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Long-run equilibrium, short-term adjustment, and spillover effects across Chinese segmented stock markets and the Hong Kong stock market

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Abstract

This paper adopts a novel FIVECM-BEKK GARCH approach to examine the bilateral relationships among the A-share and B-share stock markets in China and the Hong Kong stock market. The evidence shows that these stock markets are fractionally cointegrated. Analyses of the spillover effects across these markets indicate that the A-share markets are most influential. The relaxation of government restrictions on the purchase of B shares by domestic residents accelerates the market integration process of A-share markets with the B-share and Hong Kong markets. The effects of the Asian crisis on the stock-return dynamic correlations vary across these markets.

JEL classification: G10; C32; F36

Keywords: Stock market segmentation; Cointegration; FIVECM; Multivariate GARCH

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1. Introduction

As a mechanism for developing the Chinese stock market, the Chinese government has adopted a market segmentation policy that divides its stock market into a domestic board and a foreign board to cater to the needs of different investors. Companies can issue A shares, which only Chinese citizens living in mainland China can buy; they are also allowed to issue B shares, which can be bought by foreign investors, including Chinese investors residing in Hong Kong (HK), Macau, or Taiwan.[1] A and B shares are listed on the Shanghai (SH) Stock Exchange (SHSE) and the Shenzhen (SZ) Stock Exchange (SZSE), namely, SHA, SHB, SZA, and SZB in mainland China. A shares are denominated in the local currency (RMB), while B shares are denominated in U.S. dollars on the SHSE and in HK dollars on the SZSE. Because of the isolation of Chinese currency from foreign currencies, different information environments, diverse regulatory policies, and heterogeneous investors, the segmented markets have shown various patterns of evolution.

Hong Kong is an important partner of mainland China for her location, economic development, and political relationship. From both geographical and strategic points of view, Hong Kong acts as an intermediary for China's international trade through

[1] This restriction was relaxed on February 22, 2001, when it became permissible for domestic citizens to buy and sell B shares.

re-exports and offshore transactions. In addition, a substantial amount of capital to finance China's economic expansion has been raised through Hong Kong's channels. However, this intermediary role for managing and engaging international trade and capital also shapes Hong Kong's economic structure, leading to her economic prosperity. These multilateral economic activities help in bridging know-how gap, transferring technology, disseminating and processing information, creating investment opportunities, and generating higher return, but they also assume higher risk for stock markets in both Hong Kong and mainland China. It is this unique setting as well as the increasingly important role played in world financial markets that prompts us to explore the explicit long-run equilibrium, short-run adjustment, and spillover effects across the mainland China stock markets on two stock exchanges (SHSE and SZSE) and the HK stock market.

In this study, we incorporate a fractionally integrated vector error correction model (FIVECM) into the BEKK GARCH framework (Engle and Kroner, 1995) to examine the bilateral relationships between each of the following six pairs of stock markets: HK-SHA, SHB-SHA, and SHB-HK; HK-SZA, SZB-SZA, and SZB-HK. This finding will be very useful to investors, since the presence of the fractional cointegration implies the existence of both long-run co-memories and long-periodic comovements between the two markets. As a result, it would affect investors' asset allocation strategies in the long and medium terms (Cheung and Lai, 1995). At the same time, the presence of a fractional cointegrating relationship between two stock markets has an important implication for their short-run linkages. As a generalization of the standard linear VECM, which allows only the first-order lag of the cointegration residual to affect the equilibrium relationship, the FIVECM specification is appealing, since it not only helps investors to observe short-run adjustments and long-term equilibrium relationships among co-integrated variables, but also accounts for the possible long memory in the cointegration residual series that otherwise might distort the estimation (Ding et al., 1993). Finally, incorporating the FIVECM into a bivariate BEKK formulation allows us to capture the second moment autocorrelations of the return series and analyze the first and second moment spillover effects across these stock markets simultaneously.

Our empirical results show that all six pairs of stock markets are fractionally cointegrated. In each of the six pairs, only one market adjusts to return to equilibrium. We also find bi-directional volatility spillover effects between the A-share markets and the B-share markets and between the B-share markets and the Hong Kong market. However, we find only unidirectional volatility spillover effects from the A-share stock markets to the Hong Kong stock market. The evidence concludes that the A shares are the most influential markets in both mean and volatility spillover effects. Investigation of the dynamic path of correlation coefficients suggests that relaxation of government restrictions on the purchase of B shares by domestic residents increased the correlation between the A- and B-share markets and accelerated the market integration process of the A-share markets with the Hong Kong stock market. Our results also suggest that the Asian crisis had a different spillover effect on stock-return dynamic correlations across Chinese segmented markets and the Hong

Kong stock market.

The remainder of this paper is organized as follows. Section 2 offers a review of the relevant literature. Section 3 discusses the data and methodology. Section 4 provides empirical results, and Section 5 summarizes our conclusions and comments.

2. Literature review

Much empirical work has been done on analyzing the Chinese segmented stock markets and the linkages between Chinese segmented stock markets and international stock markets. For instance, Li et al. (2006) find that the risk premiums associated with the Hong Kong and mainland Chinese markets in a two-factor model successfully explain the cross section of returns on the A and H shares. They conclude that the risk premiums associated with the segmented A-share and H-share markets exert crucial impacts on the price differentials between the two classes of shares. Chakravarty et al. (1998) report the bivariate return correlations among the A- and B-share indices, as well as Hong Kong, Japanese, and U.S. market indices and suggest that the Chinese market is still isolated, even after the introduction of B shares. Wang and Firth (2004) find a unidirectional returns spillover effect from developed stock markets to stock indices in the Greater China economic zone.

Several groups have applied Granger causality tests to determine the lead-lag relationships between the A-share and B-share markets. For example, Kim and Shin (2000) find that the A-share markets lead the B-share markets before 1996, but the relationship either disappears or reverses after 1996. On the other hand, Laurence et al.

(1997) observe a causal relationship from the SHB to all other Chinese markets and feedback from SHA and SZB to SHB. In addition, adopting VAR and bivariate GARCH-M models, Yeh et al. (2002) find that the unexpected changes in the premium ratio of A-share price over B-share price contribute to the return volatility of both A and B shares. Chiang et al. (2007) present evidence that the correlation coefficients between A-share and B-share stock returns are time varying. Their results suggest that the time-varying correlations are significantly associated with excessive trading activity measured by excessive trading volumes and high-low price differentials.

Our work extends the existing literature in the following two ways. First, our paper is the first to examine the equilibrium mechanism among segmented Chinese stock markets and the Hong Kong stock market. The FIVECM approach is a more general specification because it contains both the traditional VECM and the effects of the long memory of the cointegrating relationship, which is important for revealing the true relationships among markets. Second, by combining the FIVECM with a bivariate BEKK-GARCH formulation, this model allows us to investigate Chinese stock-return linkages in a multivariate framework. Different from previous studies that mainly use univariate models, the bivariate BEKK-GARCH method enables us to detect the conditional correlations between these markets. Within this novel framework, empirical lead-lag relationships in the mean as well as volatility in a cross-market setting can be simultaneously estimated. The empirical results derived from this research reveal the nature of the complicated structure between two different markets, which, in turn, provides additional information to investors and fund managers for their investment decisions and strategies in these markets. Our findings are also useful for policy makers in setting regulations for these markets.

3. Data and methodology

3.1. Data

The data in this study include price indices of Shanghai A-share (SHA), Shenzhen A-share (SZA), Shanghai B-share (SHB), Shenzhen B-share (SZB), and Hong Kong Hang Seng (HK). All data are taken from *DataStream International*, covering January 1995 through December 2005. In light of the evidence of the unusual pattern of the day-of-the-week effect observed by Cai et al. (2006), in this paper we employ weekly Wednesday indices to alleviate the impact of noise created by using daily data and to avoid day-of-the-week effects.[2]

3.2. Methodology

One of the principal tasks in this paper is to examine stock-return behavior by exploring the short-run dynamics in relation to the long-run equilibrium in a cross-market setting. To achieve this end, we employ the cointegration test to examine whether two series that drifted apart in long-run equilibrium have a tendency to be brought back together again. Usually, the disequilibrium error used in the VECM framework is neither $I(1)$ nor $I(0)$ but follows a fractionally integrated process, $I(d)$, where $-0.5<d<0.5$ (Engle and Granger, 1987). Without accounting for the long memory (when $d<0.5$) feature of the disequilibrium error, the true relationships

[2] Cai et al. (2006) find that average Monday returns from A-share indices are significantly negative during the third and fourth weeks but average Tuesday returns on most of the A-share and B-share indices are negative during the second week of the month.

among cointegrated variables disclosed by traditional VECM may be misspecified. To circumvent this problem, we employ a fractionally integrated VECM (Baillie, 1996) to study the nature of comovements for each pair of stock-return series.

First, we employ the Engle-Granger (1987) two-step approach by fitting the following dynamic ordinary least squared model (*DOLS*) (Saikkonen, 1991) to the pairs of stock indices and thereafter obtain the estimated cointegrating residual $\hat{z}_t$:

$$y_{1t} = \alpha + \beta y_{2t} + \sum_{j=-p}^{p} \omega_j \Delta y_{2t-j} + v_t$$

$$\hat{z}_t = y_{1t} - \hat{\beta} y_{2t} . \tag{1}$$

where y_{1t} and y_{2t} are a pair of stock indices in natural logarithms; each could represent SHA, SHB, SZA, SZB, and HK. By using this procedure, we can remove the deleterious effect of short-run dynamics in the equilibrium error v_t and obtain the estimate $\hat{\beta}$, which is super-consistent as well as efficient (Stock and Watson, 1993).

Next, to test for the existence of any long memory in the $\hat{z}_t$ series, we use Lo's modified R/S test (Lo, 1991). If we confirm that $\hat{z}_t$ follows an *I(d)* (-0.5<d<0.5) process, then y_{1t} and y_{2t} are said to be fractionally cointegrated. In this situation, we proceed to fit the following autoregressive fractionally integrated moving average (ARFIMA) model:[3]

$$\Psi(L)^{-1}\Phi(L)(1-L)^d \hat{z}_t = a_t \tag{2}$$

where $\Psi(L)$ and $\Phi(L)$ are MA and AR polynomials, L is a backward shift operator,

[3] For $0 < d < 0.5$, the ARFIMA process is said to possess a long memory or long-range dependence. When $d = 0$, an ARFIMA process can be reduced to the conventional ARMA process. For $-0.5 < d < 0$, it has a short memory. For $0.5 < d < 1$, the process is mean-reverting because there exists a non-long-run effect of an innovation on the future values of the process. For $d > 1$, the process is not mean-reverting, since any shock to the process could make it drift away from its equilibrium permanently. See Baillie (1996) for more information.

and a_t is an i.i.d. noise. If there is any cointegration relationship among the variables, a VECM representation can be established to adequately capture the relevant long-run and short-term relationships (Engle and Granger, 1987). We incorporate the VECM into the following bivariate FIVECM to account for the fractional integration property in $\hat{z}_t$ series by employing the ARFIMA model (2):

$$\begin{aligned}\Delta y_{1t} &= c_1 + \alpha_1 a_{t-1} + \sum_{i=1}^{m} \phi_{11}^{i} \Delta y_{1t-i} + \sum_{i=1}^{m} \phi_{12}^{i} \Delta y_{2t-i} + \varepsilon_{1t} \\ \Delta y_{2t} &= c_2 + \alpha_2 a_{t-1} + \sum_{i=1}^{m} \phi_{21}^{i} \Delta y_{1t-i} + \sum_{i=1}^{m} \phi_{22}^{i} \Delta y_{2t-i} + \varepsilon_{2t}.\end{aligned} \quad (3)$$

Both Δy_{1t} and Δy_{2t} in equation (3) represent the return series for each pair of stock indices, namely, HK-SHA, SHB-SHA, SHB-HK, HK-SZA, SZB-SZA, and SZB-HK in this study; $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is the vector of error terms; and the coefficients α_1 and α_2 indicate the short-run dynamic adjustments with their magnitudes representing the speeds of the adjustment. A VAR (*m*) structure in the VECM model, in particular *m*=1, is employed in this paper.

To capture the heteroskedasticity in the return series and to ensure that the variance matrix of error terms is positive definite, we apply the following bivariate BEKK (1, 1) model (Engle and Kroner, 1995):[4]

$\varepsilon_t \mid \Omega_{t-1} \sim N(0, \Sigma_t)$ for t =1, 2, ….. T;

$$\Sigma_t = \begin{pmatrix} \sigma_{11,t} & \sigma_{12,t} \\ \sigma_{21,t} & \sigma_{22,t} \end{pmatrix} = A_0 A_0' + A_1 (\varepsilon_{t-1} \varepsilon_{t-1}') A_1' + B_1 \Sigma_{t-1} B_1', \quad (4)$$

where ε_t is assumed to follow a bivariate normal distribution conditional on the past information set Ω_{t-1}; Σ_t denotes the variance-covariance matrix of ε_t, which is symmetric and positive semi-definite; A_0 is a lower triangular matrix; and A_1 and

[4] BEKK (1, 1) is usually sufficient to model volatility in financial time series.

B_1 are unrestricted square matrices. On the basis of this framework, the volatility spillover effects across return series indicated by the off-diagonal entries of coefficient matrices A_1 and B_1 are estimated.

The BEKK specification is a more general and flexible multivariate GARCH model as there are no restrictions imposed on the coefficients. In this paper, we estimate the FIVECM-BEKK model (i.e., systems (3) and (4) jointly) in which the coefficient estimates would be more efficient, and the relationships among the series would be delineated more accurately.

4. Empirical results

A summary of the basic statistics of the natural logarithm value of price indices is reported in Table 1. By conducting the ADF and PP unit root tests to test their stationarity property, the results indicate that all of these series are I (1).[5] The next step is to estimate the six cointegration residuals $\hat{z}_t$ based on Equation (1) for the six pairs of stock indices: HK-SHA, SHB-SHA, and SHB-HK; HK-SZA, SZB-SZA, and SZB-HK. This is done by performing a *DOLS* estimation with lag length *p*=2. The resulting error series are denoted by z_{SHA}^{HK}, z_{SHA}^{SHB}, z_{HK}^{SHB}, z_{SZA}^{HK}, z_{SZA}^{SZB} and z_{HK}^{SZB}, respectively, where the superscript stands for the dependent variable, and the subscript for the independent variable.

We use Lo's modified R/S test (Lo, 1991) to examine the long-memory behavior in the six residual series, and the results are contained in Table 2. The evidence indicates that all residual series have long memory. This finding leads us to apply

[5] The results are available on request.

the ARFIMA model to model each of these six series. It may be seen from Table 3 that all of the estimated values of d fall into the range (0, 0.5) and the estimated coefficients of the AR terms meet the stationarity condition, suggesting that the cointegrating variables follow long-memory stationary processes. We, therefore, conclude that the six pairs of stock markets are fractionally cointegrated with each other.

Having verified the feature of the long-term cointegration relationships in each pair of the stock indices, we proceed to estimate the FIVECM-BEKK(1,1), and the results are presented in Table 4. The estimated statistics allow us to analyze the short-term adjustment, the long-term equilibrium relationship, and the spillover effects between each segmented Chinese market and the HK market. Specifically, the estimated coefficient ϕ_{12}^{1} (ϕ_{21}^{1}) for HK-SHA measures the mean spillover effects from the SHA (HK) market to the HK (SHA) market; ARCH(1,2) and GARCH(1,2) (ARCH (2,1) and GARCH(2,1)) measure the volatility spillover effects from the SHA (HK) market to the HK (SHA) market, and parameters α_1 and α_2 indicate short-term adjustments to the equilibrium of the HK and SHA markets, respectively.

4.1. Relationships among Hong Kong, Shanghai A- and B-share stock markets

From Panel A of Table 4, ϕ_{12}^{1} has a negative sign and is statistically significant, but ϕ_{21}^{1} is not significant, indicating that there is a mean spillover effect from the SHA market to the HK market, but the reverse relationship does not hold. The value of the short-term adjustment parameter α_1 is -0.683, which is significant at the 1%

level, suggesting that the HK stock market makes a partial adjustment when it drifts away from long-run equilibrium. The magnitude of α_1 indicates that 68.3% of the discrepancy between the two stock markets would be corrected in each week, corresponding to an adjustment period of 1.46 weeks. α_2 bears a positive sign but is insignificant, suggesting that the cointegrating relationship between the two markets does not reveal movements on the part of the SHA stock market. For the variance equation, we find that off-diagonal ARCH (1,2) and GARCH (1,2) terms are significant, while those of ARCH (2,1) and GARCH(2,1) are not, indicating the existence of a unidirectional volatility spillover effect from the SHA to the HK stock market.

With respect to the estimates of the SHB-SHA pair market, the evidence shows that ϕ_{12}^1 is significant but ϕ_{21}^1 is not, indicating a unidirectional mean spillover effect from the SHA to the SHB stock market. In other words, SHA leads SHB in returns. The value of the short-term adjustment parameter α_1 is -0.824, which is significant at about the 6% level, suggesting that the SHB market adjusts when it drifts away from long-run equilibrium and the adjustment speed is about 1.21 weeks. The non-significance of the α_2 estimate indicates that the SHA market is not bound by the cointegration relationship. For the variance equation, the test results show that all off-diagonal ARCH terms and GARCH terms are significant and disclose a bi-directional volatility spillover effect between the SHA and SHB stock markets, implying strong transmission of information between these two stock markets.

The third column of Table 4 provides the estimates for the SHB-HK pair of stock returns. From the results, we find that neither ϕ_{12}^{1} nor ϕ_{21}^{1} is significant, concluding that there is no spillover effect in the first moment between the SHB and the HK markets. The adjustment speed coefficient α_1 is significantly negative, while coefficient α_2 is insignificant, implying that the HK market is not bound by the cointegration relationship. For the spillover effect of volatility, evidence shows that all off-diagonal ARCH terms and GARCH terms are significant, which is similar to the situation for the SHA and SHB pair. Thus, we conclude that there also exists strong transmission of information between the SHB and HK stock markets.

To sum up, evidence shows that there are bi-directional volatility spillover effects between SHB-SHA and between SHB-HK, but only a unidirectional volatility spillover effect from the SHA to the HK market. We conclude that the SHA market plays the most influential role among the three markets: it not only passes return realizations to the SHB and HK markets, but it also leads in the transmission of their volatilities. We also find that among the three pairs of stock markets, only one market is found to adjust to return to equilibrium: the HK market adjusts disequilibrium conditions with the SHA market, while the SHB market adjusts in response to disequilibrium with both the SHA and HK markets.

4.2. Relationships among Hong Kong and Shenzhen A- and B-share stock markets

Columns 4-6 of Table 4 report the estimated results of FIVECM-BEKK for HK-SZA, SZB-SZA, and SZB-HK. In general, we find that the relationships among these three markets are very similar to those of their counterparts presented in the sub-section above. For the HK-SZA pair, we find a unidirectional mean spillover from the SZA market to the HK market. Next, the estimated parameter α_1 has a value of -0.639, which is statistically significant, suggesting that the HK market adjusts as it diverges from its long-run equilibrium with the SZA. The length of the adjustment is 1.56 weeks. On the other hand, the estimate of α_2 is not significant, indicating that the movement of the SHA stock market is not governed by the cointegrating relationship between these two markets. By checking with the variance equations, the results indicate that the volatility spillover effect is running only unidirectionally from the SZA market to the HK stock market.

As we inspect the SZB-SZA pair relationship, our results show that there is no mean spillover effect between these two markets. For the short-term adjustment parameter, we find α_1 to be -0.481 and statistically significant. The comparable coefficient, α_2, also shows a negative sign; however, it is insignificant, suggesting that the SZB market makes the adjustment when it deviates from a long-run equilibrium relationship and the speed of adjustment is about 2.08 weeks. In contrast, no evidence indicates that the SZA market is bound by the cointegration relationship. On the basis of the conditional variance equations, we find that there are bi-directional volatility spillover effects between the SZA and SZB stock markets, implying strong transmission of information between the two stock markets.

Finally, we examine the SZB-HK pair of markets. Since both ϕ_{12}^1 and ϕ_{21}^1 are insignificant, there is no evidence to indicate any spillover effect in stock returns between the SZB and HK markets. As far as the adjustment coefficient is concerned, the estimated α_1 is -0.360 and statistically significant, while α_2 is insignificant, revealing that the disequilibrium between the two markets will be corrected only by the SZB market, and the correction will occur within 2.78 weeks. With respect to the spillover effect of volatility, evidence indicates the existence of bi-directional volatility spillover effects between the SZB and HK markets.

The model diagnostics reported in Panel B of Table 4 list Ljung-Box tests of white noise applied to both the standardized residuals and the squared standardized residual series. It demonstrates that none of the Ljung-Box test statistics for the HK-SHA, SHB-SHA, SHB-HK, and HK-SZA pairs of markets is significant, indicating the adequacy of the fitted models to successfully capture the dynamics in the first two moments of the index return series. However, the null hypothesis of the absence of joint significance for the SZB return series of the SZB-SZA and the SZB-HK pairs is rejected, pointing to the need for further investigation of the dynamics of the SZB market.[6]

In short, interrelationships among these three markets are very similar to those among the SHA, SHB, and HK stock markets: there are bi-directional volatility spillover effects between SZB-SZA and between SZB-HK and only a unidirectional volatility spillover effect from the SZA market to the HK market. Similarly, we find that the SZA market is the most influential among the three markets: it not only passes return realizations to the HK market, but it also leads the transmission of information about volatility. Moreover, among HK-SZA, SZB-SZA, and SZB- HK, only one side of the connected markets is characterized by a partial adjustment process to return to

[6] We tried other specifications for the mean equation for the SZB return series, but the results do not improve. It could be due to spurious correlations with some missing variables.

long-run equilibrium. We find that the HK market is capable of adjusting its disequilibrium positions to the SZA market and the SZB market adjusts in response to disequilibrium with both the SZA and HK markets.[7]

4.3. Analyses of dynamic correlations

Having modeled the long-term equilibrium, short-term adjustment, and spillover effects across these markets, it is of interest to analyze the effects of changes in financial policy and economic conditions on the dynamic correlations between the markets. By visual inspection of these figures, we identify two interesting points.[8] First, after February 2001, the correlations between the SHA-SHB and SZA-SZB markets show an upward trend over time. This pattern may be attributable to the more liberal governmental policy allowing domestic citizens who invest in A-share markets to invest in B-share markets. Second, the time-varying correlation coefficients show different patterns of evolution during the Asian financial crisis, which started in early July 1997. For example, from late 1997 through early 1998, we find that the correlations between any of the A-share markets and the HK or B-share markets decrease. However, the correlations between any of the B-share markets and the HK market increase.

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[7] It is of interest to compare the speeds of adjustment across different markets. Our evidence shows that the SHB market has a faster speed of adjustment in response to disequilibrium with the SHA (α_1=-0.824) than it does with the HK market (α_1=-0.636). Similarly, the SZB market adjusts faster in response to disequilibrium with the SZA (α_1=-0.481) than it does with the HK market (α_1=-0.360). One possible reason for this phenomenon is that all of the companies listed on the SHB and SZB markets belong to local Chinese companies. Thus, their price discovery process relative to A-share markets is more efficient than their price discovery process relative to the HK stock market.

[8] We investigated the time-varying conditional correlation coefficients estimated from the FIVECM-BEKK model for each pair of markets. The figures are not shown to save space. However, they are available upon request.

In light of these observations, we examine the time-varying correlation coefficients in response to unusual market conditions, such as a financial crisis and changes in regulation. Expressing this notion in a regression model, we write:

$$\rho_{ij,t} = d_0 + d_1 crisis1_t + d_2 crisis2_t + d_3 FP_t + \varepsilon_t \quad (5)$$

where $\rho_{ij,t}$ are the conditional correlation coefficients between Markets *i* and *j*; $crisis1_t$ and $crisis2_t$ are dummy variables, denoting the early stage (7/2/1997 -10/15/1997) and the effective stage (10/22/1997-12/28/1998) of the Asian financial crisis, respectively,[9] and FP_t is a dummy to capture the impact of the removal of the restriction on investment in B shares (2/22/2001-12/28/2005). The dummy variables are set to unity to indicate the presence of an effect and are zero otherwise.

The estimated coefficients for Equation (5) are reported in Table 5. The evidence shows that the indicator of the effect of the Asian financial crisis, d_1, is positive for the six pairs of markets. Thus, in the early stage of the crisis, 7/2/1997-10/15/1997, the effect was not fully hitting these six markets. They tend to be correlated with each other at a bit higher level. However, from HK and Chinese investors' point of view, the crisis took effect on October 20, 1997. This led to the negative and highly significant d_2 for HK-SHA, SHB-SHA, HK-SZA, and SZB-SZA. In contrast**,** the contagion effect spread the crisis to the HK and two B-share markets, which led to herding, as evidenced by a positive correlation and significant d_2 on the SHB-HK pair. The evidence suggests that the market segmentation policy imposed by the

[9] Although the crisis originated in Thailand and the market declined sharply in June 1997, followed by the collapse of the Indonesian market in August, no serious attention was given to these markets until the crisis hit the Hong Kong market in mid-October (between October 20 and October 23 the Hang Seng Index dipped by 23%). From the perspective of Chinese stock investors, the Hong Kong market crash in mid-October was a direct threat to their investments, since the portfolio performance in the B-share markets is perceived to be highly correlated with that of Hong Kong's market and Shenzhen B shares are measured in HK dollars

Chinese authority is an effective instrument for shielding the A-share markets from external turbulence.

The coefficient of the FP_t variable, d_3, is significantly positive for SHB-SHA and SZB-SZA, indicating that the correlations between A- and B-share markets increased after domestic investors in A-share markets were allowed to purchase B shares. Interestingly, we find that d_3 for HK-SHA and HK-SZA is also positive and highly significant, suggesting that even domestic investors in A-share markets are still not allowed to invest in the HK market and their participation in B-share markets tends to stimulate active transmission of information between the A-share and the HK markets. We conclude that this more relaxed policy on purchasing B shares helped to accelerate the market integration process of A-share markets with international financial markets. In contrast, we find that d_3 for SHB-HK is negative and highly significant, suggesting that the participation of domestic citizens in SHB is less efficient in transmitting information between the SHB and the HK market and, consequently, reduces the correlation between these two markets.

5. Conclusions

In this study, we apply a relatively novel FIVECM-BEKK GARCH framework to examine the long-term equilibrium, short-term adjustment, and spillover effects among six pairs of stock markets, namely, HK-SHA, SHB-SHA, SHB-HK, HK-SZA, SZB-SZA, and SZB-HK. Our FIVECM approach is considered to be more general than the traditional VECM approach, since it can measure the effect of the long memory on the cointegrating relationship, which is important for revealing the true relationships between the relevant stock markets. Furthermore, augmenting the FIVECM with a bivariate BEKK GARCH formulation, we investigate the mean and volatility spillover effects across these markets simultaneously.

Our equilibrium analyses indicate that all six pairs of markets are fractionally cointegrated. The Hong Kong stock market adjusts to return to equilibrium with the two A-share stock markets, while the two B-share markets adjust to return to equilibrium with the corresponding two A-share markets and the Hong Kong market. The volatility spillover effect shows that there are bi-directional volatility spillovers between the two A-share markets and the two B-share markets and between the two B-share markets and the Hong Kong market. However, only unidirectional volatility spillover effects from the two A-share markets to the Hong Kong market are present. Among the alternative markets, we find that the two A-share markets are most influential in both mean and volatility spillover effects. Further investigation of the dynamic path of correlation coefficients suggests that relaxation of government restrictions on the purchase of B shares by domestic residents increases the correlation between the two A- and the two B-share markets, indicating that the degree of segmentation has been moderated and that the two classes of markets have tended to gradually merge. Evidence also shows that this liberal policy accelerated the market integration process of the A-share markets with the Hong Kong stock market. Finally, we find that the effects of the Asian crisis on the stock-return dynamic correlations vary across these markets.

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Table 1

Descriptive statistics for Chinese stock indices and the Hang Seng index

	SHA	SHB	SZA	SZB	HK
Mean	5.079	4.272	3.799	2.872	7.327
Median	5.147	4.213	3.909	2.870	7.334
Maximum	5.643	5.454	4.440	3.994	7.751
Minimum	4.169	3.068	2.572	1.680	6.786
Std. Dev.	0.353	0.507	0.468	0.568	0.202
Skewness	-0.870	0.080	-1.192	-0.125	-0.157
Kurtosis	3.182	2.340	3.719	1.667	2.272

Note: These are descriptive statistics of the logarithms of stock indices. Sample covers January 1995 through December 2005. The total number of observations is 574.

Table 2

Long memory tests on cointegration residuals

Residual series	Modified Range Over Standard Deviation (R/S) test	
	Test statistic	P-value
z_{SHA}^{HK}	2.040	P<0.05
z_{SHA}^{SHB}	3.551	P<0.01
z_{HK}^{SHB}	3.686	P<0.01
z_{SZA}^{HK}	1.951	P<0.05
z_{SZA}^{SZB}	3.934	P<0.01
z_{HK}^{SZB}	4.135	P<0.01

Note: The residual series are constructed using Equation (1) in the text. Superscript stands for a dependent variable and subscript for an independent variable.

Table 3
ARFIMA fit results

Residual series	ARFIMA(p,d,q)	
	d	AR(1)
z_{SHA}^{HK}	0.093(0.046)**	0.967(0.015)***
z_{SHA}^{SHB}	0.064(0.037)*	0.991(0.006)***
z_{HK}^{SHB}	0.100(0.039)***	0.988(0.008)***
z_{SZA}^{HK}	0.102(0.046)**	0.966(0.015)***
z_{SHA}^{SZB}	0.171(0.041)***	0.982(0.010)***
z_{HK}^{SZB}	0.211(0.044)***	0.972(0.014)***

Note: The residual series are constructed using Equation (1) in the text. Superscript stands for a dependent variable and subscript for an independent variable. Numbers in parentheses are standard errors. Selection of AR (lag) and MA (lag) terms, *p* and *q*, is based on the examination of ACF, PACF, and Bayesian Information Criterion (BIC). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 4
Estimates for FIVECM-BEKK (1, 1) model

	HK-SHA	**SHB**-SHA	**SHB**-HK	**HK**-SZA	**SZB**-SZA	**SZB**-HK
Panel A: Estimated results						
c_1	0.002 (0.001)*	-0.001 (0.002)	-0.001 (0.002)	0.002 (0.001)*	0.000 (0.002)	0.000 (0.002)
c_2	0.000 (0.001)	0.000 (0.001)	0.001 (0.001)	-0.001 (0.002)	-0.002 (0.001)	0.002 (0.001)
ϕ_{11}^{1}	0.729(0.289)***	0.885(0.440)**	0.650(0.342)**	0.676(0.282)**	0.507 (0.284)*	0.460(0.183)***
ϕ_{12}^{1}	-0.217(0.074)***	-0.497 (0.294)*	-0.009 (0.058)	-0.164 (0.06)***	-0.134 (0.172)	-0.206 (0.148)
ϕ_{21}^{1}	-0.078 (0.253)	0.274 (0.300)	0.039 (0.201)	-0.154 (0.324)	0.088 (0.139)	-0.024 (0.098)
ϕ_{22}^{1}	0.032 (0.075)	-0.188 (0.203)	0.055 (0.049)	0.066 (0.074)	0.025 (0.098)	0.019 (0.078)
α_1	-0.683(0.286)***	-0.824 (0.444)*	-0.636 (0.354)*	-0.639 (0.280)**	-0.481 (0.284)*	-0.360 (0.195)*
α_2	0.097 (0.252)	-0.263 (0.302)	-0.093 (0.200)	0.188 (0.325)	-0.065 (0.143)	-0.018 (0.097)
A(1,1)	0.003 (0.002)*	0.014 (0.002)***	0.018 (0.002)***	0.002 (0.002)	0.013 (0.002)***	0.014 (0.002)***
A(2,1)	0.008 (0.003)***	0.007 (0.001)***	0.000 (0.002)	0.010 (0.006)*	0.010 (0.001)***	-0.001 (0.001)
A(2,2)	0.000 (37.495)	0.000 (8.743)	0.000 (27.681)	0.001 (0.077)	0.003 (0.002)	0.000 (3.055)
ARCH(1,1)	0.252 (0.033)***	0.437 (0.036)***	0.420 (0.036)***	0.206 (0.028)***	0.436 (0.031)***	0.387 (0.023)***
ARCH(1,2)	0.060 (0.028)**	0.132 (0.051)***	-0.146(0.060)***	0.038 (0.023)*	0.185 (0.040)***	-0.282(0.049)***
ARCH(2,1)	0.010 (0.055)	0.061 (0.023)***	0.062 (0.027)**	0.002 (0.062)	0.018 (0.027)	0.005 (0.021)
ARCH(2,2)	0.277 (0.032)***	0.257 (0.028)***	0.226 (0.042)***	0.376 (0.040)***	0.422 (0.034)***	0.156 (0.035)***
GARCH(1,1)	0.962 (0.010)***	0.864 (0.019)***	0.831 (0.033)***	0.977 (0.007)***	0.886 (0.013)***	0.880 (0.015)***
GARCH(1,2)	-0.028(0.009)***	-0.044 (0.021)**	0.085 (0.035)***	-0.024(0.009)***	-0.103(0.015)***	0.040 (0.023)*
GARCH(2,1)	-0.009 (0.015)	-0.038(0.010)***	-0.044(0.018)***	-0.002 (0.015)	-0.024 (0.012)**	0.019 (0.008)**
GARCH(2,2)	0.940(0.014)***	0.958 (0.010)***	0.980 (0.014)***	0.897 (0.019)***	0.888 (0.016)***	0.980 (0.007)***

Panel B: Model diagnostic statistics

LB (10)-HK	8.019	NA	6.813	7.813	NA	7.366
LBS (10)-HK	7.681	NA	5.680	10.503	NA	6.768
LB (10)-SHA	12.261	10.712	NA	NA	NA	NA
LBS (10)-SHA	3.694	8.143	NA	NA	NA	NA
LB (10)-SHB	NA	9.617	11.472	NA	NA	NA
LBS (10)-SHB	NA	6.107	8.649	NA	NA	NA
LB (10)-SZA	NA	NA	NA	10.329	12.461	NA
LBS (10)-SZA	NA	NA	NA	6.501	6.895	NA
LB (10)-SZB	NA	NA	NA	NA	22.993***	20.205**
LBS (10)-SZB	NA	NA	NA	NA	10.486	16.605*

Note: The estimates are based on Equations (3) and (4) in the text. The dependent variable in each model is marked in bold. The first-order ARCH(i,j) and GARCH(i,j) terms are the elements of the ARCH and GARCH coefficient matrices A1 and B1 in Equations (4) Numbers in parentheses are standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively. LB (10) and LBS (10) are the Ljung-Box statistics based on the level and the squared level of the time series up to the 10^{th} lag.

Table 5
Effects of crisis and policy change on conditional correlation across Chinese segmented stock markets and Hong Kong stock market

Estimates	Markets					
	HK-SHA	SHB-SHA	SHB-HK	HK-SZA	SZB-SZA	SZB-HK
d_0	0.013(0.010)	0.437(0.010)***	0.194(0.009)***	0.024(0.009)***	0.442(0.012)***	0.194(0.010)***
d_1	0.145(0.042)***	0.078(0.041)*	0.023(0.036)	0.172(0.038)***	0.033(0.050)	0.161(0.039)***
d_2	-0.103(0.023)***	-0.223(0.022)***	0.220(0.020)***	-0.097(0.021)***	-0.224(0.027)***	0.007(0.021)
d_3	0.168(0.015)***	0.244(0.014)***	-0.067(0.013)***	0.122(0.013)***	0.190(0.017)***	0.024(0.014)*

Note: The estimates are based on Equation (5) in the text. Numbers in parentheses are standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.