An Empirical Analysis of East Asian Stock Market Crisis: Application of the Extended EGARCH Model

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ABSTRACT

This paper investigates the dynamic transmission mechanism of the Asian stock market crash during 1997-1998. The paper, in particular, examines the price and volatility spillovers from Thailand, followed by Indonesia, Korea, Hong Kong, Japan and USA, to each Asian stock market by using the extended EGARCH model. Within this framework, we analyze the linkage between the Asian stock markets using the correlation matrix of the standardized residuals with spillovers. This paper also estimates the EGARCH model to investigate the following issues : return autocorrelation, risk premium, persistence of stocks to volatility, asymmetry between positive and negative returns in their effects on volatility, and contributions of nontrading days to volatility.

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I. Introduction

As the dust settles on the Asian financial crisis, the bad news is that there is still widespread disagreement among economists about what needs to be done. However, the good news is that we are beginning to understand what went wrong and to identify ways to prevent it from happening elsewhere. Asia's financial crisis of 1997 has raised several important questions for financial analysis. The academic community is challenged to consider the implications of such a crash and to address two important questions : (1) Why did the crisis happen ? What were the causes of the crisis ? (2) How and why did Asia's stock market crash propagate internationally ? There are already many papers and commission reports which have attempted to answer these questions. In relation to the first question, Krugman (1998a,1998b) argues that Asia's crisis is rooted from a serious problem of moral hazard, overinvestment and overvaluation of assets in Asia by domestic financial intermediaries. The fragile and inefficient banking systems allowed excessive credit to build up, creating bubbles which caused untold damage as they burst (Krugman, 1998b). In the study of the international crash of October 1987, Malliaris and Urrutia (1992) investigate and critically evaluate some answers to the second question. Briefly, one could summarize the answers provided to the first question as belonging in two categories : macroeconomic and microeconomic causes. Among the macroeconomic causes, the overvaluation of currency (i.e., the trigger for the Thai economic crisis was the overvaluation of its currency), inappropriate financial policy (i.e., too much debt supporting too many investments with too low a rate of return), and the big current account deficits are cited most often. Inefficient banking systems (i.e., cheap loans to big conglomerates for continual expansion regardless of world demand, especially in South Korea's case), speculative activities in property and land developments, the possible existence of speculative bubbles, over-investment, and speculative attacks from foreign investors, are listed as microeconomic causes.

Given the wide array of causes, it is difficult to provide *empirical* evidence to confirm the validity of any of these causes. Since the first question is so broad and difficult to answer, this paper attempts to answer the second question, focussing on the Asian stock market, rather than focussing on the overall causes of the financial crisis.

So, the *purpose* of this paper, more specifically, it aims to provide the statistical evidences regarding the international propagation and transmission mechanism of the Asian stock market crash. Using the EGARCH model, this paper will analyze statistical behavior of stock index return and volatility in Asian stock markets during 1997-98. We will trace price and volatility spillover from the Thailand crisis, followed by Indonesia, Korea, Hong Kong, Japan and USA, to each Asian stock market by expanding the EGARCH model (Nelson 1991). The paper is organised as follows. Section II describes the data and preliminary statistical analysis. Section III presents the exponential GARCH(EGARCH) model to investigate the time-series characteristics of stock returns and volatility in Asian stock markets. Section IV presents the major, empirical findings based on the EGARCH and the extended EGARCH model, and discusses their implications. Section V provides a summary and concluding remarks.

II. Data and Preliminary Statistical Analysis

This study uses data covering the aggregate stock price indices of the USA and nine Asian stock markets : Hang Seng Index (Hong Kong), KOSPI (Korea), Australian Stock Exchange Index (Australia), All Shares Index (Singapore), Taiwan Stock Exchange Index (Taiwan), Jakarta Stock Exchange Index (Indonesia), Composite Stock Price Index (Manila), SET Index (Thailand), Nikkei 225 Index (Japan), New York Dow Jones Industrial Average (USA). The data set ranges from February 3, 1997 to June 30,1998 for a total of 354 observations. The daily returns for each index are the continuously compounded percentage returns calculated as the difference in the logarithm of the closing index value for two consecutive days, $r_t = 100\times(\log P_t - \log P_{t-1})$.

The daily stock price indices are collected from Korean Stock Exchage web site, Jakarta Stock Exchange web site and Mobydata web site.

Table 1 summarizes some of the basic statistics. From Table 1, the sample means are mostly negative in many countries during the crisis period. For example, during the crisis period, Thailand was the least profitable on average, with a rate of -0.13%, while Korea and Philippines average returns were the second (-0.10%) and the third (-0.08%) lowest rate, respectively. Most individual stock markets experience negative stock returns during the crisis period. The standard deviations range from the lowest, Australia (0.42) to the highest, Hong Kong (1.16). As the figure (1a & 1b) indicates, the most countries except for USA and Australia in the region participate in the stock market decline.

The measures for skewness and kurtosis are also reported to check whether daily stock returns are normally distributed or not. The sign of skewness varies, depending on countries. In general, if the values of kurtosis are larger than 3.0, then daily returns are more peaked and have fatter tails than normal distributions. The Ljung-Box statistics (LB) for up to 10 lags, calculated for both the return and the squared return series, suggest the presence of significant linear and nonlinear dependence, respectively. The values of LB (10) for return series are significant at the 1% level except for Australia and Taiwan. The LB (10) for the squared return series are highly significant for all the markets, suggesting the possibility of the presence of autoregressive conditional heteroskedasticity.

III. The EGARCH Model : Modeling the Stock Returns and Volatility in East Asian Stock Markets

Many economic and financial time series such as stock returns exhibit periods of unusually large volatility, indicating the non-constant variance (heteroskedasticity). Conditionally heteroskedastic models (ARCH or GARCH) introduced by Engle (1982) and Bollerslev (1986) allow the conditional variance of a stock return to depend on the past realization of the error process. The literature in financial modeling (ARCH/GARCH models) is far too vast to give a complete citation list here. However, in relation to statistical analysis of stock prices in Asian Pacific markets, there have a few studies. For example, Lee and Ohk (1991) and Corhay and Rad (1993) study time-series characteristics of stock prices in Pacific-Basin markets using the GARCH model. Ng *et al* (1991) study the repercussions of volatility in USA stock prices on those of Japan, Korea, Taiwan and Thailand, using the GARCH model. Chu and Cusatis (1993) analyze the linkage in stock prices in Japan, Hong Kong, Singapore and Korea using the multivariate GARCH-M model. Finally, Watanabe (1996) analyzes stock prices in the Pacific-Basin countries and finds that Hong Kong, Singapore, Malaysia, Philippines and Thailand are significantly affected by the U.S.

Our analysis in this paper, among various ARCH variants, is based on the following exponential general autoregressive conditional heteroskedastic (EGARCH) model developed by Nelson (1991).

$$r_t = b_0 + b_1 r_{t-1} + b_2 h_t + b_3 \varepsilon_{t-1} + \varepsilon_t \qquad (1)$$

The residual ε_t was modeled as $(h_t)^{1/2} Z_t$, where Z_t is *i.i.d.* with density function[1] and where h_t evolves according to

$$\log(h_t) - \theta_t = a_2 \{\log(h_{t-1}) - \theta_{t-1}\} + a_3 Z_{t-1} + a_4(|Z_{t-1}| - E|Z_{t-1}|) \qquad (2)$$

Nelson allowed θ_t, the unconditional mean of $\log(h_t)$, to be a function of time : $\theta_t = a_0 + \log(1+a_1 N_t)$
where r_t is the stock return at time t, h_t is the conditional variance of r_t, which we call volatility, ε_t is the innovation at time t, Z_t is the standardized innovation (i.e., $Z_t = \varepsilon_t / (h_t)^{1/2}$), and N_t denotes the number of nontrading days (including holidays and weekends) between trading day t-1 and t. One of the important implications of the EGARCH specification is that if $a_3 = 0$, then a positive suprprises ($Z_{t-1} > 0$) has the same effect on volatility as a negative surprise of the same magnitude. If $-1 < a_3 < 0$, a positive surprise increases volatility less than a negative surprise. If $a_3 < -1$, a positive surprise actually reduces volatility while a negative surprise increases volatility.

The EGARCH model over the ARCH model of Engle (1982 & 1990) and the Generalized ARCH(GARCH) of Bollerslev (1986) has obvious advantages. First, the EGARCH model can capture the asymmetric impact of positive returns and negative returns on volatility. Second, there are no restrictions on the parameter in equation (2) to ensure nonnegativity of the conditional variance. In short, estimating unknown parameters in the EGARCH model given by equations (1) and (2) enables us to examine the following issues : (i) return autocorrelation (b_3), (ii) risk premium (b_2), (iii) contribution of nontrading days to volatility (a_1), (iv) persistence of

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[1] Nelson(1991) proposed using the generalized error distribution(GED), normalized to have zero mean and unit variance:

$$f(Z_t) = \frac{\exp[-(1/2)|Z_t/\ |\ ]}{2^{[(\ +1)/\ ]}\ (1/\ )}$$

where ( ) is gamma function, is a constant given by $= [\,(2^{(-2/\ )}\ (1/\ ))/\ (3/\ )]^{1/2}$

shocks to volatility (a_2), (v) asymmetry[2] between positive and negative returns in their effects on conditional variance (a_3). As usual, the estimation of these parameter values is based on the maximum likelihood method.

Within the EGARCH framework, our main objective of this paper is to investigate the dynamic transmission mechanism of the Asian stock market during the crisis period. It is assumed that during the Asian crisis period, each Asian stock market volatility is significantly affected by changes in volatility in the other markets. To study volatility spillovers across international markets, for example, to examine the effects of price and volatility transmission mechanism from Thailand on each Asian stock markets, we extend the EGARCH model in following ways : we first take the most recent Thailand innovation and standardized innovation derived from the EGARCH model, denoted by $\varepsilon_{Thai,\,t-1}$, $Z_{Thai,\,t-1}$, respectively.

To accommodate price spillovers, we append $\varepsilon_{Thai,t-1}$ to equation (1), while, to capture volatility spillovers, we modify the specification in equation (2) by expanding the definition of the conditional variance to include $|Z_{Thai,t-1}|$ as the most recent volatility surprise observed in the Thailand stock market. We also include $Z_{Thai,\,t-1}$ into equation (2) to exert an asymmetric impact on the volatility of each East Asian market. The resulting form of the model is :

$$r_t = b_0 + b_1 r_{t-1} + b_2 h_t + b_3 \varepsilon_{t-1} + b_4 \varepsilon_{Thai,t-1} + \varepsilon_t \qquad \varepsilon_t = (h_t)^{1/2} Z_t, \qquad Z_t \sim GED(\upsilon) \qquad (3)$$

$$\log(h_t) - \theta_t = a_2 \{\log(h_{t-1}) - \theta_{t-1}\} + a_3 Z_{t-1} + a_4(|Z_{t-1}| - E|Z_{t-1}|) \qquad (4)$$
$$+ a_5 Z_{Thai,t-1} + a_6(|Z_{Thai,t-1}| - E|Z_{Thai,t-1}|)$$

where $\theta_t = a_0 + \log(1 + a_1 N_t)$

Note that coefficient b_4 in equation (3) measures the extent of price spillover from the Thailand to each Asian stock market. Volatility spillover from the Thai to each Asian market is captured by a_6. A significant negative coefficient a_5 implies that negative innovations in the Thailand market have a higher impact on the volatility of each Asian stock market than positive innovations, i.e., the volatility spillover mechanism is *asymmetric.*

[2] The asymmetry means that stock market declines ($Z_{t-1} < 0$) will be followed by higher volatility than stock market advances ($Z_{t-1} > 0$) if a_3 is negative. Such a response would be consistent with the leverage effect whereby, market declines produce a higher aggregate debt to equity ratio and hence higher volatility. The relative importance of the asymmetry or, *leverage effect*, can be measured by the ratio $|-1 + a_3|/(1 + a_3)$ (Koutmos 1996).

In summary, we will perform the following analyses in this paper using daily stock returns for 10 Asian countries including the USA. We will examine the time-series characteristics of stock returns and volatility in Asian countries, based on the EGARCH model. Next, we will analyze how stock returns in respective countries are influenced by stock price and volatility fluctuations in Thailand, Indonesia, Korea, Hong Kong, Japan and USA under the extended EGARCH model. Third, we evaluate correlations between stock returns of various markets based upon correlation coefficients for standardized residual in the EGARCH model, expanded to account for the influences of Thailand, Indonesia, Korea, Hong Kong, Japan and USA, respectively.

IV. Empirical Results : Model Estimates, Price and Volatility Spillover Effect

In this section, first, we present model estimates for the EGARCH model. The econometric specification of the model is as in equation (1) and (2). The maximum likelihood estimates (with corresponding standard errors in parenthesis) are reported in Table 2.

Overall, the estimates for the model are appealing. Diagnostic checks of the residuals did not indicate the presence of serial correlation. The values of LB (10) for standardized residuals are relatively small in all countries. The hypothesis that there is no autocorrelation from the first to the 10^{th} lags of the standardized residual can not be rejected at the significance level of 5% in all Asian stock markets except for Thailand and Philippines (10%). The values of LB (10) for squared standardized residuals also show relatively small values, indicating that autocorrelation in stock index returns in all Asian stock markets can fully be captured by ARMA (1,1) model.

Next, we examine each parameter in the EGARCH model. Starting from the stock return equation, overall, the coefficients from the stock return equation are of reasonable signs and magnitudes. The b_1 coefficient which captures the effect of past own returns is statistically significant in Thailand, Korea, Hong Kong and Taiwan. The estimated coefficient b_2 which indicates the risk premium is statistically significant only in USA. The estimated coefficient b_3 which measures the return autocorrelation is statistically significant except for Indonesia, Thailand, Philippines, Singapore, Australia and USA.

The estimated value of a_1 which reflects the contribution of nontrading days to volatility is significantly positive for all Asian stock markets except for Indonesia and Philippines. This implies that volatility after a holiday increases with the number of holidays. The coefficient a_1 ranges widely from 0.06 (Indonesia) to 0.71 (Korea), indicating that nontrading days contribute to a rise in volatility less than a trading day. This empirical result is consistent with the results of French and Roll (1986) and the nonsynchronous trading model of Lo and Mackinlay (1988), which have found that the value of a_1 ranged between zero and one. Therefore, nontrading periods contribute much less than do trading periods to stock return variance.

The persistence level of volatility is measured by a_2. The estimated value of a_2 is high and close to 1 for all markets, ranging from 0.555 (USA) to 0.981 (Japan). In all cases, the degree of persistence of shocks to volatility is high and lasts for a considerable time.

The estimated value of a_3 coefficient, which indicates the leverage effect or asymmetric impact on current volatility, is statistically significant and negative values in all markets except Thailand. This means that volatility is more likely to rise on the day after shock prices fall compared with the day after they rise. In other words, negative shock innovation in one market increases volatility more than positive shock innovation. A number of researchers (see Pagan and Schwert (1990) and the studies cited in Bollerslev, Chou and Kroner (1992, p24)) have found evidence of asymmetry in stock price behavior - negative surprises seem to increase volatility more than positive surprise. Since a lower stock price reduces the value of equity relative to corporate debt, a sharp decline in stock prices increases corporate leverage and could thus increase the risk of holding stocks. For this reason, the apparent finding that $a_3 < 0$ is sometimes described as the leverage effect. In contrast to our *a priori* expectations, the coefficient for Thailand has the positive sign but is statistically insignificant.

Finally, since the estimated value of a_4 is positive in all markets, the impact of Z_{t-1} on h_t is positive when the magnitude of Z_{t-1} is greater than its expected value $E \mid Z_{t-1} \mid$. This empirical finding supports the notion that the size of the innovation is one of the important determinants of the volatility transmission mechanism.

The empirical analysis to measure the effects of price and volatility spillovers from Thailand, Indonesia, Korea, Hong Kong, Japan and USA, respectively, on each Asian stock market is reported in Table 3. Overall, the estimates of the model are appearing since the extended EGARCH model is well-suited to reflect the price and volatility spillover from Thailand, Indonesia, Korea, Hong Kong, Japan and USA stock market. First, using the extended EGARCH model, we investigate how stock returns in Asian stock markets are affected by fluctuations in

Thailand, Indonesia, Korea, Hong Kong, Japan and USA stock market, respectively. In Table 3A, the coefficient b_4 measures the effect of price spillover from Thailand to Asian stock markets. The coefficient b_4 is statistically significant for Indonesia and Hong Kong. The coefficient b_4 in Table 3B which measures the price spillover from Indonesia to Asian stock markets is statistically significant for Thailand and Hong Kong. Similarly, the effect of price spillover from Korea to Asian stock markets is measured by coefficient b_4 in Table 3C, significant for Indonesia and Thailand.

The coefficient b_4 in Table 3D which measures the price spillover from Hong Kong, is statistically significant for Indonesia, Thailand and Korea. From Table 3E, the spillover effect from Japan, the coefficient b_4 is statistically significant for Thailand, Korea and Hong Kong. From Table 3F, the coefficient b_4 is significant for Indonesia and Hong Kong.

Turning to second moment interdependencies, the coefficient a_6 measuring the volatility spillover from Thailand to Asian stock markets is significant for Indonesia, Philippines, Australia and Taiwan in Table 3A. In Table 3B, the coefficient a_6 is statistically significant for only Hong Kong. The coefficient a_6 in Table 3C is statistically significant for Thailand, Philippines, Australia, Taiwan, and Hong Kong, respectively. The coefficient a_6 in Table 3D is significant for all Asian stock markets except for the Philippines. Finally, the coefficient a_6 in Table 3F, indicating the volatility spillover from USA, is statistically significant for Thailand, Philippines, Japan and Taiwan.

The coefficient a_5 measures the asymmetry effect. The estimated coefficient a_5 in Table 3A is statistically significant for Indonesia and Korea. Similarly, the asymmetry effect from Indonesia to Asian stock markets is measured by the coefficient a_5 in Table 3B and significant for the Philippines. The coefficient a_5 in Table 3C which measures the extent of the asymmetry form Korea to Asian stock markets is statistically significant for Indonesia and Philippines. From Table 3D, the asymmetry effect from Hong Kong to other countries is statistically significant for only USA. In the case of asymmetry effect from Japan(Table 3E), the coefficient is significant for USA. Finally, The coefficient a_5 in Table 3F, which measures the asymmetry effect from USA, is significant for Australia and Japan. Overall, each Asian stock market's volatility is significantly and substantially affected by the changes in volatility in the other markets, especially by Hong Kong, Korea, Thailand and USA.

In the case of Korea, the estimated value of a_6 is not significant but a_5 is significant in Table 3A. This implies that the volatility of Korea tends to increase the day after Thailand stock prices fall and decrease the day after Thailand stock prices rise. In other words, it is not the quantity of the news (i.e., the size of the innovation) but the quality of news (i,e., the sign of the innovation) that determine the degree of volatility spillovers from Thailand to Korea. The same relationship can be shown in Table 3B (Philippines and Indonesia), Table 3C (Indonesia and Korea), Table 3E (USA and Japan) and Table 3F (Australia and USA).

In short, an interesting aspect of empirical findings is that during the crisis period, there is an increasing tendency for stock markets in Asia to move together.

When we examine the price and volatility spillover from each individual country such as Thailand, Indonesia, Korea, Hong Kong, Japan and USA to other Asian stock markets, it is clear that during the regional crisis period, half or more of the individual stock markets were affected and influenced one another. Apparently, this Asian stock market crisis is associated with *contagion*, in the sense that most Asian stock markets declined. So, most individual stock markets experience negative returns during the crisis period. However, this is not the case for USA and Japan, indicating that those countries are relatively less affected by the price and volatility spillover from Thailand, Indonesia and Korea.

In the case of spillover from USA to other Asian stock markets, it is found that in contrast with the empirical finding by Watanabe(1996)[3], the influence from USA to Asian stock markets has diminished during the Asian crisis. However, it is found that Hong Kong stock market influences all Asian stock markets other than the Philippines. This implies that Hong Kong stock market plays an important role as channel of spillover across Asian stock markets. Furthermore, this indicates that during the crisis, negative innovations in the Asian stock markets have no strong impact on the USA stock market, to a lesser extent on the Japanese stock market. In other words, it can be concluded that a major player as price volatility producer in Asian stock markets is not USA or Japan but Hong Kong.

The correlation coefficients of the standardized residuals derived from the extended EGARCH model are reported in Table 4. Six correlation coefficients matrices have been computed after taking into account the spillover effect from Thailand, Indonesia, Korea, Hong Kong, Japan and USA, respectively.

According to Table 4, the strongest correlation relation is observed between Singapore and Hong Kong (0.474), followed by Hong Kong and Australia (0.412), Singapore and Indonesia (0.386), Singapore and Philippines (0.364), Australia and Japan (0.362), and Hong Kong and Philippines

(0.360). It appears that among Asian stock markets, Hong Kong, Singapore and Indonesia play the most important role in integrating the linkage between Asian stock markets. However, the correlation between Taiwan and USA with any Asian countries is very weak and shows the lowest correlation values.

When we have the correlation matrix analysis with spillover from Indonesia, the results consistently show that Hong Kong, Singapore and Australia play the most important role in enhancing the linkage between Asian stock markets. Similarly, from the correlation matrix of the standardized residuals with spillover from Korea, we can conclude that the pairwise correlations are strongest in Hong Kong, Singapore, Australia and Indonesia markets. From the correlation matrix with spillover from USA, we can observe Hong Kong, Singapore and Philippines as important players in enhancing the linkage between Asian stock markets. From the correlation matrix with spillover from Hong Kong, it can be concluded that the pairwise correlations are strongest in Singapore, Philippines and Australia.

Finally, regardless of the sources of spillover, the USA and Taiwan market do not show a strong correlation with any Asian countries, indicating that stock prices in USA and Taiwan are not affected by the other countries. In other words, stock price fluctuations in USA and Taiwan are highly independent.

V. Summary and Concluding Remarks

In this paper, we analyze the behavior of major Asian stock market indices during the Asian stock market crisis period (1997-98). We examine the time-series characteristics of stock returns and volatility in the 10 Asian-Pacific countries using the EGARCH model. Next, this paper investigates dynamic interactions in terms of price spillover (i.e., first moment interdependencies) and volatility spillover (i.e., second moment interdependencies) among the stock markets of 10 Asian-Pacific countries. We analyze how stock returns in Asian stock markets are influenced by stock price fluctuations in Thailand, Indonesia, Korea, Hong Kong, Japan and USA using the extended EGARCH model. We also analyze the linkage between stock prices among Asian stock markets.

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[3] He argued that all Pasific-Basin stock markets are severely influenced by USA. Especially, the price spillover

The key empirical findings can be summarized as : (1) The high level of persistence of volatility in all Asian stock markets is well observed and predominant during the Asian crisis period. (2) During the Asian crisis period, we find evidence of "leverage effect" (i.e., if the stock returns fall further than we expect, volatility increases). The negative innovations in each Asian stock market have a higher impact on the volatility than positive innovations. This well-known phenomenon of asymmetry between positive and negative returns in their effect on volatility is confirmed and observed in all Asian stock markets except Thailand. So, the volatility transmission mechanism is noticeably asymmetric. (3) We document significant volatility or second moment interactions. Our empirical results support the view that Asian stock markets are rapidly integrated in the sense that they have developed the dynamic first and second moment interactions among the Asian stock markets. In other words, Asian stock markets are integrated in the sense that news affecting asset pricing is not purely domestic in nature (Koutmos 1996) (4) The volatility of Korea increases the day after Thailand stock price fall. The same phenomenon is observed in between Philippines and Indonesia, Indonesia and Korea, USA and Japan, and Australia and USA, respectively. (5) During the Asian crisis period, the returns of Asian stock markets are weakly correlated with those of USA, indicating that there is *less* significant linkage between USA stock market and all other markets. However, some combinations among Asian stock markets - Hong Kong, Singapore, Philippines, Australia, Indonesia show a strong correlation coefficient of over 0.3, even after the elimination of spillover effect from Thailand, Indonesia, Korea, Hong Kong, Japan and USA. Our results show that geographically and economically close countries such as Hong Kong and Singapore, Hong Kong and Philippines, Hong Kong and Australia, and Japan and Australia exert significant influence over each other. Especially, it appears that Hong Kong plays the most important role in enhancing the linkage between Asian stock markets. (6) It is interesting to note that the influence of the USA stock market on other Asian markets has noticeably diminished in both price and volatility spillover effect during the crisis period. By contrast with USA, Hong Kong influences all Asian stock markets except Philippines. It can be concluded that Hong Kong as the world 4th largest financial market exerts greater influence on all Asian stock markets during the Asian crisis period.

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effect is statistically significant for all Pasific-Basin stock markets except Korea.

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Table 1

Descriptive Statistics

Sample Period : February 3, 1997 – June 30, 1998

statistics	Indonesia	Thailand	Singa pore	Korea	Phili ppines	Australia	Japan	Taiwan	USA	Hong Kong
Mean	-0.0531	-0.1326	-0.0728	-0.1026	-0.0825	0.0116	-0.0163	0.0033	0.0336	-0.0557
St.Dev.	1.1450	1.0659	0.6970	1.2720	0.9154	0.4198	0.6884	0.6999	0.4832	1.1608
T(mean=0)	-0.8726	-2.3410	-1.9639	-1.5170	-1.6953	0.5216	-0.4467	0.0894	1.3091	-0.9026
Skewness(1)	0.2368	0.9305	0.3122	-0.0847	0.3049	-0.9178	0.1348	-0.4995	-0.7748	0.3937
Kurtosis(2)	5.1405	3.5088	7.5316	2.5236	4.3216	13.8996	2.4143	2.2616	6.1769	9.7176
LB(10)(3) for R_t	35.5343 (8.87E-06)	49.8353 (2E-08)	29.5116 (0.0001)	20.2258 (0.0051)	31.9905 (4.08E-05)	6.7853 (0.4515)	12.2079 (0.0939)	9.8457 (0.1974)	21.2131 (0.0034)	38.0453 (2.97E-06)
LB(10) for R_t^2	65.4809 (0.0000)	92.4237 (0.0000)	83.4666 (0.0000)	99.2966 (0.0000)	37.6538 (3.53E-06)	120.4152 (0.0000)	77.5271 (0.0000)	30.7983 (6.77E-05)	31.4587 (5.12E-05)	138.6643 (0.0000)

Significance level in parenthesis

notes

(1) The skewness, or normalized third moment, of a random variable, stock returns r_t with mean and variance

^{2} can be obtained as $S = \frac{1}{T\ ^3}\sum_{t=1}^{T}(r_t - \ )^3$, where $= \frac{1}{T}\sum_{t=1}^{T} r_t$, $^2 = \frac{1}{T}\sum_{t=1}^{T}(r_t - \ )^2$ & T = sample size

(2) The Kurtosis, or normalized fourth moment, of a stock return, r_t can be obtained as $K = \frac{1}{T\ ^4}\sum_{t=1}^{T}(r_t - \ )^4$

In large sample of normally distributed data, the estimators S and K are normally distributed with means 0 and 3 and variances /T and 24/T, respectively

(3) LB(10) critical values : 15.99(10%), 18.31(5%), 23.21(1%)

LB(n) is the Ljung-Box statistic for up to n lags, distributed as ^{2} with n degrees of freedom

Table 2

Maximum Likelihood Estimates of the EGARCH Model

Parameter	Indonesia	Thailand	Singapore	Korea	Phili ppines	Australia	Japan	Taiwan	USA	Hong Kong
b_0	-0.100	-0.642	-0.123	-0.166	-0.150	0.014	-0.045	-0.046	-0.170	0.029
	(0.067)	(0.173)	(0.057)	(0.068)	(0.068)	(0.046)	(0.048)	(0.044)	(0.067)	(0.079)
b_1	0.300	-0.406	0.047	-0.465	-0.074	-0.544	0.300	0.633	0.208	-0.649
	(0.332)	(0.339)	(0.422)	(0.349)	(0.288)	(0.664)	(0.326)	(0.331)	(0.324)	(0.250)
b_2	0.050	0.433	0.097	0.048	0.062	0.198	0.070	0.101	0.908	-0.041
	(0.056)	(0.170)	(0.120)	(0.054)	(0.101)	(0.301)	(0.103)	(0.102)	(0.325)	(0.089)
b_3	-0.126	0.442	0.099	0.554	0.278	0.579	-0.432	-0.582	-0.014	0.735
	(0.353)	(0.339)	(0.434)	(0.327)	(0.291)	(0.657)	(0.309)	(0.365)	(0.342)	(0.221)
a_0	0.287	-0.051	-0.980	-0.115	0.442	-2.247	-0.965	-1.073	-1.729	-0.353
	(0.291)	(0.139)	(0.304)	(0.533)	(0.455)	(0.167)	(0.266)	(0.111)	(0.096)	(0.283)
a_1	0.058	0.134	0.315	0.708	-0.010	0.306	0.258	0.629	0.230	0.261
	(0.054)	(0.068)	(0.092)	(0.202)	(0.059)	(0.138)	(0.121)	(0.182)	(0.115)	(0.096)
a_2	0.947	0.835	0.961	0.980	0.961	0.923	0.981	0.745	0.555	0.942
	(0.011)	(0.058)	(0.015)	(0.011)	(0.014)	(0.027)	(0.012)	(0.063)	(0.131)	(0.021)
a_3	-0.176	0.047	-0.165	-0.097	-0.129	-0.189	-0.082	-0.241	-0.343	-0.219
	(0.044)	(0.041)	(0.031)	(0.037)	(0.031)	(0.033)	(0.019)	(0.063)	(0.081)	(0.044)
a_4	0.208	0.381	0.185	0.281	0.371	0.148	0.046	0.270	0.059	0.210
	(0.049)	(0.077)	(0.043)	(0.075)	(0.054)	(0.047)	(0.030)	(0.108)	(0.092)	(0.058)
Log-likelihood	-131.5	-152.9	30.7	-156.2	-86.0	197.0	-17.8	-12.1	114.4	-120.5
LB(10) for standardized residuals	10.903	27.418	11.095	6.237	12.417	3.409	3.565	10.338	11.754	9.670
LB(10) for squared standardized residuals	1.310	7.709	7.373	12.357	6.324	17.715	14.913	5.286	8.547	4.816

notes :

Standard error in parenthesis

LB(10) critical values : 15.99(10%), 18.31(5%), 23.21(1%)

Table 3

Maximum Likelihood Estimates of the extended EGARCH Model

Parameter	Indonesia	Thailand	Singapore	Korea	Philippines	Australia	Japan	Taiwan	USA	Hong Kong
	A. Spillover from Thailand									
b_4	0.0875*	-	0.0364	-0.0198	0.0615	0.0076	0.0370	0.0165	0.0287	0.0945*
	(0.0270)	-	(0.0269)	(0.0451)	(0.0460)	(0.0181)	(0.0343)	(0.0360)	(0.0195)	(0.0504)
a_5	0.0772*	-	0.0085	-0.0754*	-0.0222	-0.0026	-0.0255	-0.0639	-0.0279	-0.0199
	(0.0269)	-	(0.0301)	(0.0361)	(0.0276)	(0.0471)	(0.0263)	(0.0681)	(0.0607)	(0.0371)
a_6	0.1955*	-	0.0431	0.0178	0.1174*	-0.1340*	0.0252	0.1541*	-0.1009	0.0739
	(0.0424)	-	(0.0580)	(0.0631)	(0.0679)	(0.0710)	(0.0397)	(0.0859)	(0.0766)	(0.0743)
	B. Spillover from Indonesia									
b_4	-	0.1038*	0.0214	-0.0167	0.0415	0.0116	0.0448	0.0039	0.0123	0.0798*
	-	(0.0480)	(0.0219)	(0.0388)	(0.0352)	(0.0191)	(0.0336)	(0.0280)	(0.0228)	(0.0400)
a_5	-	0.0520	-0.0644	-0.0581	-0.0797*	-0.0676	-0.0408	0.0220	-0.0029	-0.0155
	-	(0.0688)	(0.0397)	(0.0476)	(0.0389)	(0.0526)	(0.0425)	(0.0636)	(0.0527)	(0.0508)
a_6	-	-0.0164	-0.0137	-0.0085	-0.0950	-0.0628	0.0060	0.0008	-0.0752	0.0974
	-	(0.0591)	(0.0544)	(0.0535)	(0.0631)	(0.0478)	(0.0323)	(0.0749)	(0.0629)	(0.0513)
	C. Spillover from Korea									
b_4	0.1314*	0.2095*	0.0099	-	0.0360	0.0110	0.0318	0.0062	0.0035	0.0570
	(0.0412)	(0.0364)	(0.0206)	-	(0.0331)	(0.0176)	(0.0325)	(0.0300)	(0.0192)	(0.0419)
a_5	-0.1427*	0.0770	-0.0519	-	0.0853*	-0.0012	-0.0102	-0.0542	0.0884	0.0120
	(0.0410)	(0.0540)	(0.0385)	-	(0.0396)	(0.0415)	(0.0240)	(0.0561)	(0.0557)	(0.0351)
a_6	0.0622	0.2538*	0.0286	-	0.1976*	0.1657*	0.0606	0.2946*	-0.0567	0.2301*
	(0.0531)	(0.0964)	(0.0690)	-	(0.0598)	(0.0645)	(0.0449)	(0.1016)	(0.0962)	(0.0680)
	D. Spillover from Hong Kong									
b_4	0.1037*	0.3051*	0.0147	-0.0565*	0.0371	-0.0080	0.0257	-0.0055	-0.0178	-
	(0.0199)	(0.0475)	(0.0242)	(0.0289)	(0.0349)	(0.0167)	(0.0311)	(0.0225)	(0.0193)	-
a_5	-0.0001	-0.0227	-0.0157	-0.0322	-0.0405	-0.1538*	-0.0181	-0.0202	-0.1699*	-
	(0.0325)	(0.0497)	(0.0458)	(0.0269)	(0.0261)	(0.0401)	(0.0265)	(0.0631)	(0.0843)	-
a_6	0.2331*	0.1070*	0.1132*	0.1476*	0.0244	0.1660*	0.0693*	0.2379*	0.2850*	-
	(0.0460)	(0.0544)	(0.0517)	(0.0462)	(0.0495)	(0.0534)	(0.0358)	(0.1043)	(0.1104)	-
	E. Spillover from Japan									
b_4	-0.0244	0.2481*	0.0267	-0.0584*	0.0313	0.0116	-	0.0011	0.0018	0.0886*
	(0.0706)	(0.0609)	(0.0208)	(0.0296)	(0.0355)	(0.0182)	-	(0.0261)	(0.0195)	(0.0370)
a_5	0.0086	-0.0762	-0.0136	0.0471	-0.0001	-0.0577	-	0.0672	0.0826*	0.0540
	(0.0525)	(0.0538)	(0.0287)	(0.0397)	(0.0388)	(0.0506)	-	(0.0664)	(0.0497)	(0.0413)
a_6	-0.0305	0.0092	0.0218	0.0679	-0.0360	0.0038	-	-0.0675	0.0633	0.0572
	(0.0552)	(0.0940)	(0.0577)	(0.0500)	(0.0586)	(0.0667)	-	(0.0854)	(0.0743)	(0.0648)
	F. Spillover from USA									
b_4	0.4343*	-0.1578	0.0384	-0.0279	0.0433	0.0181	0.0569	0.0143	-	0.1013*
	(0.0544)	(0.1092)	(0.0243)	(0.0331)	(0.0303)	(0.0164)	(0.0389)	(0.0296)	-	(0.0414)
a_5	-0.0260	-0.0159	-0.0263	0.0361	0.0177	-0.3467*	-0.1856*	-0.0398	-	0.0377
	(0.0386)	(0.0454)	(0.0426)	(0.0384)	(0.0406)	(0.0538)	(0.0693)	(0.0583)	-	(0.0412)
a_6	0.0988	0.1795*	0.0739	0.0459	0.1401*	0.0287	0.1989*	0.2081*	-	0.0832
	(0.0611)	(0.0744)	(0.0521)	(0.0652)	(0.0765)	(0.0504)	(0.1056)	(0.0990)	-	(0.0628)

Standard error in parenthesis

(*) denotes significance at the 10% level

Table 4

Correlation Matrix of the Standardized Residuals with Spillover from Thailand

	Indonesia	Singapore	Korea	Phili ppines	Australia	Japan	Taiwan	USA	Hong Kong
Indonesia	1.000	0.386	0.057	0.320	0.274	0.232	0.139	0.008	0.340
Singapore		1.000	0.071	0.364	0.265	0.218	0.199	0.061	0.474
Korea			1.000	0.101	0.131	0.066	0.151	0.081	0.112
Philippines				1.000	0.255	0.103	0.173	0.150	0.360
Australia					1.000	0.362	0.187	0.135	0.412
Japan						1.000	0.173	0.073	0.293
Taiwan							1.000	-0.050	0.215
USA								1.000	0.196
Hong Kong									1.000

Correlation Matrix of the Standardized Residuals with Spillover from Indonesia

	Thailand	Singapore	Korea	Phili ppines	Australia	Japan	Taiwan	USA	Hong Kong
Thailand	1.000	0.231	0.201	0.227	0.245	0.159	0.136	0.009	0.203
Singapore		1.000	0.078	0.368	0.267	0.216	0.201	0.061	0.473
Korea			1.000	0.105	0.132	0.064	0.140	0.097	0.112
Philippines				1.000	0.261	0.100	0.163	0.153	0.362
Australia					1.000	0.361	0.186	0.128	0.404
Japan						1.000	0.183	0.063	0.281
Taiwan							1.000	-0.057	0.212
USA								1.000	0.189
Hong Kong									1.000

Correlation Matrix of the Standardized Residuals with Spillover from Korea

	Indonesia	Thailand	Singapore	Phili ppines	Australia	Japan	Taiwan	USA	Hong Kong
Indonesia	1.000	0.210	0.389	0.292	0.205	0.217	0.120	0.039	0.333
Thailand		1.000	0.207	0.230	0.178	0.115	0.078	0.005	0.185
Singapore			1.000	0.360	0.259	0.220	0.198	0.061	0.473
Philippines				1.000	0.205	0.094	0.160	0.160	0.352
Australia					1.000	0.351	0.179	0.139	0.367
Japan						1.000	0.167	0.060	0.282
Taiwan							1.000	-0.049	0.228
USA								1.000	0.183
Hong Kong									1.000

Table 4(cont'd)

Correlation Matrix of the Standardized Residuals with Spillover from Hong Kong

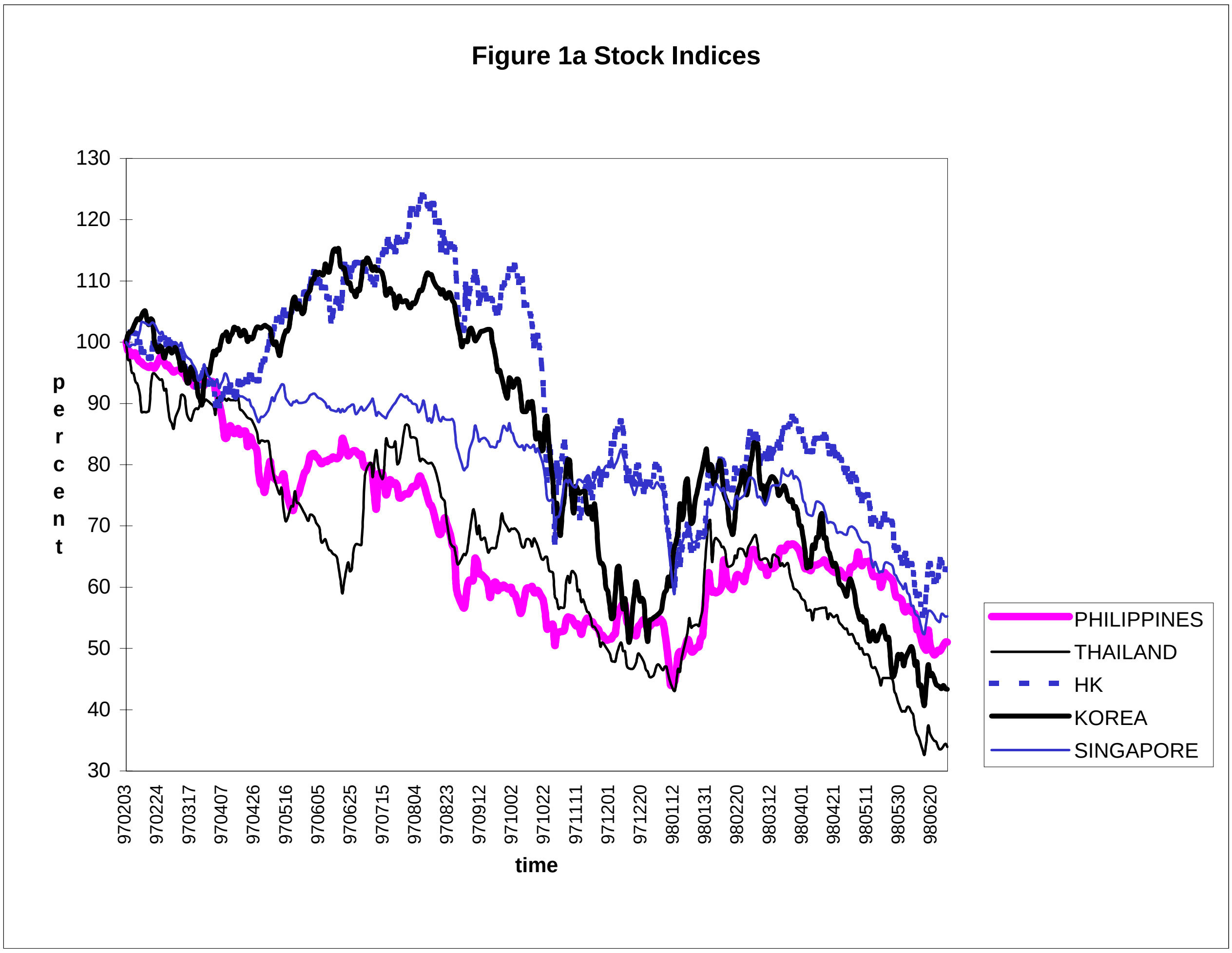
	Indonesia	Thailand	Singapore	Korea	Phili ppines	Australia	Japan	Taiwan	USA
Indonesia	1.000	0.092	0.378	0.082	0.294	0.239	0.201	0.099	-0.001
Thailand		1.000	0.062	0.183	0.126	0.084	0.058	0.056	0.018
Singapore			1.000	0.084	0.359	0.262	0.218	0.186	0.018
Korea				1.000	0.095	0.121	0.078	0.156	0.083
Philippines					1.000	0.240	0.103	0.168	0.114
Australia						1.000	0.341	0.172	0.082
Japan							1.000	0.163	0.030
Taiwan								1.000	-0.069
USA									1.000

Correlation Matrix of the Standardized Residuals with Spillover from Japan

	Indonesia	Thailand	Singapore	Korea	Phili ppines	Australia	Taiwan	USA	Hong Kong
Indonesia	1.000	0.200	0.400	0.092	0.315	0.256	0.163	0.024	0.344
Thailand		1.000	0.190	0.187	0.222	0.187	0.119	0.017	0.186
Singapore			1.000	0.086	0.367	0.273	0.204	0.058	0.469
Korea				1.000	0.092	0.137	0.161	0.096	0.121
Philippines					1.000	0.256	0.171	0.161	0.359
Australia						1.000	0.182	0.131	0.402
Taiwan							1.000	-0.052	0.213
USA								1.000	0.184
Hong Kong									1.000

Correlation Matrix of the Standardized Residuals with Spillover from USA

	Indonesia	Thailand	Singapore	Korea	Phili ppines	Autsralia	Japan	Taiwan	Hong Kong
Indonesia	1.000	0.175	0.309	0.020	0.254	0.161	0.152	0.083	0.258
Thailand		1.000	0.223	0.197	0.228	0.157	0.125	0.123	0.239
Singapore			1.000	0.085	0.357	0.161	0.175	0.183	0.470
Korea				1.000	0.100	0.073	0.050	0.153	0.130
Philippines					1.000	0.137	0.071	0.156	0.360
Australia						1.000	0.322	0.108	0.305
Japan							1.000	0.154	0.260
Taiwan								1.000	0.209
Hong Kong									1.000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120
110
100
90
80
70
60
50
40
30
percent
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970224
970317
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970516
970605
970625
970715
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970912
971002
971022
971111
971201
971220
980112
980131
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time
PHILIPPINES
THAILAND
HK
KOREA
SINGAPORE

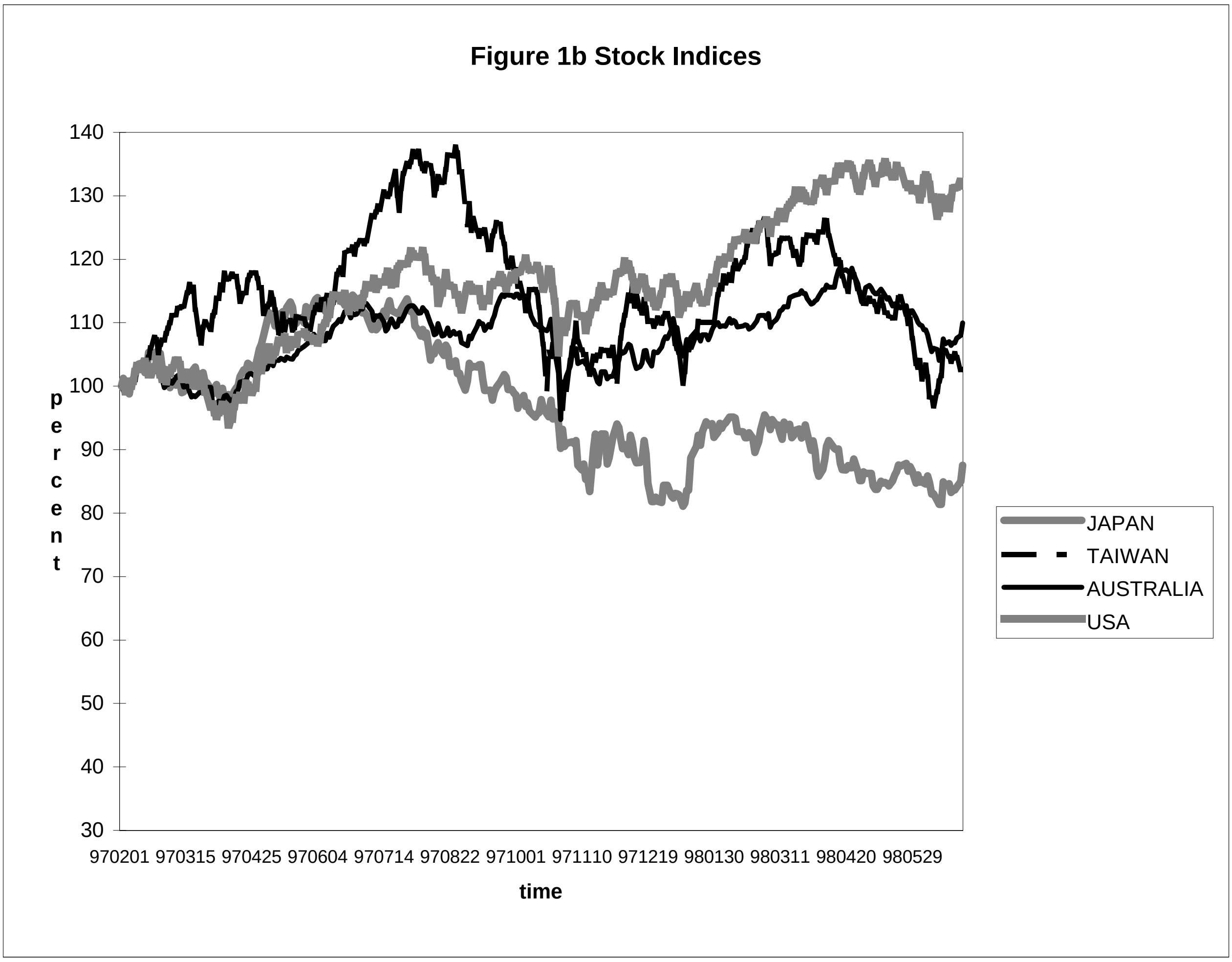
Figure 1b Stock Indices
140
130
120
110
100
90
80
70
60
50
40
30
percent
970201 970315 970425 970604 970714 970822 971001 971110 971219 980130 980311 980420 980529
time
JAPAN
TAIWAN
AUSTRALIA
USA