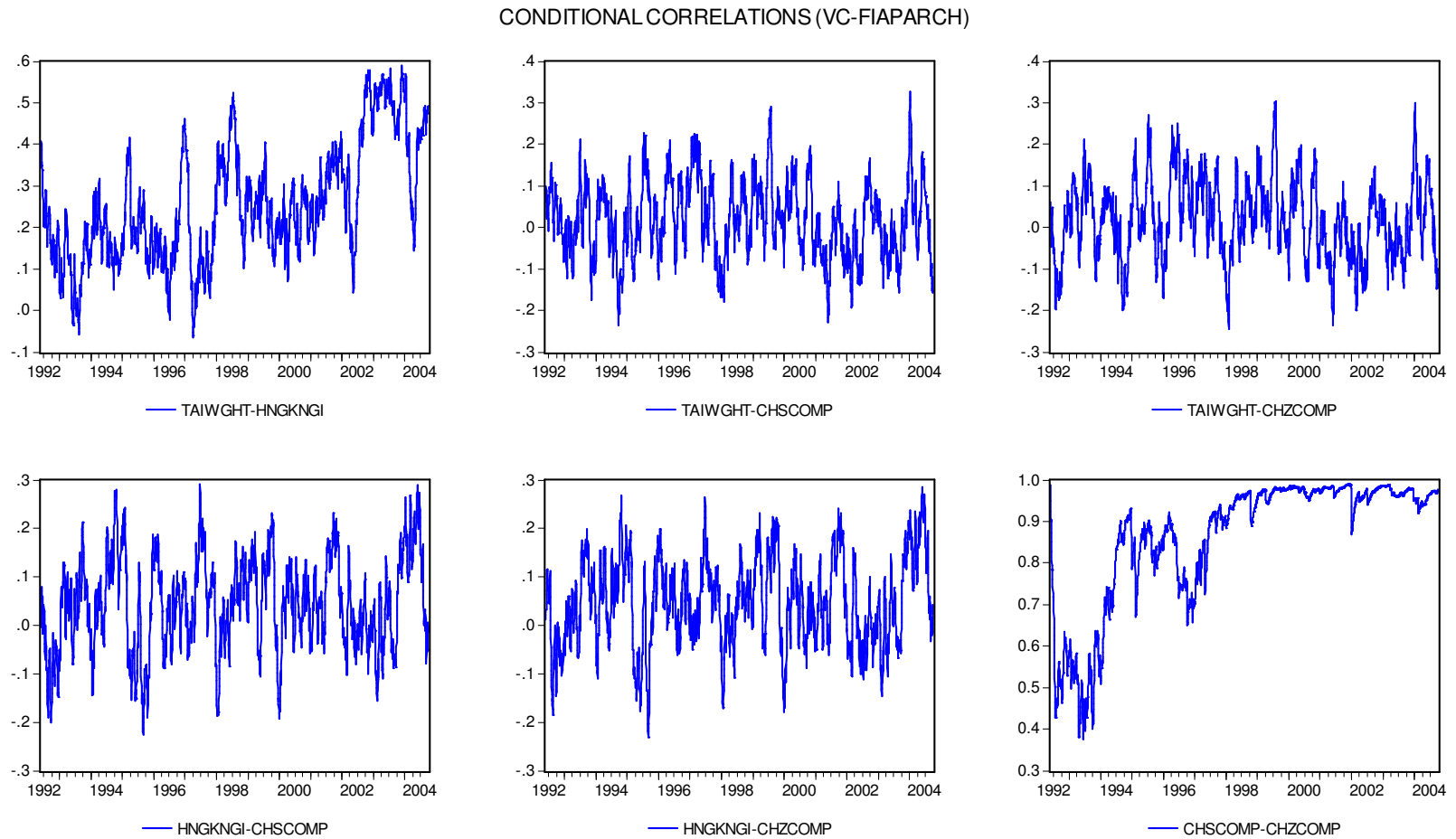

CONDITIONAL CORRELATIONS (VC-FIAPARCH)

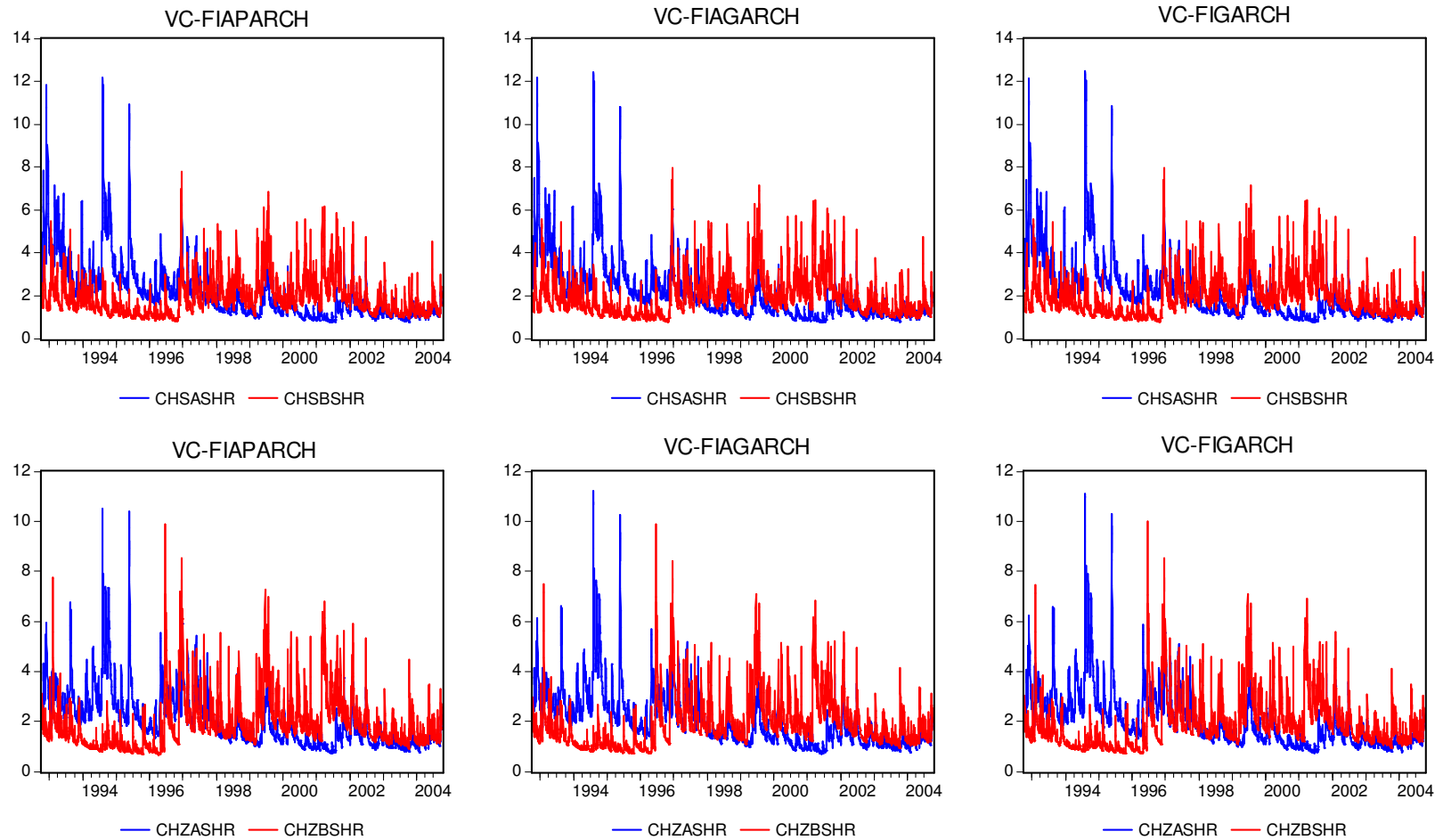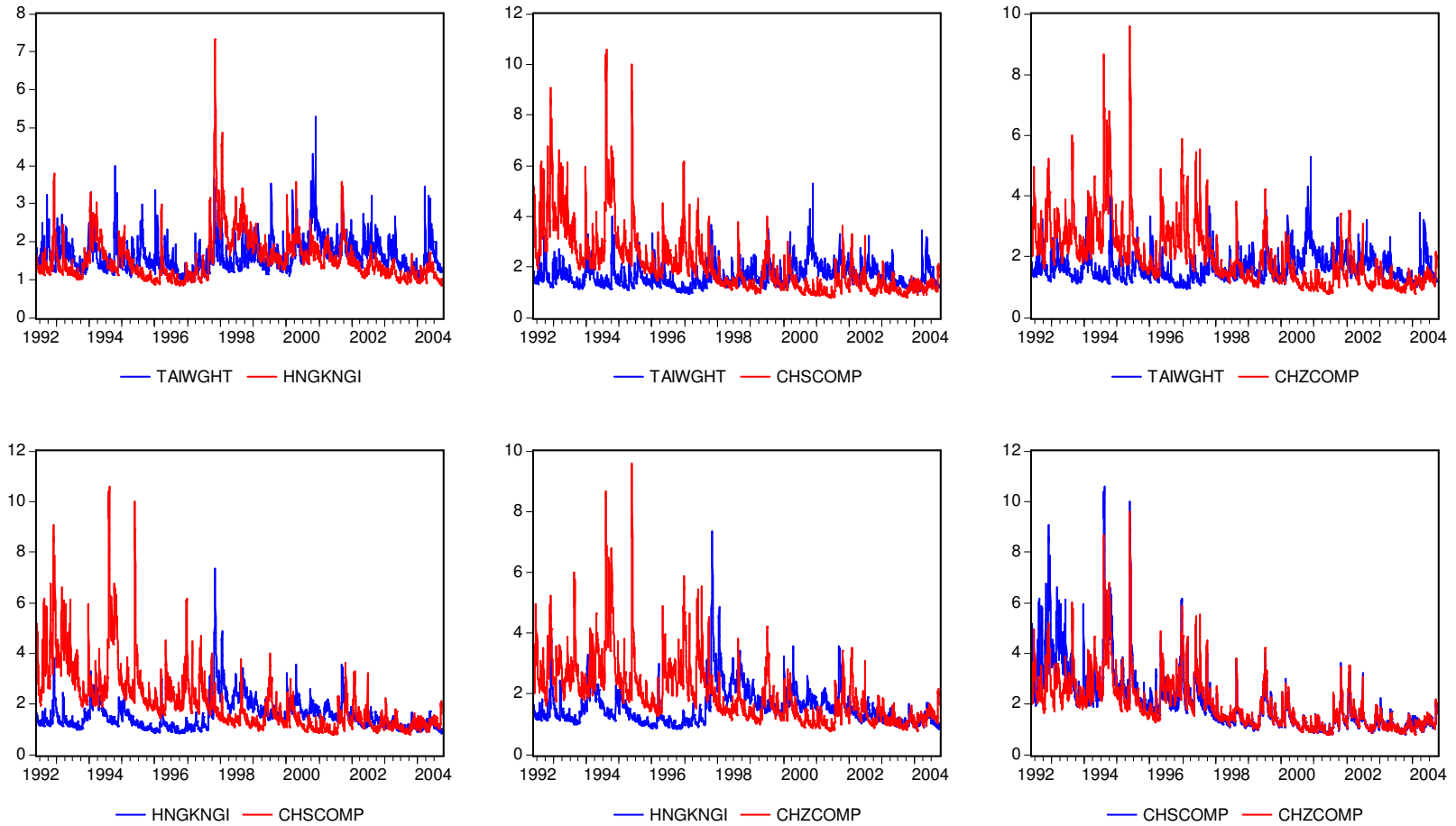Figure 2: Conditional Volatility (A-share, B-share)

Figure 3: Conditional Volatility (VC-FIAPARCH)

Data Appendix

Three groups of data sets are used in this paper:

Data Set	Dates	DataStream International Full Name	Mnemonic
Group 1			
Taiwan Weighted Index Hong Kong Hang Seng Index Shanghai Composite Index Shenzhen Composite Index	May 22 1992 – September 30 2004	TAIWAN SE WEIGHTED - PRICE INDEX HANG SENG - PRICE INDEX SHANGHAI SE COMPOSITE - PRICE INDEX SHENZHEN SE COMPOSITE - PRICE INDEX	TAIWGHT(PI) HNGKNGI(PI) CHSCOMP(PI) CHZCOMP(PI)
Group 2			
Taiwan Weighted Index Hong Kong Hang Seng Index Shanghai A-Share Index Shenzhen A-Share Index	October 5 1992 – September 30 2004	TAIWAN SE WEIGHTED - PRICE INDEX HANG SENG - PRICE INDEX SHANGHAI SE A SHARE - PRICE INDEX SHENZHEN SE A SHARE - PRICE INDEX	TAIWGHT(PI) HNGKNGI(PI) CHSASHR(PI) CHZASHR(PI)
Group 3			
Taiwan Weighted Index Hong Kong Hang Seng Index Shanghai B-Share Index Shenzhen B-Share Index	October 5 1992 – September 30 2004	TAIWAN SE WEIGHTED - PRICE INDEX HANG SENG - PRICE INDEX SHANGHAI SE B SHARE - PRICE INDEX SHENZHEN SE B SHARE - PRICE INDEX	TAIWGHT(PI) HNGKNGI(PI) CHSBSHR(PI) CHZBSHR(PI)