The Co-Movement of Stock Markets in East Asia.

Did the 1997–1998 Asian Financial Crisis Really Strengthen Stock Market Integration?

by

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Abstract:

This paper examines the integration and causality of interdependencies among six major East Asian stock markets before, during and after the 1997–1998 Asian financial crisis. For this purpose, we use daily stock market data from July 1, 1992 to June 30, 2003, in local currency and US dollar terms. Multivariate VAR results show that the relationships between East Asian stock markets are time-variant. Specifically, the integration of East Asian stock markets was strengthened during as well as after the 1997–1998 Asian financial crisis. Furthermore, we find that the Singaporean and Hong Kong stock markets are two interactive and influential markets in the region, while our results do not support the leading role of Japan. As of the Asian financial crisis, the stock markets in Taiwan and South Korea became largely influenced by but do not have much impact on the other East Asian markets. Overall, the Chinese stock market remains an isolated market, despite the country's increased importance in the world economy. Finally, incorporating the US stock market in the analyses reveals that it has a large influence on East Asian stock markets – except for China – in all subperiods whereas the reverse does not hold true. Yet, in more recent years, the interactions among most East Asian countries and the USA were strengthened somewhat, consistent with the idea of increased global capital market integration.

Keywords: Interdependency, VAR analysis, Granger Causality, Co-integration, Impulses response analysis.

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I. Introduction

Numerous studies have investigated the transmission mechanisms of stock price movements across international equity markets and how these mechanisms may change over time. This is indeed a non-trivial research question as changes in the covariance structure of cross-country stock returns affect asset prices and the return volatility of investment portfolios. As argued by Stulz (1995) and Karolyi and Stulz (1996), among others an increase in these covariances will lead to fewer domestic risks that can be diversified internationally. Yet, when capital markets become more globally integrated, the risk premium on the world market portfolio is likely to decrease and, as a result, the cost of capital for individual firms may fall as well. For developed countries, the literature indeed has pointed out a high degree of stock market integration. Friedman and Shachmurove (1997), for instance, conclude from a Vector Auto-Regressive (VAR) model of daily stock returns that most European stock markets are closely connected. Likewise, Westermann (2004) demonstrates that any lead-lag relationships within Europe have disappeared after the introduction of the Euro whereas Quan and Huyghebaert (2006) document that the Euro even promoted further integration of European stock markets with those in the USA and Japan.

In emerging countries, however, capital markets likely are less globally integrated and hence stock market segmentation may still be a highly important issue. Korajczyk (1996), for example, shows that stock market segmentation – although declining over time – tends to be much larger for emerging markets than for developed ones. This study also suggests that explicit capital controls, capital market development, and economic growth in emerging markets are all related to the degree of stock market integration. Likewise, Carrieri *et al.* (2001) document a time-variation in the level of integration among eight emerging markets, in particular Argentina, Brazil, Chile, India, South Korea, Mexico, Taiwan and Thailand. While a lot of cross-sectional variation in the level of stock market integration remains, these authors also highlight that integration is rising with time.

However, not all research points in this same direction. Bekaert and Harvey (1995), for example, estimate the degree of stock market integration for 21 developed and 12 emerging market economies. They conclude that some emerging markets did become more integrated over time whereas others – including Chile and India – have become less so.[1]

In this paper, we wish to examine the degree of stock market integration among six major East Asian countries, including both developed and emerging ones, i.e. Japan, Singapore, Hong Kong, Taiwan, South Korea and China. For one thing, empirical studies on the co-integration of stock markets in Asia up till now have yielded mixed results (e.g., Chung and Liu, 1994; DeFusco *et al.*, 1996; Masih and Masih, 1999; Ng, 2000; Manning, 2002). Besides, we also want to find out the direction (causality) of stock market interdependencies and determine whether the enhanced importance of China in the region and the world economy has affected the co-movement of stock prices in East Asia. Indeed, China has received scant attention in this prior research on Asian stock market integration. One exception is Huang *et al.* (2000), who examine the causality and co-integrating relationships among the stock markets of the United States, Japan, and the South China Growth Triangle (SCGT), i.e. Hong Kong, Taiwan, Shanghai and Shenzhen, over the period from October 2, 1992 to June 30, 1997. These authors conclude that China is hardly integrated with other Asian stock markets. Bahang and Shin (2003) reach similar conclusions from examining China, Japan, South Korea and the USA during the period 1991–2000. Although Bahang and Shin analyze a more elaborate period, they do not explore the possibility of changes in China's integration with other stock markets over time. Nevertheless, with the development of China's capital markets since the beginning of the 1990s, its huge economic growth in more recent years and its enhanced economic interactions with the world through imports/exports and FDI,

[1] Besides, Bekaert and Harvey (1995) show that the return volatility in emerging markets is greater than that in developed markets. Also, emerging markets may have greater leptokurtosis, with more pronounced fluctuations (see also Huang *et al.*, 2000).

China's integration with other stock markets in Asia and the world may have been affected (based on the conclusions of Korajczyk, 1996). So, in this paper we wish to re-examine the co-movement of stock prices in East Asia during an extended time window, from July 1, 1992 to June 30, 2003, and thereby take into account potential changes in stock market interdependencies over time.[2]

In these analyses, we will pay special attention to the effects of the 1997–1998 Asian financial crisis. The reason is that the relationships between stock markets may change due to some major economic event. Granger and Morgenstern (1970), for example, argue that the existing linkages among stock markets are likely to become much stronger in the case of a crisis, due to a market *contagion effect*.[3] Hilliard (1979) already found this effect when studying stock market returns during the 1973–1974 OPEC crisis. Regarding the 1987 stock market crash, Hamao *et al.* (1990) document significant price-volatility spillovers from New York to London and Tokyo, and from London to Tokyo. However, it is not entirely clear whether such crises have a long-lasting impact on stock market interdependencies. Chan *et al.* (1997) conclude that the 1987 stock market crash did not promote any enduring integration among the 18 countries in their sample. Likewise, Forbes and Rigobon (2002) find no significant increase in cross-market correlations after the 1987 stock market crash, the 1994 Mexican peso devaluation and the 1997–1998 Asian financial crisis after calculating heteroskedasticity-adjusted correlation coefficients. In contrast, Tan and Tse (2002) and Yang *et al.* (2003), who also focus on the 1997–1998 Asian financial crisis, conclude that both long-run equilibrium relationships and short-term dynamic causal linkages in Asian stock markets were strengthened in a lasting manner following this crisis. Hence, in this paper we also wish to carefully re-examine the impact that the Asian financial crisis has had on stock market co-movements in East Asia.

[2] The US stock market will be included in subsequent analyses, to examine its linkages with East Asian stock markets.
[3] Karolyi and Stulz (1996) argue that *contagion* results when (lack of) enthusiasm for stocks in one market brings about (lack of) enthusiasm for stocks in other markets, regardless of the evolution of market fundamentals.

To investigate the above research questions, we cautiously develop our research design. Indeed, mixed results in prior research on East Asia may have been partly due to different research methodologies, sampling frequencies and sample periods. So, we try to deal with these issues by investigating stock market co-movements using a multivariate Vector Auto-Regressive (VAR) framework rather than focusing on the bivariate relationships among the various markets. Thereby, we meticulously account for the structural breaks that the Asian financial crisis may have engendered. Also, as the optimal lag length is a crucial parameter in these models and the tests that are based upon them, we use the Sims likelihood-ratio test to correctly specify the various VAR models. Furthermore, we implement co-integration tests to examine the long-run equilibrium relationships – if any – among stock markets in the East Asian region while generalized rather than traditional orthogonalized impulse response analyses are used to figure out the short-term causal linkages among the markets in our sample. All the above analyses are done using daily data in both local currency and US dollar terms, respectively. Finally, we also examine a more elaborate time period, from July 1, 1992 to June 30, 2003, thereby covering five years before and five years after the 1997–1998 Asian financial crisis. We therefore should be able to identify possible time-variant integration among East Asian stock markets, and the relation between the Asian financial crisis and stock market co-movements.

Overall, our results show that stock market integration in East Asia was strengthened during the 1997–1998 Asian financial crisis, but not in a lasting manner. Indeed, the data point out a strong but transient market contagion effect during that period, where the Hong Kong stock market played a very important role in spreading the crisis. Interestingly, the impulse response analyses reveal that in more recent years, interdependencies were enhanced again in most countries, except for China, consistent with the idea of increased global capital market integration. On the one hand,

most East Asian stock markets are now more heavily affected by a one unit shock in another country than during the crisis. Nevertheless, stock markets in East Asia in general bear no long-run equilibrium relationship and thus do not exhibit joint underlying forces that drive their long-run swings. On the other hand, incorporating the USA in the analyses also makes clear that in recent times the US stock market has become somewhat more responsive to shocks in East Asia. Besides, during the Asian financial crisis, a one unit shock in one market may lead to a response in the other countries that lasts for several days, suggesting that stock markets in East Asia were not highly efficient during that period. In contrast, we find that before as well as after the financial crisis, responses generally take place on the same day. When it takes two days to adjust, then this can be attributed to differences in time zone and – for stock markets in the same time zone – differences in opening hours of the exchanges.

Next, our findings do not support the notion that the Japanese stock market is the leading market in East Asia. During the Asian financial crisis, however, we do find that the Japanese stock market leads that of Taiwan and South Korea. Rather, we document that the stock markets of Singapore and Hong Kong are two interactive markets and this before, during as well as after the 1997–1998 Asian financial crisis. Also, these markets are highly influential in the East Asian region, especially during and since the crisis, as a shock in one of these markets greatly affects share prices in Japan, Taiwan and South Korea. In contrast, the Taiwanese and South Korean stock markets have not much impact on the other East Asian markets, pointing out their largely endogenous nature. It was only during the Asian financial crisis that we found some leading role of South Korea vis-à-vis Japan, Singapore and Hong Kong. In more recent years, the South Korean stock market only Granger causes the stock markets of Japan and Taiwan. In addition, and consistent with Huang *et al.* (2000) and Bahang and Shin (2003), we find that China is hardly

integrated with the other stock markets in East Asia. What's more, China's stock market isolation was not significantly reduced over time, despite its capital market development and its huge economic growth. Finally, our results indicate that the US stock market exerts a great influence on all Asian markets – except for China – while the reverse generally is not true. Indeed, it was only during the Asian financial crisis that shocks in Japan and especially Hong Kong had some impact on US stock prices, pointing out again the seriousness of this crisis. Nevertheless, in more recent years, the impact of East Asian stock markets on US share prices has been strengthened somewhat.

The remainder of this paper is organized as follows. Section II briefly reviews previous studies on Asian stock market integration, from which we draw inferences for our own research design. Section III describes the data and employs unit root testing, while the empirical results based on multivariate VAR modeling are presented in Section IV. Finally, Section V concludes this paper.

II. Literature Review and Implications

The empirical findings in the literature regarding the co-integration and causality of Asian stock markets are mixed and in some cases even contradictory. The earliest study of Asian stock market integration utilizing a multivariate co-integration analysis is probably Chung and Liu (1994). Using weekly data denominated in local currencies during the period from July 1, 1985 to May 18, 1992, these authors build a system including five East Asian stock markets (Japan, Singapore, Hong Kong, Taiwan, and South Korea) and the USA, and find two co-integrating relationships based on a model with 24 lags. Following Chung and Liu (1994), DeFusco *et al.* (1996) examine weekly data from January 1989 to May 1993, but denominated in US dollars. They conclude that there is no co-integration between the USA and the Asian countries in their sample, i.e. Taiwan, South Korea,

Thailand, Malaysia and the Philippines. In fact, their results even suggest that capital markets are segmented. Masih and Masih (1999) collect daily data from February 14, 1992 to June 19, 1997, expressed in US dollars. They find one co-integrating vector among four Asian markets, i.e. Singapore, Hong Kong, Malaysia and Thailand, and four major developed countries, i.e. the USA, Japan, the UK and Germany. Manning (2002) examines both weekly and quarterly data from January 1988 to February 1999, denominated in both local currency and US dollar terms. His system includes Japan, Singapore, Hong Kong, South Korea, Indonesia, Malaysia, the Philippines, and Thailand, and alternatively excludes or includes the United States. His general conclusion is that there are two common stochastic trends, indicating partial convergence of the indices.[4] Furthermore, Ng (2000) investigates the magnitude and changing nature of the return and volatility spillovers from Japan and the United States to six Pacific-Basin equity markets for the period until the last week of December 1996.[5] Besides the effect of world factors (proxied by the US stock market), he finds significant spillovers from the region (captured by the Japanese stock market) to many of the Pacific-Basin countries.

Some studies focus in more detail on stock market co-integration during the 1997–1998 Asian financial crisis, in particular on the impact that this financial crisis has had on Asian stock market co-movements. For example, Ghosh *et al.* (1999) document pairwise co-integration between some Asian-Pacific stock markets and the USA (or Japan) during the 1997–1998 Asian financial crisis. For this purpose, they collected daily data expressed in local currency terms. Sheng and Tu (2000), also using daily data in local currencies, report no co-integration between the USA and many Asian stock markets in the year before the crisis but find one co-integrating vector

[4] His results also show that using another frequency of the data and different denominating currencies affect the number of countries that determine these two common stochastic trends.

[5] The starting point of their data collection depends on the country. For example, for Hong Kong, Japan and the USA, the data gathering starts in March 1975 whereas this is July 1983 for South Korea, November 1980 for Malaysia, July 1986 for Singapore, October 1986 for Taiwan, and April 1985 for Thailand.

during this crisis. Furthermore, Tan and Tse (2002) include daily data in local currencies during 1988–2000 in a nine-variable VAR model, to examine the dynamic linkages among the USA, Japan and seven other Asian countries. They conclude that stock markets appear to be more integrated after the crisis than before, and that Asian markets are most heavily influenced by the United States while the impact of Japan is increasing. Yet, they do not examine whether the various markets are co-integrated. Finally, Yang *et al.* (2003) examine the multivariate long-run equilibrium relationships and short-term dynamic causal linkages among the stock markets of the USA, Japan and ten other Asian countries (Hong Kong, India, Indonesia, South Korea, Malaysia, Pakistan, the Philippines, Singapore, Thailand, and Taiwan), with particular attention to the 1997–1998 Asian financial crisis. They find evidence of two co-integrating relationships before and after the 1997–1998 Asian financial crisis. Like Tan and Tse (2002), Yang *et al.* also conclude that stock markets in Asia generally have become more integrated after the crisis than before.

Regarding the research on the causality of stock market interdependencies in Asia, empirical results again are mixed. The role of Japan as the leader in the Asian region has been a highly controversial issue in this debate. While Ghosh *et al.* (1999) as well as Masih and Masih (2001) conclude that Japan is a market leader, other studies suggest that Japan does not play a pivotal role in non-crisis periods. For example, Yang *et al.* (2003) demonstrate that Japan did not have much influence on the other Asian financial markets, neither before nor after the 1997–1998 financial crisis. Yet, during this crisis, stock markets in Hong Kong, Indonesia, South Korea, Malaysia, the Philippines, Singapore, and Thailand all responded significantly to shocks in the Japanese market. Dekker *et al.* (2001) and Bessler and Yang (2003) even argue that Japan is a relatively isolated market under normal market conditions, meaning that it neither affects nor is affected by innovations (shocks) in other countries. Yang *et al.* (2003) further suggest that the Singaporean

stock market plays the role of market leader in the Asian region. A few other studies have shown that especially the Hong Kong stock market is the most interactive and influential market in Asia (e.g., Masih and Masih, 1999; Dekker *et al.*, 2001). Moreover, many papers find that the Taiwanese stock market is normally an isolated market (e.g., Ghosh *et al.*, 1999; Dekker *et al.*, 2001). Regarding the South Korean market, Yang *et al.* (2003), among others argue that it is a fairly endogenous market, as it responds strongly to shocks in other countries without having much impact itself on these markets; this effect became even stronger after the Asian financial crisis.

Although the Chinese economy plays an increasingly important role in Asia and in the world, China has received scant attention in this prior empirical research. This may be partly due to the short time period since the stock markets of Shanghai (1990) and Shenzhen (1991) in the Mainland were established. Nevertheless, one could argue that the common culture (Confucianism), language (Chinese) and other traits may induce China's integration with at least some other East Asian stock markets, especially Hong Kong, Taiwan and perhaps also Singapore. What's more, to the extent that one country's economy can influence that of others, for instance through imports and exports, their expectations about economic development may be somewhat similar. Then different stock markets may also respond in the same way to economic shocks, inducing the co-movement of their share prices (e.g., Johnson and Soenen, 2003). Over the years, the economic linkages between China and its neighboring countries indeed have been strengthened, through imports and exports, and outright FDI. Finally, an increased cross-listing of Chinese firms on foreign exchanges, in particular Hong Kong but also the USA, may have enhanced China's stock market interdependencies with these countries, as news about these firms could be reflected in several markets within a short time period. So, stock markets in different geographic locations can then exhibit a high degree of co-movement after a shock in one market.

Starting from this prior research, our study will try to figure out the common long-run stochastic trends and short-term interaction mechanisms among the stock markets of six major East Asian countries, i.e. Japan, Singapore, Hong Kong, Taiwan, South Korea and China, and finally include the United States as an additional market. As the mixed and sometimes even contradictory empirical results regarding stock market interdependencies in Asia mentioned above could be partly attributable to different research methodologies, a wide range of sampling frequencies and sample periods, there are some key features in our research design. First, different from many previous studies, which typically have used several smaller – bivariate – systems to model the relationships among a large number of stock markets, this study will employ a multivariate VAR framework on these six stock market indices to pinpoint their long-run and short-term interdependencies. Second, as VAR models, Granger causality tests and co-integration analyses are very sensitive to the number of lags chosen (e.g., Brocato and Smith, 1989; Chung and Liu, 1994; Click and Plummer, 2005), we will employ lag-length tests and choose the 'best' lag length based on a likelihood-ratio test. Although the Akaike information criterion and the Schwarz Bayesian criterion always suggested a shorter number of lags compared with the likelihood-ratio test, including too few lags in the VAR models could make it impossible to capture any delayed adjustment in the responses of one market to movements in the other markets (or in its own market). Considering more lags indeed is likely to be important especially in an emerging-market context and therefore may allow us to obtain more robust conclusions. A final methodological issue is that traditional orthogonalized impulse response analysis, which is based on the widely-used Choleski decomposition of VAR innovations, is highly sensitive to the ordering of the variables. Hence, this paper will employ a generalized impulse response analysis, which is invariant to the ordering of the variables (see also Koop *et al.*, 1996; Pesaran and Shin, 1998). Given the strong contemporaneous correlations among East Asian

stock market innovations, especially during the 1997–1998 Asian financial crisis, such a generalized response analysis is likely to have important advantages.

Next, we will use daily data in this study to implement more powerful tests of cross-country co-movements. The reason is that weekly, monthly or quarterly data could obscure interactions between stock markets that last for only a few days (e.g., Eun and Shim, 1989; Karolyi and Stulz, 1996).[6] Whereas most papers examining Asian stock market integration are conducted in local currencies, we will consider data denominated in both local currency and US dollar terms. Local currency data abstain from the effects of exchange rate risk, which may be an important concern for international investors. Bessler and Yang (2003), for example, find that exchange rate adjustments can influence long-run co-integrating relationships, although they generally do not affect the short-term dynamic linkages among stock markets. In the period before the Asian financial crisis, some countries in the Asian region – Hong Kong and South Korea are the only ones in our sample who did this – were pegging their exchange rate to the US dollar. Singapore, on the other hand, adopted a currency board system, implying that its exchange rate also could not float freely against the US dollar. Using either local currency or US dollar terms is therefore unlikely to affect the empirical results for those three countries, but the choice of currency may still matter for the other countries in our sample. Besides, in the aftermath of the Asian financial crisis, currency issues may have become more important, once countries allowed their currencies to float freely against the

[6] However, when using daily data, we will have to take into account differences in time zones and trading hours of exchanges when interpreting the results. The opening hours of the six East Asian stock markets in our sample is highly overlapping, as the Japanese and South Korean stock markets are in the same time zone whereas the other four stock markets, i.e. Singapore, Hong Kong, Taiwan and China, also have their own time zone. Still, there are some differences in the opening and closing times of each stock exchange. For example, the Japanese stock market is open from 9:00 to 11:00 and from 12:30 to 15:00, while the South Korean stock exchange is open from 9:00 to 15:00, local time. Besides, the Singaporean stock market is open 9:00–17:00, with a one-and-a-half hour break from 12:30 to 14:00 whereas the Hong Kong stock market is open from 10:00 to 12:30 and from 14:30 to 16:00 in summer time, and between 9:00–11:30 and 13:30–15:00 in winter time. Also, the trading hours of the Taiwanese stock exchange are from 9:00 to 13:30. Finally, the Shanghai stock market in China is open from 9:30 to 11:30 in the morning and from 13:00 to 15:00 in the afternoon.

US dollar (with the exception of Singapore, Hong Kong and China).[7]

Finally, as different sample periods could account for different findings, and taking the 1997–1998 Asian financial crisis into account, this study will cover an extended time period, from July 1, 1992 to June 30, 2003 and split it up into three subsamples to capture possible time-variant stock market integration in East Asia before, during and after this crisis. Hence, we divide the entire sampling period into three subperiods. The first subsample in our study is from July 1, 1992 to June 30, 1997, which is the pre-crisis period. According to Click and Plummer (2005), five years should be a long enough time span to uncover the long-run equilibrium relationships – if any – among financial markets. In line with Sheng and Tu (2000) and Yang *et al.* (2003), the period used to examine the impact of the 1997–1998 Asian financial crisis is from July 1, 1997 to June 30, 1998. The post-crisis period then dates from July 1, 1998 to June 30, 2003, again covering a five-year window. In order to check the robustness of our results, we further split the post-crisis period into two subperiods, as in Yang *et al.* (2003). One is the transition period from July 1, 1998 to June 30, 1999 while the other should be a true post-crisis period.

III. Data and Unit Root Testing

The data for this study were retrieved from Thomson Financial's Datastream, and consist of daily stock market index closing prices from six major East Asian stock markets, i.e. the Japanese Nikkei 225 Stock Average (JP), the Singaporean Strait Times (SG), the Hong Kong Hang Seng (HK), the Taiwanese SE Weighted (TW), the South Korean SE Composite (KR), and the Shanghai SE Composite (SH). Besides, we also collected data on the US S&P 500 Composite index (US). As the sample period extends from July 1, 1992 to June 30, 2003, our sample includes 2,869 daily

[7] After the crisis, Singapore continued to use a currency board system whereas the HKD is still pegged to the USD. Finally, the Chinese RMB cannot be traded freely and its exchange rate is more or less fixed against the US dollar.

observations for each series. All stock market indices are expressed in both local currency and US dollar terms. We subsequently take the natural logarithm of these daily closing values. Daily returns can then be computed as the first difference of each log-transformed series. This is convenient, given that percentage growth rates of economic variables, like stock prices, are more constant over time than absolute changes.[8] Figure 1 presents the data plot of the seven log-transformed indices in local currencies.

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We first implement unit root tests to examine whether the series of the seven log-transformed stock market indices are stationary. For this purpose, we start by employing the commonly-used Augmented Dickey-Fuller (ADF) test to decide on the presence of a unit root in each of the index series. This analysis is based on the following equation:

$$\Delta Y_t = \mu + \beta Y_{t-1} + \alpha_1 \Delta Y_{t-1} + ... + \alpha_m \Delta Y_{t-m} + u_t \quad (1)$$

The ADF-test is equivalent to examining whether the parameter β is equal to zero. If we cannot reject the null hypothesis that $\beta = 0$, we can conclude that the series contains a unit root and thus is non-stationary. However, since the true data-generating process is unknown, we first have to settle some concerns about unit root testing. First, the optimal number of lags m in equation (1) needs to be determined. Lags in the function ΔY_{t-m} are used to make sure that u_t is white noise. If m is too small, residuals will not be white noise whereas a too large m will reduce the power of the test. In our study, we choose the optimal number of lags based on the Schwarz Bayesian criterion, using 15 days as maximum.[9] The second concern is about the deterministic component of the series, i.e.

[8] Using this logarithm transformation also allows us to interpret the parameter estimates as elasticities.

[9] In line with Eun and Shim (1989), Friedman and Shachmurove (1997), Janakiramanan and Lamba (1998), Dekker *et al.* (2001), among others, 15 days should be enough as maximum for this test, as too many lags will reduce the power of

whether or not it should contain an intercept and/or a time trend. After visually inspecting the data in Figure 1, we decided to include an intercept in equation (1), but no time trend.[10]

Table 1 reports the results of the unit root tests. Using 0.05 as cutoff level, the ADF-test results in columns 2–3 of Panel A reveal that the null hypothesis of a unit root in the stock market data cannot be rejected in any market during the full sampling period. These conclusions hold when the series are expressed in local currency as well as US dollar terms. In other words, all series examined in this paper contain a unit root, which is consistent with the idea of weak-form stock market efficiency for the individual markets (e.g., Fama, 1970; 1991). Furthermore, when testing for a unit root in the first difference of each series, it turns out that in none of these markets such a unit root exists (not reported). In addition, we also employ Phillips-Perron tests to examine the presence of a unit root (not reported). The latter is a generalization of the ADF-procedure that allows for milder assumptions regarding the error distribution. Again, the results show that all series examined in this paper are integrated of order one, i.e. $I(1)$.

Finally, Perron (1989, 1994) has argued that unit root test results may be biased when the series contains a structural break. Therefore, Perron has extended the ADF-test by incorporating two dummy variables that represent a potential structural break in the regression equation in order to test for unit roots. Specifically, the first dummy variable takes the value of one after the potential break date and zero otherwise; the second variable takes the value of one at this potential break date and zero otherwise. As our sampling period covers the 1997–1998 Asian financial crisis, it seems necessary to take two structural breaks in the series into account when conducting these additional unit root tests. We considered July 1, 1997 and June 30, 1998 as potential break

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the test.

[10] To judge on the appropriateness of these specifications, we also have calculated the Ljung-Box Q model diagnostics for each lag. These statistics (not reported) show that the residuals are white noise under the selected specifications. All results that are not reported in this paper are available from the authors upon request.

dates in the series, and subsequently generated four dummies for these two data points. The results in columns 4–5 of Panel A show that once potential structural breaks are accounted for, the South Korean SE Composite and the Shanghai SE Composite indices no longer contain a unit root. Nevertheless, the null hypothesis of a unit root still cannot be rejected for the other East Asian stock market indices and the USA. In other words, the stock market indices of South Korea and China now can be considered as stationary whereas all other series remain non-stationary. These conclusions again are independent of the numeraire that is being used (local currency versus USD).

Finally, the ADF-test results for the various subperiods in our sample (i.e. pre-crisis, crisis and post-crisis), as reported in Panel B of Table 1, indicate that all series in all subperiods are non-stationary in the level of the index. Additional tests show that all series are stationary in the first difference of the index (not reported). Given the above results, it seems necessary to not mingle up the data of the various subperiods into one model in our analyses hereafter.

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Insert Table 1

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IV. Empirical Results: A Multivariate VAR Analysis

In this section, we examine the co-movement and causality of interdependencies among East Asian stock markets, starting from a multivariate VAR model on the stock market returns in the various countries. Indeed, a VAR model is based on stationary data, so we have to take the first difference of the log-transformed stock market indices, given the earlier-obtained unit root test results. Also, the results in Table 1 made clear that these VAR models can best be estimated for each subperiod, given the structural breaks that the 1997–1998 Asian financial crisis engendered in some

countries.[11] The multivariate VAR model in first differences with no co-integrating equation then looks as follows:

$$\Delta X_t = \Gamma_0 + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \varepsilon_t \quad (2)$$

where ΔX_t is the vector containing the six log-transformed stock market indices in first differences, while Γ_0, Γ_i and ε_t are the vector of constants, matrix of parameters and vector of error terms, respectively.

Based on the above VAR model, we first implement Granger causality tests to figure out the interdependencies among the East Asian stock markets in our sample. Overall, *x* is said to be a *Granger cause* of *y* if the present value of *y* can be predicted with greater accuracy by using also past values of *x* rather than not using such information, all else equal (Granger, 1969). Thereafter, we further examine the long-run equilibrium relationships among these markets – if any – by means of co-integration tests. Finally, we conduct generalized impulse response analyses to uncover the short-term causal relationships among the various East Asian stock markets in our sample. As we are particularly interested in the impact of the 1997–1998 Asian financial crisis, we henceforth examine the dynamic linkages among East Asian stock markets before, during and after this crisis.

1. Interdependencies among Major East Asian Stock Markets

First, we implement Granger causality tests during each subperiod for the entire sample of East Asian stock markets, to examine their interdependencies. Thereafter, we also incorporate the US stock market in the analyses. As Granger causality results are very sensitive to the number of lags chosen (e.g., Brocato and Smith, 1989; Chung and Liu, 1994; Click and Plummer, 2005), we first

[11] We also estimated the model for the entire sampling period, but this is not the base case of our analyses. We discuss the results from this model at the end of Section IV.1.

estimated the VAR model with 15 days as the maximum lag length and then implemented a lag-length test.[12] Whereas the Akaike and Schwarz information criteria indicated that fewer lags may be sufficient, we use the Sims likelihood-ratio test in this part of the analyses in order to ensure that all the dynamics in the data are being captured. As a result, the number of lags in the Granger causality tests are 9, 3 and 13, respectively for the pre-crisis, crisis and post-crisis analyses.[13] When the post-crisis period is considered to start at July 1, 1999, the models include 8 lags. The Granger causality test results are reported in Table 2. Overall, the findings in this part are not very different when using local currency versus US dollars terms.

The results for the pre-crisis period point out that the East Asian stock markets are rather segmented before the 1997–1998 Asian financial crisis, consistent with the findings of DeFusco *et al.* (1996). Using 0.05 as cutoff level, we only find some marginally significant evidence that the Japanese Nikkei 225 Stock Average (JP) Granger causes the South Korean SE Composite (KR).[14] Also, we document some marginally significant interaction mechanisms between the stock market indices of Singapore and Hong Kong. The strongest result is that of the Singaporean Strait Times (SG) Granger causing the Taiwanese SE Weighted (TW), but this relation is only significant when returns are expressed in local currencies. Once the US stock market is included in the analyses, we find that it leads the Japanese, Singaporean, Hong Kong and Taiwanese stock markets in local currency as well as US dollar terms whereas the reverse does not hold true. We find no interaction

[12] We believe that 15 days should be enough to capture one stock market's response to innovations in the other markets. Eun and Shim (1989) and Janakiramanan and Lamba (1998) also use 15 lags whereas Dekker *et al.* (2001) use 9 lags. Yang *et al.* (2003) use only two lags while Click and Plummer (2005) use one and five lags in their VAR models.

[13] For the crisis period, the FPE and AIC statistics indicate that two lags are sufficient whereas the SC and HQ statistics suggest that only one lag is needed. Given that the impulse response analyses in Section IV.3 reveal that a one unit shock in a market may lead to a response in the other countries that can last for five to six days during the crisis period, we have checked the robustness of our results when using 6 lags in the Granger causality analyses for the crisis period. Our results show that when using 6 lags, the Japanese market does not interact with the Taiwanese market while it is leading the South Korean stock market. Also, the Singaporean stock market lags the Hong Kong stock market while it is interacting with the Taiwanese stock market. All other results in Table 2 are robust.

[14] When returns are expressed in US dollar terms, there is some marginally significant evidence that the South Korean stock market is also Granger caused by the Singaporean and Hong Kong stock markets before the Asian financial crisis.

mechanisms between the USA and either South Korea or China. When combined, these results allow us to conclude that before the 1997–1998 Asian financial crisis, stock markets in East Asia respond mostly to worldwide shocks while regional factors have no large impact on share prices.

During the crisis period, the Japanese stock market is no longer as isolated as before, as it Granger causes the Taiwanese stock market and interacts with that of South Korea. The Singaporean and Hong Kong stock markets play a rather comparable role in East Asia during the 1997–1998 Asian financial crisis. They are interacting strongly with each other and are both leading the Taiwanese SE Weighted while responding to innovations in the South Korean and Shanghai stock markets. Yet, these results are somewhat stronger for Hong Kong than for Singapore. Once we incorporate the US stock market in the analyses, we still find that it only Granger causes the Japanese, Singaporean, Hong Kong and Taiwanese stock markets and not those of South Korea and China, as before the crisis. Yet, interestingly, we also find that the Japanese and especially the Hong Kong stock market influence the US S&P 500 Composite index during the 1997–1998 Asian financial crisis.[15] So, shocks in these East Asian countries are directly contaminating US stock market returns, pointing out again the seriousness of this crisis.

Finally, in the post-crisis period starting from July 1998, the Japanese stock market is still not much integrated with the other markets in East Asia, as it only Granger causes the Taiwanese stock market whereas it is lagging the Hong Kong stock market. Compared with the other markets in the region, the Singaporean and Hong Kong stock markets are two interactive markets, where the impact of the Hong Kong Hang Seng (HK) on the Singaporean Strait Times (SG) is somewhat stronger than vice versa. Next, they both Granger cause stock market returns in Taiwan and South Korea whereas the Hong Kong stock market also has some marginally significant impact on the

[15] In US dollar terms, however, the Japanese stock market does not Granger cause the US market during the crisis.

Shanghai stock exchange and, as already pointed out, Japan. Overall, these results become stronger when the series are expressed in US dollar terms than in local currencies. The Taiwanese and South Korean stock markets are largely endogenous markets, as they are fundamentally affected by but do not have much impact on the other East Asian markets.[16] As before, the Shanghai stock exchange remains a rather isolated market after the 1997–1998 Asian financial crisis. Finally, once the US stock market is included in the analyses, we find that it is still a leading market, now to all East Asian stock markets, except for China. Moreover, the results suggest that its impact on East Asian stock markets is strengthened after the Asian financial crisis.

Next, we have split up the post-crisis period into a transition period from July 1, 1998 to June 30, 1999 and a true post-crisis period from July 1, 1999 to June 30, 2003, to examine in more detail the changing nature of East Asian stock market interdependencies. Doing so should help us to determine whether the increased stock market integration as of the Asian financial crisis was transient or permanent. Our Granger causality results for the transition period reveal that East Asian stock markets again are fairly segmented during this period (not reported). We only find that the South Korean SE Composite is Granger caused by the Singaporean Trait Times and the Hong Kong Hang Seng whereas the US S&P 500 Composite index leads all stock markets in East Asia, except for China. For the period from July 1, 1999 to June 30, 2003, Table 2 shows that the interaction mechanism between the Singaporean and Hong Kong stock markets has become much weaker (only significant at the 10% level), whereas these two markets still Granger cause the Japanese, Taiwanese and South Korean stock markets. Also, the Japanese stock market now leads the Singaporean market whereas the South Korean SE Composite Granger causes the Japanese Nikkei 225 Stock Average as well as the Taiwanese SE Weighted. Finally, the influence of the

[16] Yet, when the series are expressed in US dollars, the South Korean stock market Granger causes the Hong Kong and Taiwanese stock markets in the post-crisis period.

USA in the region turns out to be even larger when considering only the period as of July 1, 1999.

Finally, we implemented Granger causality tests for the entire sampling period (not reported). Given the unit root test results in Table 1, we used the first difference of the log-transformed stock market indices of Japan, Singapore, Hong Kong and Taiwan to make them stationary whereas we included the stock market data for South Korea and China in the level. In this model, we also included a dummy variable for the 1997–1998 Asian financial crisis, which equals one during the crisis period and zero before as well as thereafter. Overall, these additional results are largely consistent with those for the after-crisis subperiod, except that Japan is interacting with a larger number of countries than is revealed in the subperiod analysis. In particular, it is interacting significantly with the Singaporean and Hong Kong stock markets. These results thus stress again the importance of not mingling up the subperiod data and may also partly explain why we find less evidence of Japan's leading role as compared with prior studies (e.g., Tan and Tse, 2002).

To conclude, although some studies have argued that the Japanese stock market is the leading market in the Asian region (e.g., Ghosh *et al.*, 1999; Masih and Masih, 2001), our results do not support this notion, at least not for the six East Asian stock markets that are included in our study. In contrast to Tan and Tse (2002), we also do not find that the influence of Japan has been increasing in more recent years. Rather, our findings point out that the Japanese stock market is quite an endogenous market under normal market conditions; it was only during the 1997–1998 Asian financial crisis that we found some increased impact of this market on the Taiwanese, South Korean and – to some extent – also the US stock market. After the crisis, however, these effects largely disappeared while the Japanese Nikkei 225 Stock Average became sensitive to shocks in Singapore, Hong Kong and South Korea. Second, the Singaporean and especially the Hong Kong stock market increased their influence in the region during the Asian financial crisis. What's more,

this impact was even further strengthened after the 1997–1998 Asian financial crisis, although our results do not support the idea that this effect was directly caused by the Asian financial crisis itself. Indeed, our results suggest that more is going on than just market contagion. During the crisis, these markets were also highly responsive to shocks in other East Asian countries, in particular South Korea and China, but the latter effects more clearly proved to be of a transient nature. So, unlike Yang *et al.* (2003), who point out that Singapore is the leading market, and Masih and Masih (1999) and Dekker *et al.* (2001), who stress the leading role of Hong Kong, our findings reveal that both countries have similar leading characteristics, especially as of the 1997–1998 Asian financial crisis. Yet, during the crisis itself, the influence of Hong Kong was somewhat stronger. Besides, our results point out that after the Asian financial crisis, South Korea and especially Taiwan became largely endogenous markets, responding to innovations from Singapore and Hong Kong. At the same time, the Taiwanese and, to a smaller extent, South Korean stock markets exert little influence on the other markets in the region. Next, for the Shanghai SE Composite index, tests in local currency as well as US dollar terms indicate that it is not interacting with any other East Asian stock market included in this paper, and this during each examined subperiod. During the crisis, however, we do find some marginally significant impact of the Shanghai SE Composite index on the Singaporean Strait Times and the Hong Kong Hang Seng. Nevertheless, our findings make clear that stock market in Shanghai remains quite isolated in more recent years, despite China's increased importance in the world economy. Apparently, there are some counteracting forces at work that prevent China's integration with other stock markets in East Asia and the USA. Following Korajczyk (1996), one important reason may be the restrictions on international capital flows in China, which prevent foreigners from investing in Chinese stock markets. Indeed, it was only as of 2002 onwards that the Chinese government allowed QFII, i.e. qualified foreign

institutional investors, to take some limited stake in the stock markets of the Mainland. At the same time, domestic investors are (still) facing huge restrictions on international portfolio investments. As the returns on alternative investments, e.g., bank deposits, are relatively low, a lot of the growing middle-class' accumulated savings have been channeled towards China's stock markets in more recent years, sometimes even relaxing the link between company fundamentals and stock prices. Finally, once the USA is incorporated in the Granger causality analyses, the results point out that the US stock market is the leading market for all East Asian stock markets that are included in our sample, except for China, and this before, during as well as after the Asian financial crisis. Indeed, the S&P 500 Composite index Granger causes these five East Asian stock market indices whereas there is no evidence of causality in the other direction. It was only during the 1997–1998 Asian financial crisis that we find some impact of Japan and especially Hong Kong on US stock market returns. The impact of the USA on East Asian stock markets was even further strengthened in more recent years. Overall, our results on the co-movement of stock markets in East Asia and the USA are consistent with prior findings by Chung and Liu (1994), Dekker *et al.* (2001) and Yang *et al.* (2003), among others.

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Insert Table 2

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2. Long-run Equilibrium: Co-integration Analysis

Having verified the order of all series, we now test whether a co-integrating relationship exists among (some) stock market indices such that a stationary combination can arise out of the non-stationary variables. According to Engle and Granger (1987) and Stock and Watson (1988), co-integrated variables share common stochastic trends and co-integrating vectors purge these trends from the linear combination of the variables. It is only by identifying these long-run

relationship(s) – if existent – that the short-term dynamics can be described in an accurate manner. The reason is that the short-term dynamic path of the studied variables has to bear some connection with their deviation from the equilibrium relationship(s).

In order to examine the long-run equilibrium relationship(s) among East Asian stock markets, we implemented co-integration tests in each subperiod. This co-integration analysis is implemented by means of the Johansen test, which is based on a VAR framework. It can be re-written in an error-correction (ECM) or differenced form as follows:

$$\Delta X_t = \Gamma_0 + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \pi X_{t-1} + \varepsilon_t \quad (3)$$

where $\pi = \alpha * \beta'$; the elements of the matrix α are the short-term adjustment parameters to the long-run relationship(s) reflected in the matrix β of the VAR model. The Johansen methodology centers on estimating the π matrix from an unrestricted VAR model and then testing whether the restrictions implied by the rank of π, i.e. r number of co-integrating vectors, can be rejected. Additional testing of the co-integration space spanned by β can produce further information on the long-run market linkages. Here, particular interest is in how many markets are actually included in each of the identified long-run equilibrium relationships, if any. This can be tested by examining whether $\beta_{ij} = 0$ in the i^{th} ($i = 1, \ldots, r$) co-integrating vector for the j^{th} ($j = 1, \ldots, 6$) market.

Again, before implementing the tests, we need to first specify the optimal lag length and decide on including an intercept and/or time trend. As mentioned above, the optimal number of lags for each model is selected based on a likelihood-ratio test, with 15 days as the maximum. After visually inspecting the data, we included an intercept in the tests to reflect that all series have a non-zero mean whereas we assumed that there is no time trend in each of the series. Table 3

reports the lag-length specification and co-integration test results from the Johansen test for the different subperiods, both in local currency and US dollar terms.

The Trace and Max test statistics in Table 3 indicate that there is no co-integrating vector in the pre-crisis (Panel A) and crisis (Panel B) periods whereas there is one co-integrating vector among the six East Asian stock markets after the 1997–1998 Asian financial crisis (Panel C). These findings arise when the stock market indices are expressed in local currency as well as US dollar terms. So, unlike Bessler and Yang (2003), we do not find that the co-integration results change when accounting for exchange rate risk. The result for the pre-crisis period is consistent with the findings of DeFusco *et al.* (1996), Sheng and Tu (2000) and Yang *et al.* (2003). However, unlike Sheng and Tu (2000) and Yang *et al.* (2003), who suggest one and two co-integrating vectors, respectively during the 1997–1998 Asian financial crisis, we find no co-integrating equation. Our findings thus indicate that the East Asian stock markets in our sample have no shared fundamental economic forces during that period.

For the post-crisis period, we also report the results (using local currency as the numeraire) when each stock market index is excluded – one-by-one – from the long-run equilibrium relationship identified by the above co-integration test. Using 0.05 as cutoff level, the results in Table 4 suggest that all East Asian markets examined in this paper belong to the *same* co-integrating system, although the results are only marginally significant for Japan and China. This conclusion is rather strange, given the above-documented Granger causality results for the post-crisis period. So, we checked the robustness of our findings by implementing a co-integration test for the period from July 1, 1999 to June 30, 2003. The results of this additional test are reported in Panel D of Table 3 and suggest that there is no co-integrating equation among the six East Asian stock market indices in our sample, neither in local currency nor in US dollar terms. In other words, the finding that there is

one co-integrating vector in the post-crisis period is not robust to alternative definitions of the post-crisis period. So, we can conclude that stock markets in East Asia evolve independently from one another in the long run, consistent with stock market efficiency. Lastly, we cannot conclude that the synchronized policy measures that were taken immediately after the crisis – to reduce the likelihood of a future catastrophe – are responsible for the increased regional integration showing up in Panel C of Table 3 as we find no co-integrating equation in the transition period (not reported).[17]

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Insert Tables 3 – 4
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3. Short-term Relationship: Impulse Response Analysis

In this section, we examine the short-term dynamic causal relationships among East Asian stock markets, with a special attention as to the influence of the 1997–1998 Asian financial crisis on stock market integration. For this purpose, we implement generalized impulse response analyses for three subperiods, i.e. before, during and after the Asian financial crisis. The post-crisis period here is defined as the period from July 1, 1999 to June 30, 2003, given that East Asian stock markets are largely segmented in the year following the Asian financial crisis. Given that the unit root test results revealed that the return series are integrated of order one and given that no co-integrating relationship exists among the various stock market indices in the different subperiods, we can directly employ the VAR methodology on the return series. We investigate the impact of a one unit shock rather than a one standard deviation shock, to account for the changing volatility of stock

[17] We also estimated a co-integration model for the entire sampling period. Yet, as the unit root tests pointed out that the South Korean SE Composite and the Shanghai SE Composite do not contain a unit root, we do not include these two markets in this co-integration test for the entire sampling period. Lastly, a dummy variable for the 1997–1998 Asian financial crisis, which equals one during the Asian financial crisis and equals zero before as well as after this crisis, is added to equation (3) for the co-integration test on the entire sample (and to the VAR model that is estimated to decide on the number of lags). Both Trace and Max test statistics in local currency and US dollar terms suggest that there is no co-integrating equation during the whole sampling period for the four examined stock markets, i.e., Japan, Singapore, Hong Kong and Taiwan. In a final co-integration test, we also included the USA in the system, but again find no co-integration.

returns over time.[18] Table 5 reports our findings. Figure 2 then visually presents the results of the generalized impulse response analyses during 20 days after an innovation.

Table 5 and Figure 2 show that stock markets in the East Asian region respond to shocks with a high degree of efficiency, suggesting that there is little scope to benefit from any lead-lag relationships between stock markets. Indeed, it is only during the 1997–1998 Asian financial crisis that we find an impact that can last for a longer number of days. In contrast, before as well as after the crisis, we find that responses generally take place on the same day.[19] Also, when it takes two days to adjust, then this in general can be attributed to differences in time zone and – for stock markets in the same time zone – differences in opening hours of the exchanges.

Table 5 further reveals that, consistent with the Granger causality test results, stock market integration before the 1997–1998 Asian financial crisis was very limited. The strongest interaction took place between the Singaporean and Hong Kong stock markets, where a one unit shock in the Singaporean Straight Times induced a 0.74% response in the Hong Kong Hang Seng on the same day. Alternatively, a one unit shock in the Hong Kong stock market caused a 0.31% response in the Singaporean market. Besides, a one unit shock in Singapore affects stock market returns in Taiwan by 0.16% on the same day and by 0.21% on the next day, consistent with the fact that the Taiwanese stock exchange closes before that of Singapore (see footnote 6). Yet, the impulse response analyses point out that stock market interdependencies were strengthened during the 1997–1998 Asian financial crisis, consistent with the Granger causality test results. As a consequence, the volatility in one stock market due to shocks in the other East Asian markets was relatively large during the period surrounding the Asian financial crisis, but this effect turned out to

[18] Results in local currency and US dollar terms are more or less the same, so we just report the results in local currency terms here. Dollar-denominated results are available from the authors upon request.

[19] Yet, the Shanghai stock market seems to react somewhat more slowly when compared with the other East Asian markets, although this effect has been reduced over time. As an example, before the Asian financial crisis, its responses to an innovation in other East Asian countries and the USA are largest on day 2 and 3, respectively.

be only temporary. Furthermore, it is interesting to observe that the Singaporean and especially the Hong Kong stock market were reacting more heavily to shocks from other countries during the crisis period than thereafter. The reverse holds true for Japan, Taiwan and South Korea, i.e., their reactions to shocks in the other countries actually are stronger in the post-crisis period. Hereafter, we will discuss our results mainly for the crisis and post-crisis period, country by country.

First, for the Japanese stock market, we find that during the crisis period, the Singaporean and especially the Hong Kong stock market respond most heavily to shocks in Japan, i.e. 0.31% and 0.61%, respectively on the same day. In contrast, the Japanese market reacts by only 0.20% and 0.23% to an innovation in the Singaporean and Hong Kong stock market, respectively. In the post-crisis period, the South Korean stock market responds most, by 0.67% on the same day, while the Singaporean and Hong Kong markets show responses of 0.39% and 0.49%, respectively to a unit shock in the Japanese market. Taiwan's SE Weighted increases by 0.32% on the same trading day and by 0.15% on the next day to a one unit innovation in the Japanese Nikkei 225 Stock Average after the Asian financial crisis. Finally, the Japanese stock market responds by somewhat more than 0.45% to an innovation in Singapore and Hong Kong, and by 0.21% and 0.29% to an innovation in Taiwan and South Korea, respectively in the post-crisis period.

Second, we again find that the Singaporean and Hong Kong stock markets are two interactive markets during as well as after the 1997–1998 Asian financial crisis. During the crisis, a one unit shock in the Singaporean stock market induces a 0.94% effect on the same day in the Hong Kong market whereas a one unit shock in the Hong Kong stock market engenders a 0.55% response in the Singaporean market. Also, during the crisis an innovation in one of these markets affects Taiwanese stock market returns by 0.15%–0.20% on the same day and by 0.10%–0.15% on the next day whereas a shock in the Taiwanese stock market influences the Singaporean market by

0.35% and the Hong Kong market by 0.47% on the same day. After the Asian financial crisis, we see that the interaction mechanism between Singapore and Hong Kong becomes somewhat weaker as a one unit shock in the Singaporean Strait Times induces a 0.69% effect in the Hong Kong Hang Seng whereas a one unit shock in the Hong Kong Hang Seng evokes a 0.52% reaction in the Singaporean Strait Times. Also, innovations in both markets still affect returns in Taiwan by about 0.35%–0.40% on the same day and by about 15%–0.20% on the next day. Their impact on returns in South Korea has become non-trivial as well, by 0.85% for a one unit shock in Singapore and by 0.77% for a one unit innovation in Hong Kong. In the post-crisis period, the Taiwanese stock market has an impact of 0.20% and 0.25% on the same day on stock prices in Singapore and Hong Kong, respectively. Likewise, the effects of South Korea on these two markets equal 0.30% and 0.36%, respectively. Finally, we find that shocks in the Taiwanese stock market affect South Korean stock returns by 0.42% on the same day whereas a shock in South Korea has an impact of only 0.28% in Taiwan.

Regarding the Chinese stock market, we find no important interdependencies with the other East Asian stock markets in our sample. While the Granger causality test results revealed some impact of China on Singapore and Hong Kong during the Asian financial crisis, the results in this section point out that these effects were only marginally important in size. Indeed, the strongest impact actually is that of China on Hong Kong, where a one unit shock in the Shanghai SE Composite affects stock returns in Hong Kong by only 0.14% on the same day during the financial crisis.

Finally, our impulse response results for the USA show that the US stock market influences East Asian markets in all three subperiods, mostly on the second day. The latter finding is consistent with the fact that East Asian stock markets close before US markets actually open.

Before the 1997–1998 Asian financial crisis, a one unit shock in the USA has the largest impact on Hong Kong (0.77% on day 2), Singapore (0.39% on day 2) and Japan (0.31% on day 2). During the Asian financial crisis, these effects become even stronger in all countries, except for China. In the post-crisis period, we find that the influence of a US shock has become larger only for South Korea as compared with the situation *during* the crisis period (0.60% rather than 0.36% on day 2). When compared with the situation *before* the Asian financial crisis, the impact of the USA on Japan and Taiwan was also enhanced whereas the US market has lost some of its influence on Singapore and Hong Kong over time. In contrast, our results suggest that the US stock market responds only in a very limited manner to innovations in East Asia, and this before, during as well after the Asian financial crisis. During the crisis period, for example, the US stock market reacts by 0.08% and 0.09% to innovations in Singapore and Hong Kong, respectively, whereas Japan's impact equals 0.07%. Interestingly, as of July 1, 1999, a one unit shock in East Asia generally has a somewhat larger impact on US stock returns, consistent with the idea of an increased global integration of capital markets. In the post-crisis period, the US S&P 500 index responds by about 0.18% to a one unit shock in the Singaporean Strait Times (SG) whereas the influence of Japan and Hong Kong is around 0.13%. These effects, however, are still considerably smaller than the US impact on East Asian stock markets.

Overall, our findings from the impulse response analyses are consistent with those of the Granger causality tests. They point out that during the 1997–1998 Asian financial crisis, the Hong Kong stock market was very sensitive to innovations in the other East Asian countries and the USA, but also greatly affected share prices in those countries. So, Hong Kong was a very important financial center in the East Asian region during the Asian financial crisis. After the crisis, we find that it is still highly influential, but has lost some of it huge impact while becoming also less

affected by the other East Asian stock markets and the USA. This result most clearly shows up when examining the interaction mechanisms between Singapore and Hong Kong. At the same time, the interaction mechanisms among the other East Asian stock markets were enhanced after the Asian financial crisis. As an example, shocks in South Korea (and to a smaller extent also Taiwan) now account for a larger portion of stock price volatility in the other East Asian countries, although it is still the case that these stock markets are more affected by Japan, Hong Kong and Singapore than vice versa. The results clearly point out that over time Singapore has become at least as important as a financial center in East Asia as Hong Kong. Besides, the US stock market has become more responsive to innovations in East Asia in more recent years, although we observe the reverse for the responsiveness of East Asian countries to shocks in the USA. Indeed, the impact of the USA on East Asia has been loosened somewhat over time. Lastly, and consistent with the Granger causality test results, our findings for the Shanghai stock exchange suggest that it is still a fairly isolated market, as it does not respond much to shocks in the other East Asian stock markets, while at the same time its influence on these other markets remains limited.

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Insert Table 5 and Figure 2
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V. Conclusions

This paper examines the long-run and short-term dynamic causal relationships among six major East Asian stock markets, i.e. Japan, Singapore, Hong Kong, Taiwan, South Korea and China. For this purpose, we have built multivariate VAR models to examine the degree of integration among these stock markets, and alternatively excluded or included the USA as an additional market. In these analyses, we paid special attention to the effects of the 1997–1998 Asian financial crisis. We first implemented Granger causality tests to examine the time-varying lead-lag relationships among

stock markets. Thereafter, we implemented co-integration tests to figure out whether a long-run equilibrium relationship(s) exists among East Asian stock markets in the different subperiods. Finally, we have conducted generalized impulse response analyses to examine the short-term causal relationships before, during and after the 1997–1998 Asian financial crisis. All these analyses were done using daily data in local currency and US dollar terms. However, we can safely conclude that the currency of denomination does not matter greatly.

Our results further show that before the 1997–1998 Asian financial crisis, most stock markets in East Asia responded to worldwide shocks while regional factors had no large impact on share prices. In fact, we only found some significant interaction mechanism between the stock exchanges of Singapore and Hong Kong during that time window. Yet, the Asian financial crisis strengthened the linkages among stock markets in the East Asian region, except for China. This result was only a temporary phenomenon, however, thereby pointing out that the increased interdependencies during the financial crisis were due to a market contagion effect. East Asian stock markets did not always react in the most efficient way to shocks during the crisis, as a one unit shock sometimes led to responses in the other countries that lasted for several days. Our results also point out that the Hong Kong stock market played an important role in spreading the crisis in East Asia and the world. In the year following the 1997–1998 Asian financial crisis, we see a clear reduction in stock market interdependencies while stock market integration was strengthened again in more recent years. Yet, our results do not support the idea that stock markets are co-integrated, as they bear no long-run equilibrium relationship. Also, the influence of the Hong Kong stock market – which was substantial during the crisis – has been reduced over time, while interdependencies among other East Asian countries became more important. The Singaporean stock market thereby has become at least as important as the Hong Kong stock

exchange. Our results do not support the leading role of Japan in the region, however. Shocks in Japan, Singapore and Hong Kong do have a significant impact on share prices in Taiwan and especially South Korea whereas the latter markets still have only a limited influence on the other East Asian countries in our sample. Also, China's stock market isolation was not significantly reduced over time, despite its capital market development and its huge economic growth. Besides, US stock market returns help to explain returns in East Asia – except for China – and vice versa. We do have to point out that the latter relation is still relatively limited in importance, although has been increasing in magnitude over time. Overall, our results thus stress an enhanced integration of capital markets in East Asia, with each other and with the USA, resulting in a reduction of international diversification benefits over time. These findings are consistent with the stronger macro-economic linkages among East Asian countries and between this region and the world in more recent years, but also stress the importance of a free flow of capital to realize a further global integration of capital markets.

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Figure 1 Data Plots of Seven Stock Market Indices (Log Transformation) in Local Currencies

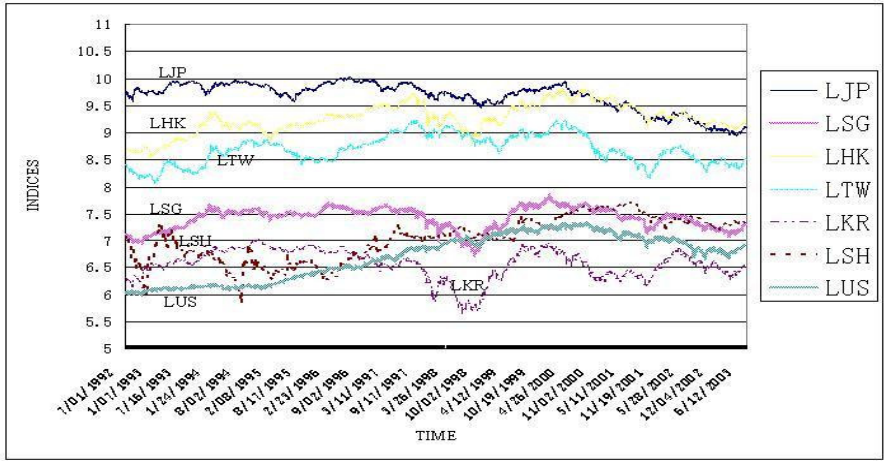
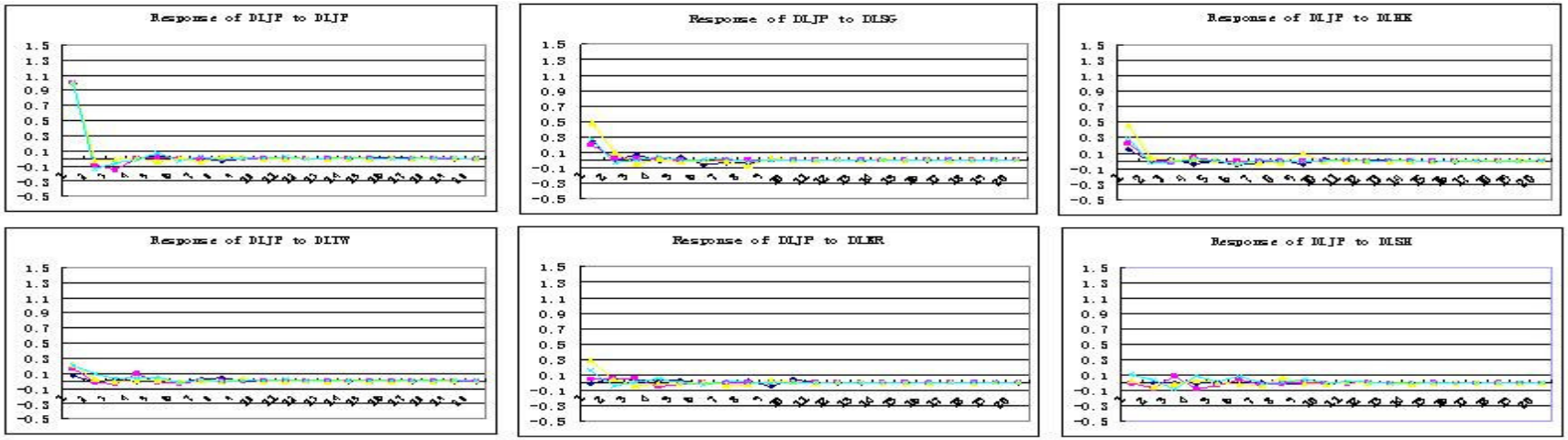
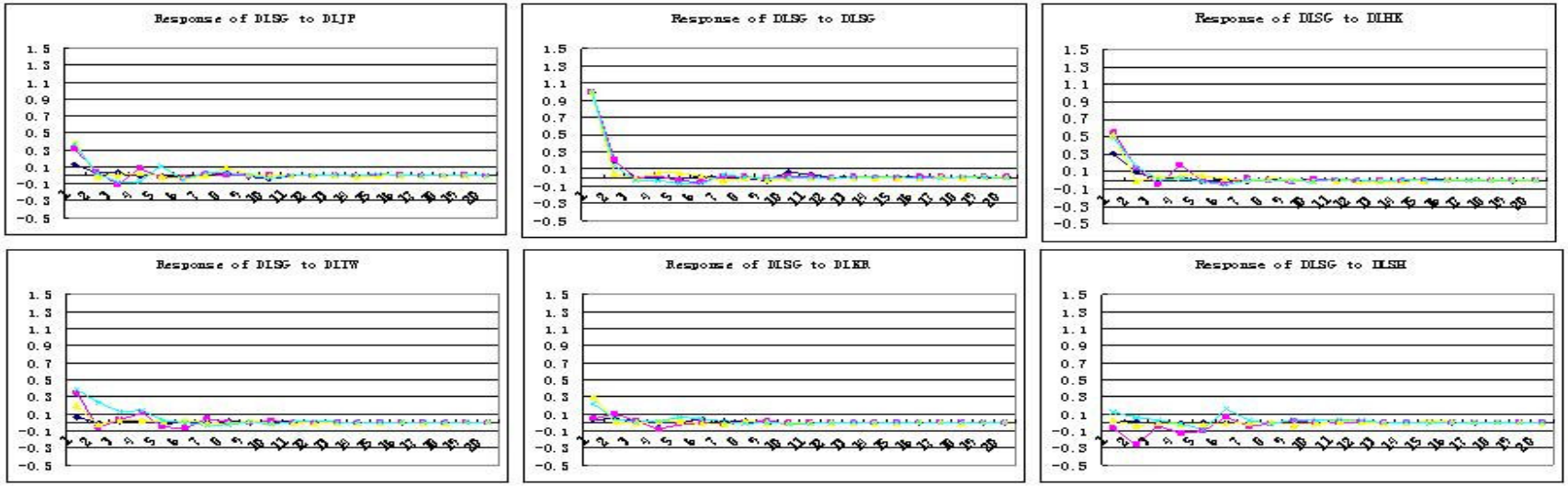


Figure 2 Generalized Impulse Responses Graph of Stock Market Returns in East Asia*

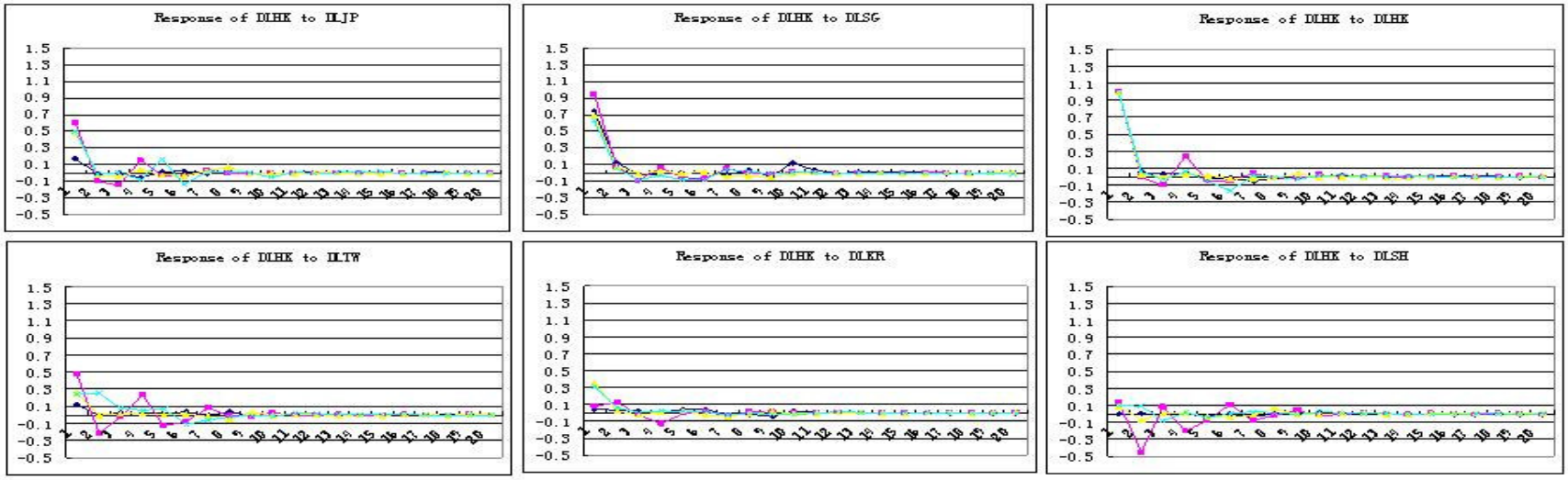
A The Japanese Stock Market



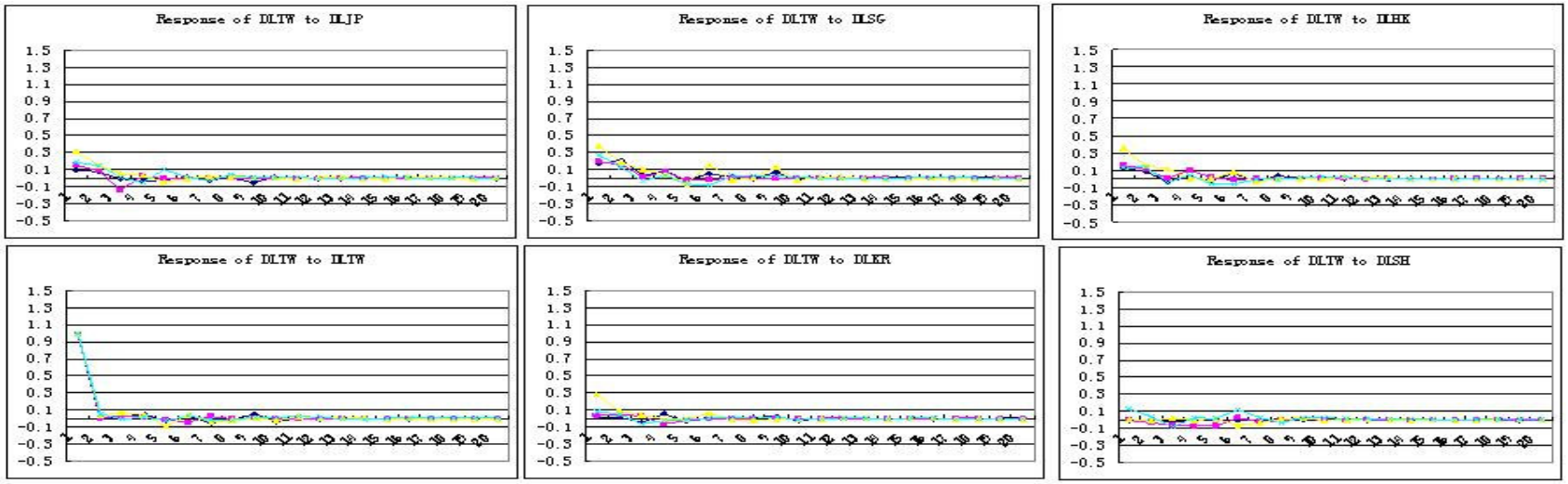
B The Singaporean Stock Market



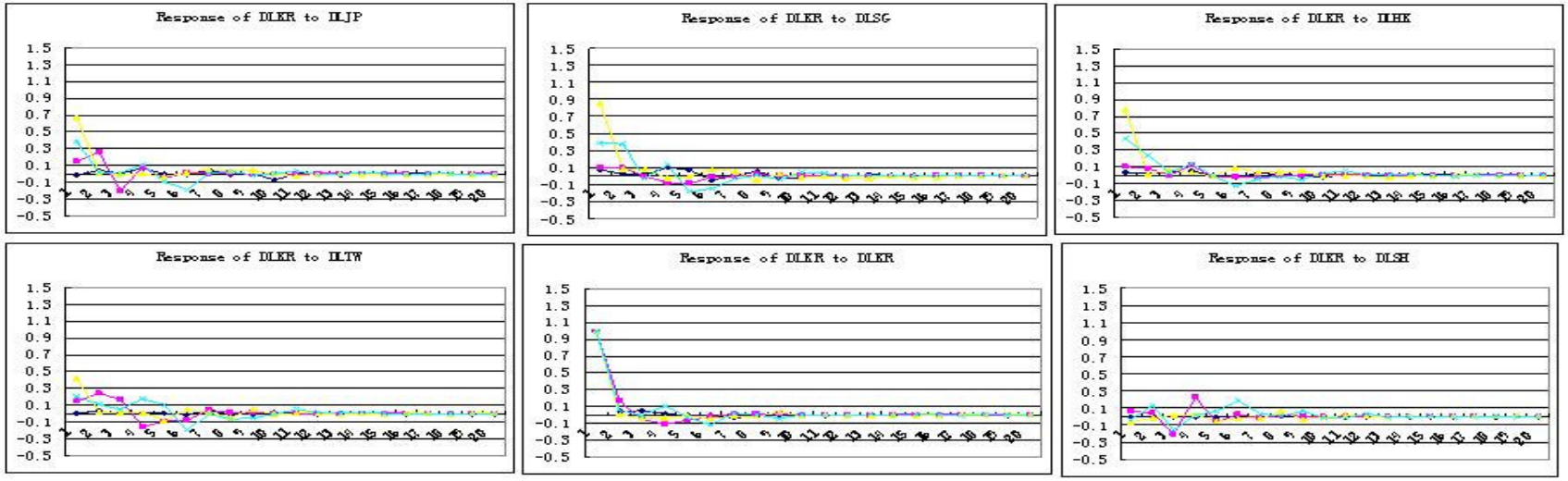
C The Hong Kong Stock Market



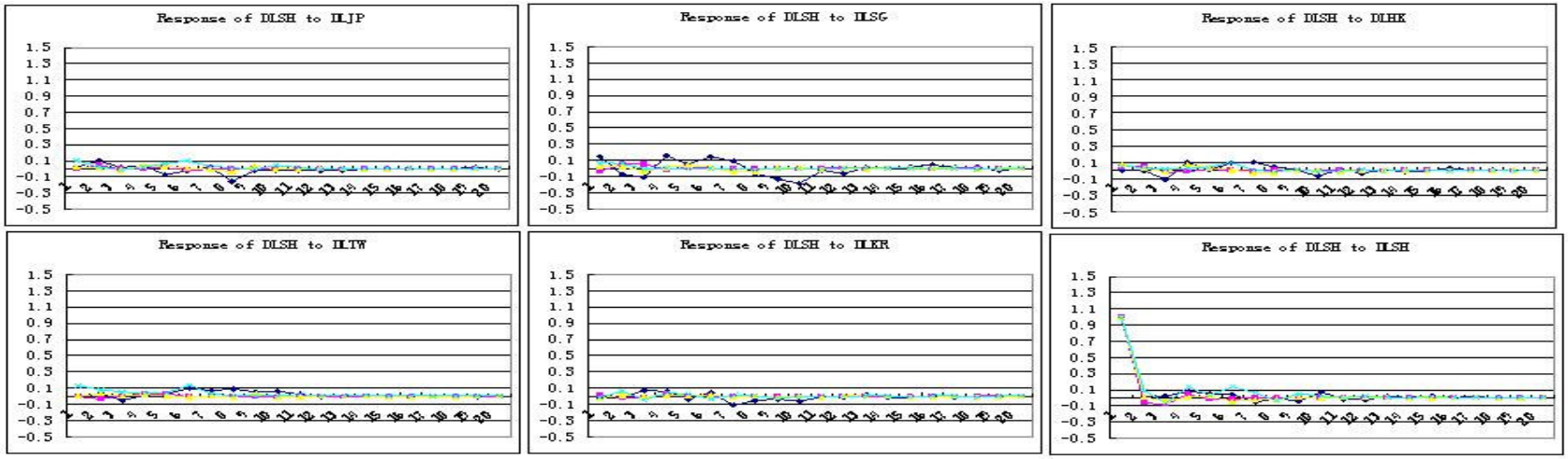
D The Taiwanese Stock Market



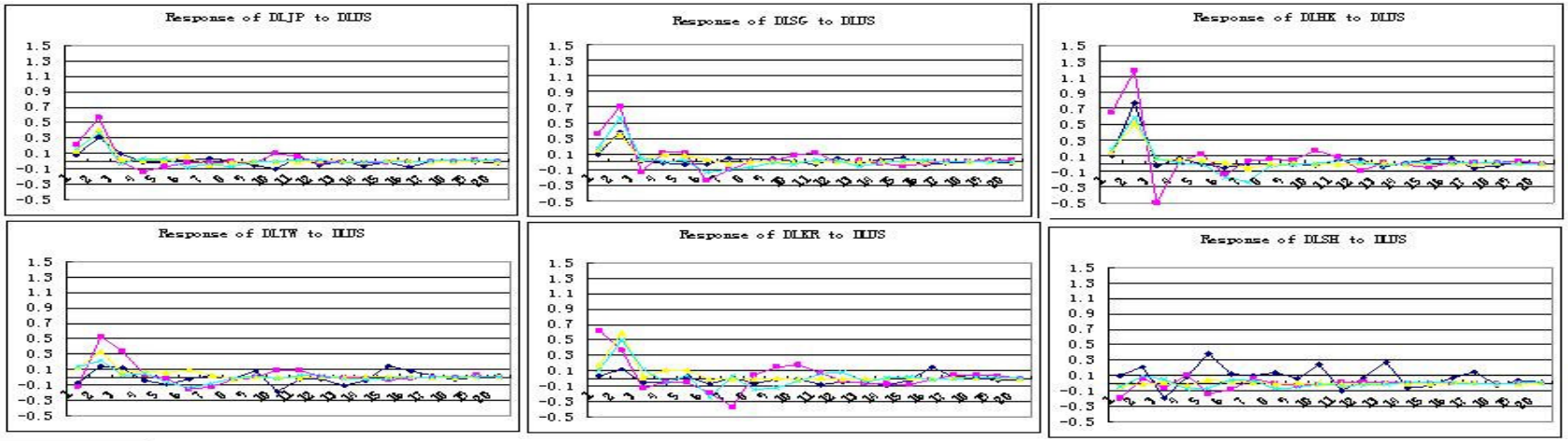
E The South Korean Stock Market

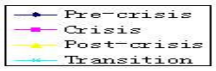


E The Shanghai Stock Market



F Responses to the US Stock Market





*

Table 1 Unit Root Tests

Panel A: Unit Root Tests for the entire Sampling Period

Market	ADF Statistic (Local Currency)	ADF Statistic (US Dollar)	ADF Statistic with structural breaks (Local Currency)	ADF Statistic with structural breaks (US Dollar)	Critical Value 10%	Critical Value 5%
JP	-0.702907	-0.680949	-1.849313	-1.866545	-2.567245	-2.862349
SG	-2.226703	-1.902634	-2.543730	-2.438943	-2.567245	-2.862349
HK	-2.424407	-2.432247	-2.058749	-2.058094	-2.567246	-2.862350
TW	-1.746904	-1.505318	-1.332693	-1.345777	-2.567245	-2.862349
KR	-2.197040	-1.535007	-3.444227*	-3.597945*	-2.567245	-2.862349
SH	-1.661871	-1.949930	-3.065829*	-3.143157*	-2.567245	-2.862349
US	-1.534722	-1.534722	-0.498333	-0.498333	-2.567245	-2.862349

Panel B: Unit Root Tests for various Subperiods

	ADF Statistic (Local Currency)	ADF Statistic (US Dollar)	Critical Value 10%	Critical Value 5%
B1: Pre-Crisis Subsample				
JP	-2.588224	-2.555536	-2.567890	-2.863550
SG	-1.706969	-1.594549	-2.567891	-2.863552
HK	-0.591381	-0.635212	-2.567890	-2.863550
TW	-0.271442	-0.476420	-2.567890	-2.863550
KR	-2.066020	-1.748871	-2.567890	-2.863550
SH	-2.246902	-2.230111	-2.567890	-2.863550
US	1.390603	1.390603	2.567890	-2.863550
B2: Crisis Subsample				
JP	-2.134588	-1.750437	-2.572660	-2.872455
SG	-0.544941	-0.820388	-2.572684	-2.872499
HK	-1.195851	-1.159686	-2.572730	-2.872586
TW	-1.278961	-0.966656	-2.572660	-2.872455
KR	-0.554648	-1.042515	-2.572660	-2.872455
SH	-1.586048	-1.577042	-2.572660	-2.872455
US	-1.062702	-1.062702	-2.572660	-2.872455
B3: Post-Crisis Subsample				
JP	-0.743006	-0.627018	-2.567890	-2.863550
SG	-1.928978	-1.840117	-2.567891	-2.863552
HK	-1.587354	-1.576329	-2.567890	-2.863550
TW	-1.306611	-1.087250	-2.567890	-2.863550
KR	-2.664265	-2.737703	-2.567890	-2.863550
SH	-1.536603	-1.536867	-2.567890	-2.863550
US	-1.260058	-1.260058	-2.567890	-2.863550

* significant at the 1% significant level.

Table 2 Granger Causality Test Results

	Before crisis		*During crisis*		*After July 1998*		*After July 1999*			*Before crisis*		*During crisis*		*After July 1998*		*After July 1999*	
	Local	*USD*	*Local*	*USD*	*Local*	*USD*	*Local*	*USD*		*Local*	*USD*	*Local*	*USD*	*Local*	*USD*	*Local*	*USD*
Null	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	Null	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*	*F-value*
Hypothesis	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	Hypothesis	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*	*(p-value)*
Panel A: The Japanese Stock Market and Five East Asian Stock Markets																	
JP -/-> SG	1.2195	1.03158	1.16579	1.43221	1.6995	1.85799	**2.68500**	**2.99433**	SG -/-> JP	1.0886	1.33770	0.68359	0.93092	1.55458	1.90588	**2.67467**	**2.70649**
	(0.2786)	(0.41891)	(0.32336)	(0.23388)	(0.0554)	(0.06289)	**(0.00635)**	**(0.00253)**		(0.3681)	(0.17156)	(0.56281)	(0.42634)	(0.09185)	(0.05551)	**(0.00654)**	**(0.00596)**
JP -/-> HK	0.7056	1.21282	1.15796	0.68543	1.5518	1.09698	1.91246	1.54727	HK -/-> JP	1.3208	1.25259	1.02930	0.80765	**2.00151**	**2.75690**	**2.81033**	**3.35606**
	(0.7043)	(0.25460)	(0.32640)	(0.56169)	(0.0927)	(0.36238)	(0.05482)	(0.13668)		(0.2211)	(0.22548)	(0.38019)	(0.49064)	**(0.01771)**	**(0.00507)**	**(0.00438)**	**(0.00084)**
JP -/-> TW	1.1891	1.09190	**2.76083**	**2.71580**	**1.8018**	**2.61379**	1.74209	1.28819	TW -/-> JP	0.6268	0.89026	0.67685	0.81428	1.03665	0.95388	0.57040	0.62942
	(0.2978)	(0.35875)	**(0.04273)**	**(0.04533)**	**(0.0381)**	**(0.00773)**	(0.08487)	(0.14566)		(0.7749)	(0.57513)	(0.56695)	(0.48700)	(0.41269)	(0.47081)	(0.80275)	(0.75354)
JP -/-> KR	1.8631	**1.85524**	**3.46272**	**7.37167**	0.4203	1.02495	0.78238	0.85787	KR -/-> JP	1.3095	0.81763	**3.33488**	**2.81764**	1.36651	1.82573	**2.42789**	**3.02695**
	(0.0536)	**(0.02375)**	**(0.01695)**	**(9.4E-05)**	(0.9632)	(0.41489)	(0.61833)	(0.55181)		(0.2270)	(0.65864)	**(0.02008)**	**(0.03967)**	(0.16854)	(0.06835)	**(0.01335)**	**(0.00229)**
JP -/-> SH	0.9153	0.76096	0.18194	0.58332	1.3306	1.03655	0.90437	0.68362	SH -/-> JP	0.8058	0.83930	1.46702	0.83822	1.05725	0.96650	1.10715	1.28655
	(0.5108)	(0.72218)	(0.90861)	(0.62646)	(0.1879)	(0.40614)	(0.51197)	(0.70632)		(0.6109)	(0.63382)	(0.22405)	(0.47401)	(0.39317)	(0.46061)	(0.35555)	(0.24653)
Panel B: The Singaporean Stock Market and Four East Asian Stock Markets																	
SG -/-> HK	**2.14099**	1.63494	**3.38873**	**3.98572**	1.63062	**2.23333**	1.58395	1.79339	HK -/-> SG	1.82881	**1.74392**	**9.24080**	**9.00653**	**2.34572**	**2.67027**	1.88527	1.71517
	(0.02373)	(0.05840)	**(0.01870)**	**(0.00847)**	(0.07072)	**(0.02290)**	(0.12521)	(0.07454)		(0.05901)	**(0.03777)**	**(8.1E-06)**	**(1.1E-05)**	**(0.00432)**	**(0.00655)**	(0.05884)	(0.09079)
SG -/-> TW	**2.67569**	1.14905	**4.60515**	**3.64551**	**2.87582**	**4.77074**	**5.13028**	**5.36076**	TW -/-> SG	0.36754	1.10639	1.15503	1.03096	**1.74617**	1.00956	0.76690	0.72213
	(0.00443)	(0.30664)	**(0.00372)**	**(0.01331)**	**(0.00041)**	**(8.6E-06)**	**(2.8E-06)**	**(1.3E-06)**		(0.95060)	(0.34506)	(0.32755)	(0.37945)	**(0.04678)**	(0.42667)	(0.63214)	(0.67212)
SG -/-> KR	1.57881	**1.70685**	0.31946	1.45548	**3.38055**	**5.02406**	**2.18206**	**2.81105**	KR -/-> SG	1.13876	0.74517	**2.75981**	2.63456	0.73398	1.08788	0.33215	0.32629
	(0.11642)	**(0.04390)**	(0.81130)	(0.22726)	**(3.9E-05)**	**(3.7E-06)**	**(0.02658)**	**(0.00437)**		(0.33173)	(0.73933)	**(0.04279)**	(0.05040)	(0.73047)	(0.36878)	(0.95377)	(0.95617)
SG -/-> SH	1.35546	1.42873	0.67103	1.24907	1.47339	1.44146	0.86932	0.77065	SH -/-> SG	1.03860	**1.9580**	**4.44239**	**4.88283**	0.99207	0.27279	0.28408	0.23298
	(0.20366)	(0.12572)	(0.57053)	(0.29251)	(0.12025)	(0.17460)	(0.54190)	(0.62879)		(0.40660)	**(0.01524)**	**(0.00462)**	**(0.00257)**	(0.45655)	(0.97479)	(0.97133)	(0.98481)
Panel C: The Hong Kong Stock Market and Three East Asian Stock Markets																	
HK -/->TW	1.79880	1.31005	**6.89020**	**5.77073**	1.66069	**2.91940**	**2.88263**	**3.22753**	TW -/-> HK	0.49445	1.02291	1.02546	0.97291	0.94181	0.88932	0.88736	1.01573
	(0.06419)	(0.18785)	**(0.00018)**	**(0.00079)**	(0.06362)	**(0.00312)**	**(0.00353)**	**(0.00124)**		(0.87904)	(0.42796)	(0.38191)	(0.40609)	(0.50827)	(0.52465)	(0.52641)	(0.42209)
HK -/-> KR	1.29553	**1.71651**	1.52533	0.96704	**2.30972**	**3.54064**	**2.78023**	**3.23440**	KR -/-> HK	1.02369	1.18911	**4.24527**	**2.99544**	1.32331	**2.67457**	1.04126	1.25076

	(0.23446)	**(0.04222)**	(0.20843)	(0.40887)	**(0.00503)**	**(0.00046)**	**(0.00479)**	**(0.00122)**		(0.41855)	(0.27318)	**(0.00600)**	**(0.03141)**	(0.19204)	**(0.00647)**	(0.40280)	(0.26597)
HK -/-> SH	1.11832	0.94201	1.00588	0.97917	1.72624	**2.27000**	1.30657	1.30086	SH -/-> HK	1.35778	1.05094	**7.33173**	**7.40438**	0.89239	0.87115	1.04994	1.05839
	(0.34622)	(0.51616)	(0.39077)	(0.40314)	(0.05030)	**(0.02068)**	(0.23614)	(0.23907)		(0.20253)	(0.39907)	**(9.9E-05)**	**(9.0E-05)**	(0.56083)	(0.54024)	(0.39636)	(0.39016)
Panel D: Taiwanese, Korean and Shanghai Stock Markets																	
TW -/-> KR	0.96483	1.47487	1.72850	2.18581	1.22899	1.63045	1.83186	**2.06200**	KR -/-> TW	0.61278	0.52586	2.43567	2.60715	1.71609	**2.56123**	**2.31676**	**2.82687**
	(0.46753)	(0.10666)	(0.16164)	(0.09022)	(0.25207)	(0.11158)	(0.06756)	**(0.03685)**		(0.78700)	(0.92758)	(0.06530)	(0.05224)	(0.05218)	**(0.00901)**	**(0.01828)**	**(0.00417)**
TW -/-> SH	0.61496	0.60424	0.17275	0.68238	0.68647	0.88023	0.71220	0.71473	SH -/-> TW	1.03518	1.44023	0.51834	1.07104	0.84968	0.45341	0.51352	0.59703
	(0.78513)	(0.87342)	(0.91475)	(0.56356)	(0.77811)	(0.53244)	(0.68097)	(0.67871)		(0.40932)	(0.12072)	(0.67003)	(0.36195)	(0.60700)	(0.88882)	(0.84688)	(0.78091)
KR -/-> SH	0.63336	0.69952	0.34755	0.33837	1.00360	1.34165	0.33656	0.58835	SH -/-> KR	0.39030	1.19013	1.81010	1.24716	0.54686	0.31241	0.39218	0.39590
	(0.76922)	(0.78695)	(0.79095)	(0.79760)	(0.44501)	(0.21847)	(0.95192)	(0.78810)		(0.94022)	(0.27237)	(0.14581)	(0.29319)	(0.89586)	(0.96161)	(0.92514)	(0.92313)
Panel E: The US Stock Market and Six East Asian Stock Markets																	
US -/-> JP	**2.98902**	**2.33972**	**6.21478**	**2.86118**	**16.0038**	**10.4632**	**34.8237**	**27.5181**	JP -/-> US	0.77130	0.82524	**2.75214**	1.35341	1.24125	0.98143	0.37504	0.56723
	(9.9E-05)	**(0.00263)**	**(1.9E-05)**	**(0.00057)**	**(3.1E-34)**	**(5.7E-20)**	**(5.9E-33)**	**(3.3E-26)**		(0.71079)	(0.64994)	**(0.01936)**	(0.17829)	(0.24357)	(0.46441)	(0.86599)	(0.72520)
US -/-> SG	**7.43932**	**6.03865**	**9.33057**	**2.67453**	**16.4459**	**15.6164**	**34.1732**	**34.1623**	SG -/-> US	1.18354	1.15874	1.11891	1.28167	1.12166	1.08317	1.81231	1.95406
	(4.9E-16)	**(2.4E-12)**	**(3.8E-08)**	**(0.00125)**	**(3.0E-35)**	**(3.7E-31)**	**(2.3E-32)**	**(2.4E-32)**		(0.27768)	(0.29831)	(0.35085)	(0.22027)	(0.33555)	(0.37030)	(0.10768)	(0.08300)
US -/-> HK	**11.4867**	**10.9561**	**10.1998**	**4.12413**	**21.8853**	**23.9035**	**54.7751**	**54.8094**	HK -/-> US	1.11556	1.01720	**6.69760**	**2.98171**	0.80372	0.95001	0.76073	0.76016
	(8.5E-27)	**(2.2E-25)**	**(6.9E-09)**	**(2.2E-06)**	**(1.6E-47)**	**(1.4E-48)**	**(1.7E-50)**	**(1.6E-50)**		(0.33657)	(0.43396)	**(7.2E-06)**	**(0.00034)**	(0.65673)	(0.49550)	(0.57824)	(0.57866)
US -/-> TW	**2.29739**	**1.99982**	**9.59635**	**4.29376**	**6.91288**	**7.62289**	**16.6674**	**17.5033**	TW -/-> US	0.52342	0.63708	1.59378	1.38728	0.84384	0.66745	0.91316	0.90468
	(0.00322)	**(0.01267)**	**(2.2E-08)**	**(1.1E-06)**	**(4.8E-13)**	**(8.9E-14)**	**(7.5E-16)**	**(1.2E-16)**		(0.92899)	(0.84593)	(0.16243)	(0.16083)	(0.61333)	(0.78390)	(0.47159)	(0.47721)
US -/-> KR	1.46749	1.04939	1.85739	0.77482	**15.5495**	**16.3571**	**36.4917**	**39.3381**	KR -/-> US	0.71040	0.84149	0.59758	0.91086	0.84186	1.49532	1.86554	1.93456
	(0.10953)	(0.40064)	(0.10246)	(0.69584)	**(3.4E-33)**	**(9.4E-33)**	**(1.8E-34)**	**(4.8E-37)**		(0.77591)	(0.63130)	(0.70185)	(0.54786)	(0.61547)	(0.11913)	(0.09771)	(0.08605)
US -/-> SH	1.22506	1.16670	0.89452	0.65455	1.46977	1.55617	0.84501	0.84547	SH -/-> US	0.56289	0.56425	1.82607	0.57431	1.10245	1.02382	1.63374	1.63724
	(0.24536)	(0.29159)	(0.48535)	(0.81662)	(0.12168)	(0.09837)	(0.51784)	(0.51752)		(0.90409)	(0.90315)	(0.10833)	(0.88345)	(0.35217)	(0.42387)	(0.14825)	(0.14734)

* Using 5% as cutoff level.

Table 3 Co-integration Tests on Six Stock Market Indices

H_0	λ_{trace} Statistic		5%Critical Value	λ_{max} Statistic		5%Critical Value
	Local currency	US Dollar		Local currency	US Dollar	
Panel A: Pre-Crisis Subsample – 10 Lags						
r=0	64.83210	71.94524	103.8473	22.74203	24.85640	40.95680
r≤1	42.09006	47.08884	76.97277	15.45297	18.51278	34.80587
r≤2	26.63710	28.57606	54.07904	9.638579	10.63268	28.58808
r≤3	16.99852	17.94339	35.19275	8.935932	9.864017	22.29962
r≤4	8.062586	8.079369	20.26184	7.109818	6.906799	15.89210
r≤5	0.952769	1.172569	9.164546	0.952769	1.172569	9.164546
Panel B: Crisis Subsample – 6 Lags						
r=0	92.93443	103.5730	103.8473	32.19837	39.68476	40.95680
r≤1	60.73607	63.88821	76.97277	25.73216	22.63362	34.80587
r≤2	35.00391	41.25459	54.07904	18.06208	21.43428	28.58808
r≤3	16.94183	19.82030	35.19275	9.029906	10.29156	22.29962
r≤4	7.911929	9.528741	20.26184	4.301363	5.768689	15.89210
r≤5	3.610566	3.760052	9.164546	3.610566	3.760052	9.164546
Panel C: Post-Crisis Subsample as of July 1, 1998 – 14 (Local Currency) and 9 (US Dollar) Lags						
r=0	113.6393*	109.0513*	103.8473	43.89253*	41.10898*	40.95680
r≤1	69.74678	67.94229	76.97277	23.58564	25.21467	34.80587
r≤2	46.16113	42.72762	54.07904	19.34597	17.68703	28.58808
r≤3	26.81516	25.04059	35.19275	15.33004	13.36637	22.29962
r≤4	11.48512	11.67421	20.26184	7.517326	8.002805	15.89210
r≤5	3.967798	3.671408	9.164546	3.967798	3.671408	9.164546
Panel D: Post-Crisis Subsample as of July 1, 1999 – 9 Lags						
r=0	92.55969	93.53943	103.8473	35.20509	31.45656	40.95680
r≤1	57.35460	62.08287	76.97277	19.21609	20.56875	34.80587
r≤2	38.13851	41.51412	54.07904	14.82444	14.52101	28.58808
r≤3	23.31407	26.99311	35.19275	11.41745	12.46170	22.29962
r≤4	11.89662	14.53141	20.26184	7.142311	9.525099	15.89210
r≤5	4.754305	5.006312	9.164546	4.754305	5.006312	9.164546

* significant at the 5% level

Table 4 Tests for Market Exclusion (local currency, post-crisis subsample)

Excluded Market	JP	SG	HK	TW	KR	SH
χ^2-Statistic	4.270463	17.82500	18.73362	10.66782	15.85430	3.842978
p-value	0.038780	0.000024	0.000015	0.001090	0.000068	0.049955

Table 5 Summaries of Impulse Responses in Five Days by Country to Generalized One Unit Innovation in Each Stock Market

5a Pre-Crisis Period

Innovation		Responses by Country					
From Country		JP	SG	HK	TW	KR	SH
	1	1.000000	0.123923	0.174004	0.098455	-0.017393	0.021353
	2	-0.031214	0.033621	-0.011103	0.075860	0.044258	0.103347
JP	3	-0.016383	3.26E-02	-0.004899	-0.003548	0.009085	0.017470
	4	0.004643	-0.003766	-0.055517	-0.029273	0.070037	0.040221
	5	0.038046	-0.002159	0.018324	-0.026167	-0.000839	-0.074851
	1	0.247394	1.000000	0.743500	0.164454	0.075261	0.149863
	2	0.003269	0.181788	0.122655	0.211300	0.027537	-0.071750
SG	3	0.074712	-0.004257	-0.015359	0.033681	0.016895	-0.108612
	4	-0.016676	0.006714	-0.011849	0.079649	0.101591	0.159627
	5	0.035875	-0.025343	0.004860	-0.026111	0.070324	0.051015
	1	0.142907	0.305868	1.000000	0.129327	0.033000	-0.008092
	2	-0.001717	0.086687	0.052702	0.078736	0.026316	-0.005045
HK	3	0.021953	0.011329	0.030467	-0.033985	0.034337	-0.108359
	4	-0.044118	0.035604	0.039192	0.027019	0.056994	0.098227
	5	-0.000330	-0.001048	-0.012665	-0.017520	-0.009288	0.008655
	1	0.071675	0.059950	0.114666	1.000000	0.007154	-0.000614
	2	-0.011129	-0.000729	-0.002504	-0.005240	0.029942	0.032856
TW	3	0.024775	0.012586	0.027027	0.021264	0.005505	-0.048357
	4	-0.008347	0.012056	0.023715	0.046502	0.002325	0.015368
	5	-0.001755	-0.009671	0.010599	-0.019674	0.007221	0.038023
	1	-0.017368	0.037606	0.040087	0.009770	1.000000	-0.024037
	2	0.049702	0.039467	0.033574	0.009692	0.041870	-0.017679
KR	3	0.034349	0.017291	0.025587	-0.042568	0.049081	0.070559
	4	0.020237	-0.014732	0.008917	0.055284	0.012716	0.059161
	5	0.022098	0.007909	0.040785	-0.028766	-0.000516	-0.034039
	1	0.002737	0.009624	-0.001263	-0.000108	-0.003088	1.000000
	2	0.001255	0.007371	0.004256	0.005202	-0.002949	0.005202
SH	3	0.000362	0.004478	-0.006370	-0.024367	-0.007037	0.025284
	4	-0.007594	-0.007010	-0.006175	-0.002128	-0.009179	0.084560
	5	0.009402	0.000317	-0.021001	0.006704	-0.003477	0.052627

5b Crisis Period

Innovation		Responses by Country					
From Country		JP	SG	HK	TW	KR	SH
	1	1.000000	0.307724	0.609229	0.144592	0.143052	-0.003062
	2	-0.083284	0.047566	-0.103542	0.085772	0.259507	0.038503
JP	3	-0.143644	-0.109347	-0.147139	-0.134344	-0.207203	-0.006634
	4	0.001528	0.085535	0.151819	0.024286	0.081566	0.003453
	5	0.011314	-0.027485	-0.036844	-0.007167	-0.051120	0.015164
	1	0.196563	1.000000	0.943900	0.197178	0.099370	-0.035128
	2	0.021209	0.204658	0.084410	0.154429	0.093074	0.054348
SG	3	0.013682	-0.016191	-0.090517	0.010983	-0.001236	0.048715
	4	0.013256	0.026701	0.060361	0.072196	-0.082517	-0.013871
	5	-0.007007	-0.045543	-0.053402	-0.021399	-0.089571	0.013729

	1	0.226273	0.548825	1.000000	0.154507	0.097578	0.039421
	2	0.007509	0.140645	-0.008556	0.113065	0.081261	0.053969
HK	3	-0.015848	-0.046858	-0.096350	0.003231	0.007076	-0.025162
	4	0.043320	0.176347	0.242446	0.098191	0.116241	-0.010649
	5	6.86E-05	-0.007148	-0.041948	0.010036	-0.025631	0.018591
	1	0.164539	0.351257	0.473335	1.000000	0.145457	-0.000815
	2	-0.009541	-0.062366	-0.211551	0.003760	0.243018	-0.033363
TW	3	-0.045052	0.036143	-0.022431	0.032289	0.165108	0.005655
	4	0.099457	0.109756	0.234677	0.015165	-0.158410	0.028813
	5	-0.016113	-0.052319	-0.125932	-0.018514	-0.089473	0.031404
	1	0.042486	0.046199	0.078031	0.037966	1.000000	0.013818
	2	0.056626	0.103923	0.129266	0.053947	0.166973	-0.020662
KR	3	0.056207	0.017014	-0.025795	0.019338	-0.054366	-0.016174
	4	-0.050557	-0.077611	-0.131170	-0.066182	-0.111316	0.020856
	5	-0.021275	-0.021856	-0.002583	-0.024697	-0.065182	0.005230
	1	-0.003897	-0.070058	0.135170	-0.000916	0.059295	1.000000
	2	-0.069657	-0.258774	-0.449362	-0.033358	0.038372	-0.066515
SH	3	0.088977	-0.045391	0.080955	-0.061836	-0.206632	-0.080754
	4	-0.083762	-0.126479	-0.207634	-0.067251	0.226686	0.039040
	5	-0.032489	-0.095795	-0.075339	-0.075807	-0.058025	-0.010429

5c Post-Crisis Period as of July 1, 1999

Innovation		Responses by Country					
From Country		JP	SG	HK	TW	KR	SH
	1	1.000000	0.390095	0.488138	0.323013	0.671559	0.022584
	2	-0.023723	-0.016352	-0.022852	0.149444	0.017290	0.010588
JP	3	-0.015078	0.004309	-0.044900	0.050865	-0.002922	-0.016821
	4	0.001876	0.020306	0.043493	0.035317	0.002553	0.040879
	5	-0.040343	-0.011929	-0.020976	-0.047179	-0.029152	0.035250
	1	0.481608	1.000000	0.686895	0.376545	0.848846	0.028220
	2	0.097543	0.036188	0.074460	0.184810	0.080715	0.021593
SG	3	-0.054952	-0.004438	-0.005294	0.101042	0.076768	-0.033805
	4	0.018168	0.049367	0.015488	0.042293	-0.026955	0.016828
	5	-0.021519	0.052569	-0.007521	-0.058972	-0.003462	0.044080
	1	0.459338	0.523565	1.000000	0.360203	0.773711	0.072288
	2	0.041929	-0.015992	0.026068	0.144380	0.011766	0.023532
HK	3	0.014887	0.046480	-0.005045	0.119353	0.065202	-0.009686
	4	0.028213	0.055386	0.025028	0.002867	0.036404	0.070402
	5	0.005298	0.051680	0.011571	0.006195	-0.012351	0.029318
	1	0.210284	0.198551	0.249216	1.000000	0.423110	0.004282
	2	0.020006	-0.020169	-0.007083	0.034498	0.025197	0.030172
TW	3	-0.011625	0.030821	0.018979	0.066941	0.017790	0.000508
	4	0.002363	0.020872	0.016870	0.038607	0.014707	0.026874
	5	0.014275	0.009895	0.003785	-0.089867	-0.084298	0.006705
	1	0.293339	0.300337	0.359155	0.283905	1.000000	-0.023164
	2	0.046284	0.000731	0.025910	0.089025	0.009257	0.010143
KR	3	-0.040969	-0.008327	-0.025512	0.044955	-0.045398	-0.008947
	4	-0.018159	0.015768	0.001746	-0.005536	-0.035743	0.011161
	5	-0.005359	0.015192	0.027416	-0.006289	-0.006555	0.004230
SH	1	0.026751	0.027043	0.090896	0.007799	-0.062687	1.000000

	2	-0.054960	-0.030177	-0.070486	-0.012173	-0.018806	0.006589
	3	-0.013777	-0.013339	0.000955	0.021139	0.012756	-0.030906
	4	0.021867	-0.020118	0.013266	-0.009330	0.025731	0.008383
	5	0.004578	-0.020264	-0.035498	0.009913	-0.055543	0.019681

5d The US Stock Market on the Asian Stock Markets

Innovation From US		Responses by Country					
		JP	SG	HK	TW	KR	SH
Pre-Crisis	1	0.077318	0.085719	0.097075	-0.068762	0.035470	0.099098
	2	0.307872	0.390012	0.767735	0.151369	0.119633	0.214063
	3	0.103143	0.003500	-0.033759	0.123367	-0.051960	-0.199284
	4	-0.018046	-0.012352	0.060672	-0.040448	-0.047760	0.080741
	5	-0.018668	-0.032514	-0.005305	-0.086808	0.021624	0.383012
Crisis	1	0.212033	0.355828	0.643634	-0.119040	0.620062	-0.197180
	2	0.569691	0.709611	1.177591	0.533097	0.363470	0.057583
	3	-0.000639	-0.125605	-0.499085	0.334948	-0.133032	-0.063610
	4	-0.140351	0.123776	0.034872	0.030352	-0.044236	0.114089
	5	-0.074050	0.122161	0.119470	-0.014638	-0.055538	-0.138629
Post-Crisis July, 1999	1	0.130438	0.146178	0.140057	0.129855	0.174233	-0.031917
	2	0.407783	0.349341	0.505210	0.342053	0.599286	-0.014938
	3	0.019821	0.022444	0.063324	0.061430	0.012024	0.011149
	4	0.009692	0.091817	0.049843	0.072652	0.113969	-0.035488
	5	0.016396	0.081396	0.040370	0.059827	0.108577	0.041026

5e The Asian Stock Markets on the US Stock Market

Responses by US		Innovation from Country					
		JP	SG	HK	TW	KR	SH
Pre-Crisis	1	0.019891	0.045651	0.022452	-0.012701	0.008885	0.003182
	2	-0.003868	0.013059	-0.019159	-0.016644	-0.004731	-0.007843
	3	0.017839	-0.009653	0.007783	-0.006591	0.010133	-0.001616
	4	0.006836	-0.024188	-0.008157	0.000435	0.009821	-0.000279
	5	0.000079	-0.028730	-0.002432	0.005087	0.006337	-0.007592
Crisis	1	0.073833	0.080450	0.091975	-0.047877	0.060592	-0.087796
	2	-0.098526	0.015793	-0.032666	-0.024236	-0.004881	-0.023060
	3	0.061548	0.052577	0.125349	0.045169	0.000010	0.119053
	4	0.050307	0.006139	0.021843	0.037905	-0.038139	-0.054873
	5	0.026720	-0.010149	-0.008580	-0.114442	-0.012268	-0.057304
Post-Crisis July, 1999	1	0.125850	0.176971	0.139163	0.075496	0.075102	-0.032051
	2	-0.032930	-0.056611	0.010604	0.008722	-0.006075	0.039717
	3	-0.029064	-0.013151	-0.023533	-0.003239	-0.063191	-0.047602
	4	-0.016751	0.056211	0.018957	-0.048553	0.020856	-0.023582
	5	0.001990	0.052121	0.028036	0.021777	0.001354	-0.031175