Return Transmission Among Stock Markets of the Greater China

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Abstract In this article we study the return transmission among stock markets in the Greater China — Mainland China (Shanghai, Shenzhen), Hong Kong and Taiwan — a region which has been enjoying tremendous growth and expansion in the economies and the capital markets in the last decade. Using a multiple time series approach we identify explicitly the lead-lag interaction among these markets. The estimation results show that significant multivariate structures are present. These structures can reduce the residual standard error and improve the fit over the univariate models.

1. INTRODUCTION

The last decade of this millennium evident the emergence of a blueprint of "Greater China", an economic integration of the ethnically homogeneous China, Hong Kong and Taiwan. This trend of economic integration has been initiated by the economic reform in China since the early eighties.

Owing to the geographic vicinity, Hong Kong has had strong economic linkages with China. Since the early fifties, Hong Kong has been an entrepôt serving mainly as an outlet for Chinese exports to the rest of the world. The linkages have been reinforced since China began her economic reform. The importance of Hong Kong as a financial center is even more prominent. Since the early nineties, Hong Kong has been an important channel for China's state enterprises to raise capital. The shares of public companies in China, if they are also listed in the stock exchange in Hong Kong, are called H-shares. Alternatively, Chinese enterprises may choose to raise capital by listing their subsidiaries in Hong Kong. These stocks are labeled as "red chips", reflecting the market sentiments of their importance.

The economic linkage between China and Taiwan, however, is mostly indirect, due to the political tension between the two regions. Hong Kong has been playing the role of the middleman regarding the trading between the two regions. By the end of 1992, it was estimated that the total trade volume exceeded USD 7 billion, and the total investment in China amounted to USD 3 billion, regardless of the apathetic attitude of the Taiwan government toward direct investment in China.

Stock prices are commonly used as a leading indicator of economic conditions. Thus, the extremely dynamic stock market activities in the Greater China region is a reflection of her economic vitality. By the end of the first quarter in 1997, there have been 599 listed companies in the Stock Exchange of Hong Kong. The total market value was HKD 3,399.6 billion (USD 439 billion) and the average daily turnover was HKD 10.1 billion (USD 1.3 billion). Despite being a larger economy than Hong Kong, the Taiwan stock market is smaller. However, trading has been very active. By the end of the first quarter of 1997, there have been 387 listed companies with total market capitalization of NTD 8,845 billion (USD 323 billion) and an average daily turnover of NTD 85.8 billion (USD 3.1 billion).

Shanghai Stock Exchange and Shenzhen

Stock Exchange which have experienced phenomenal growth in recent years, are the two organized stock markets in China. By the end of March 1997, the total market capitalization of the listed stocks in the Shanghai Stock Exchange was RMB 750 billion (USD 93.8 billion) with average daily turnover of RMB 3.69 billion (USD 0.46 billion). Two types of stocks are listed: A share and B share. A shares are available only to Chinese residents while foreign investors are allowed to trade the B shares in foreign currencies. By the end of March 1997, there were 43 B shares and 296 A shares listed in the exchange. The trading in the Shenzhen Stock Exchange has been equally active. By the end of March 1997, the total market capitalization was 657.40 billion (USD 82.1 billion) with an average daily turnover of RMB 7.81 billion (USD 0.98 billion). Similar to the arrangement in the Shanghai Stock Exchange, A shares and B shares are traded. By the end of March, 44 stocks are listed as B shares and 258 stocks are listed as A share.

Since stock market performance is a good indicator of real economy, a study of the linkage between stock markets within the Greater China would shed some light on the economic integration of the region. The issue of transmission mechanism among stock markets is interesting. Eun and Shim (1989) constructed a vector autoregresive (VAR) model of nine–market returns. Based on the specified VAR model, dynamic responses of each of the markets to innovations in a particular market are traced using simulation. They concluded that there was a substantial amount of multi–lateral interaction and the U.S. market was identified to be the most influential. Regardless of the usefulness of the VAR model, in this study we prefer the multiple time series approach which is more parsimonious in parameters. In addition, it provides the lead–lag relations across stock markets explicitly as compared to an unrestricted VAR model.

This paper is organized as follows. Section 2 reviews the multiple time series modelling approach of Tiao and Box (1981). Section 3 describes the data. Section 4 summarizes the empirical results. Some concluding remarks are offered in Section 5.

2. METHODOLOGY

In this section we review the multiple time series modelling approach due to Tiao and Box (1981). We shall restrict the discussion to points necessary for describing the applications in this paper. Further details can be found in Tiao and Box (1981), Heyse and Wei (1985) and Chan and Tse (1993).

We consider a k-element stationary vector time series $\mathbf{Z}_t$ with mean η so that if $\widetilde{\mathbf{Z}}_t$ is defined as $\mathbf{Z}_t - \eta$, then $\widetilde{\mathbf{Z}}_t$ are generated by the following autoregressive moving average (ARMA) process

$$\Phi(B)\widetilde{\mathbf{Z}}_t = \Theta(B)\varepsilon_t \tag{1}$$

where

$$\Phi(B) = \mathbf{I} - \varphi_1 B - \ldots - \varphi_p B^p$$

and

$$\Theta(B) = \mathbf{I} - \theta_1 B - \ldots - \theta_q B^q$$

are matrix polynomials in the backward shift operator B. The residual vectors ε_t are independently and identically distributed as normal variates with mean zero and variance Σ. We assume that the zeros of the determinantal polynomials $|\Phi(B)|$ and $|\Theta(B)|$ are all on or outside the unit circle.

We define the cross-covariance matrix of order l, $\Gamma(l)$, by

$$\begin{aligned}\Gamma(l) &= E[\widetilde{\mathbf{Z}}_t \widetilde{\mathbf{Z}}'_{t-l}] \\ &= \{\gamma_{ij}(l)\}, \qquad i,j = 1,\ldots,k \end{aligned} \tag{2}$$

for all integers l. Also, $\rho(l) = \{\rho_{ij}(l)\}$ is defined as the corresponding cross–correlation matrix. Tiao and Box (1981) define the partial autoregression matrix at lag l, denoted by $\mathbf{P}(l)$, to be the last matrix coefficient when the data are fitted to a vector autoregressive process of order l. This is a direct extension of the Box and Jenkins (1976, p.64) definition of the partial autocorrelation function for univariate time series. When $p = 0$, that is, $\widetilde{\mathbf{Z}}_t$ is a vector MA(q) process, $\Gamma(l)$ and $\rho(l)$ are zero for $l > q$. On the other hand, the partial autoregression matrices $\mathbf{P}(l)$ of a vector AR(p) process are zero for $l > p$. These properties provide very useful information for identifying the order of the vector ARMA model.

Tiao and Box (1981) suggested an iterative modelling approach consisting of: tentative specification, estimation and diagnostic checking. For tentative specification the sample cross–correlation matrix (SCCM), denoted by $\widehat{\rho}(l) = \{\widehat{\rho}_{ij}(l)\}$, is used. These statistics are particularly useful in spotting low order moving average models. If the series ε_t is a white noise, the standard error of each element of the SCCM is approximately $1/\sqrt{n}$. These statistics, however, provide a crude "signal-to-noise ratio" guide and are not meant to give formal significant tests.

Estimates of $\mathbf{P}(l)$ and their standard errors can be obtained by fitting autoregressive models of successively higher order by least squares. Tiao and Box (1981) recommended using the likelihood ratio statistic to test the null hypothesis $\varphi_l = 0$ against the alternative $\varphi_l \neq 0$ if an AR(l) process is fitted. To conduct such a test, we use Bartlett's (1938) statistic, $M(l)$, which is asymptotically χ^2 distributed with k^2 degrees of freedom if the null hypothesis is true.

After the order of the ARMA model is tentatively selected, asymptotically efficient estimates of the parameters can be determined using the maximum likelihood approach. Approximate standard errors of the estimates of the elements of φ_i and θ_i can also be obtained and used to test for the significance of the parameters. Further gains in the efficiency of the estimates may be achieved by eliminating parameters that are found to be statistically insignificant.

The maximization of the likelihood function can be conducted by a conditional likelihood method or an exact likelihood method. The conditional likelihood method is computationally convenient, but may be inadequate if n is not sufficiently large. Thus, in this paper we estimate the parameters initially using the conditional likelihood approach and eliminate parameters that are small relative to their standard error. The model is then reestimated using the exact likelihood method. To guard against model misspecification a detailed diagnostic analysis of the residuals is required. This includes an examination of the plots of standardized residuals and the SCCM of the residuals. At this stage the $M(l)$ statistic provides a criterion for checking residual serial correlation.

3. DATA DESCRIPTION

The following daily market indices are used to represent the market activities of the various regions in the Greater China:

[1] The Hong Kong Hang Seng Index: Hang Sang Index is chosen as a proxy of the stock market activities in Hong Kong. The index is composed of 33 constituent stocks selected from all sectors. It is market-value weighted and represents about 70% of the total market capitalization. We shall denote this index by H.

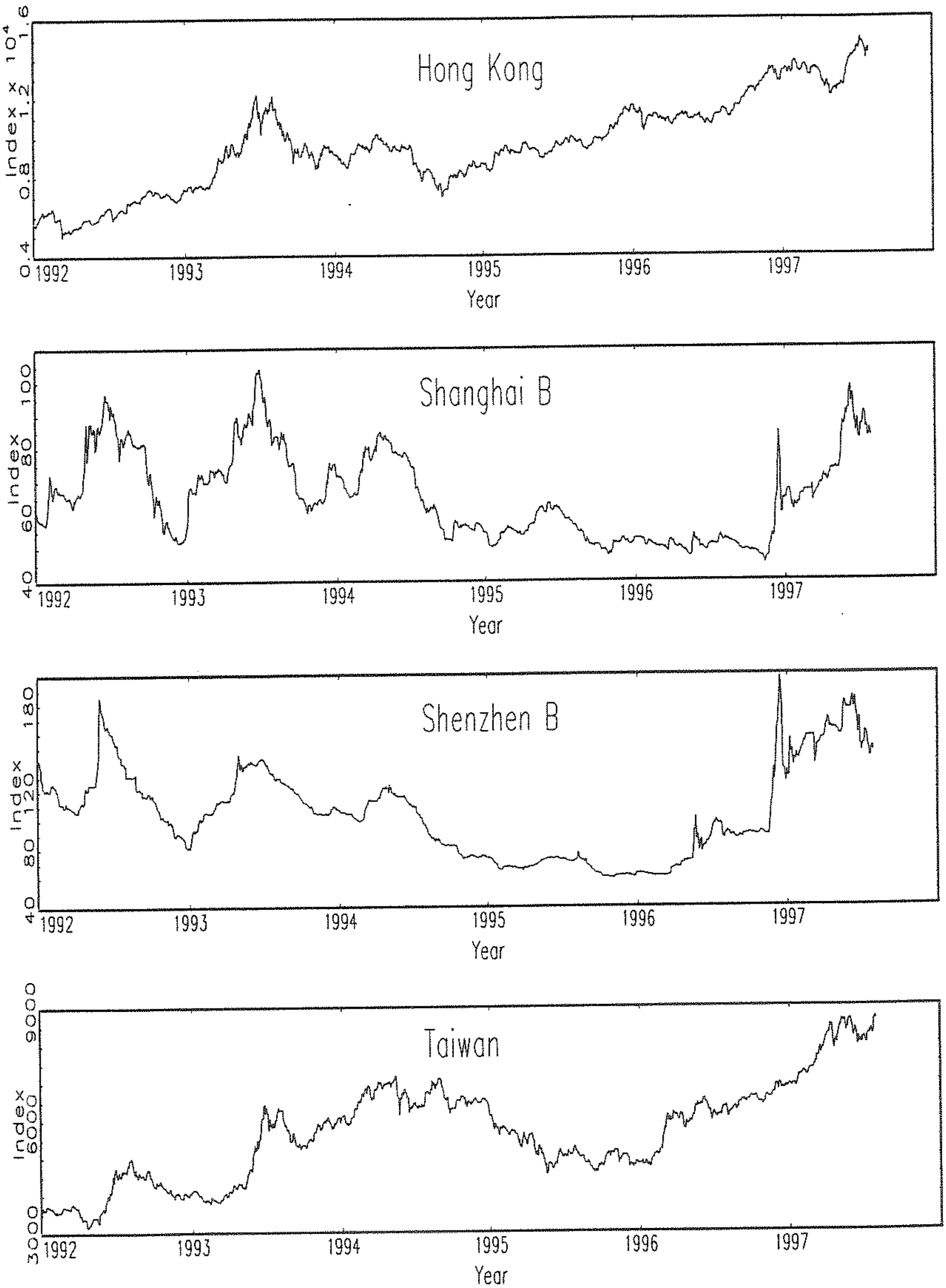
[2] The Shanghai B Share Index and Shenzhen B share Index: These two indices are used to represent the stock market activities in China. The B shares, available only to foreigners who are mostly institutional investors, are less speculative than the A shares and are more closely related to economic fundamentals (Brooks, 1995). The B share indices are market-value weighted and are composed of all the listed B shares. We shall denote the Shanghai B Share Index and the Shenzhen B Share Index by S and Z respectively.

[3] The Taiwan Stock Exchange Capitalization Weighted Stock Index: This index, denoted by W thereafter, is the most widely quoted index of all the Taiwan Stock Exchange indices. The index covers all listed stocks excluding preferred stocks, full-delivery stocks and newly-listed stocks which are listed less than one month.

Our study covers the period from 6 October 1992 to 19 June 1997, giving a total of 1228 time series observations. The data were obtained from Datastream. Figure 1 presents the daily movements of the market indices for different regions. There were some aberrant movements in the Shanghai and Shenzhen markets in the first half month of December, 1996. The sudden jump of the stock indices in Shanghai and Shenzhen in November 1996 was the consequence of a series of interest rate reduction by the monetary authority. Abrupt jumps in the markets may cause problems in statistical analysis and are dealt with as follows. We calculated the first-differences of the logarithm of prices, giving four series of daily continuously compounded rates of returns. Each series was then screened separately for outliers of the additive type using the procedure of Chen and Liu (1993). The numbers of outliers detected for regions in the order of Hong Kong, Shanghai, Shenzhen and Taiwan were 2, 5, 4 and 1. Results in this paper are based on the series adjusted for outliers.

Table 1 provides several descriptive statistics, including mean ($\overline{x}$), standard deviation ($\hat{\sigma}$), skewness (τ_3) and excess kurtosis (τ_4). The coefficients of skewness are all positive except for the Hong Kong market. Tests of significance

Figure 1: Price Indices of Four Greater China Stock Markets



of excess kurtosis in these markets indicate that they all have heavy "tail" return distributions.

Table 1: Descriptive Statistics for the Return Series

Region	$\bar{x}$	$\hat{\sigma}$	τ_3	τ_4
Hong Kong	0.0009	0.0140	-0.17	2.49
Shanghai	0.0002	0.0170	0.41	5.16
Shenzhen	0.0003	0.0182	1.10	13.91
Taiwan	0.0008	0.0149	0.14	2.79

Table 2: Cross-Corrleation Matrices

Lag		H	S	Z	W
	H	1.00			
0	S	0.13*	1.00		
	Z	0.02	0.32*	1.00	
	W	0.12*	0.02	-0.01	1.00
	H	0.08*	-0.01	0.01	0.00
1	S	0.18*	0.27*	0.18*	0.07*
	Z	0.02	0.14*	0.26*	0.02
	W	0.07*	0.01	0.01	-0.01
	H	0.00	0.03	-0.01	0.03
2	S	0.04	0.06*	0.04	0.01
	Z	0.01	0.12*	0.14*	-0.02
	W	-0.01	0.00	-0.02	0.05
	H	0.03	0.03	0.00	0.01
3	S	0.05	-0.01	-0.01	0.03
	Z	0.02	0.08*	0.09*	0.02
	W	0.02	0.00	0.00	0.03

Asterisks denote statistical significance at the 5% level

4. EMPIRICAL RESULTS

To examine the lead-lag relationship across the markets we calculated the cross-correlation matrices. Results are summarized in Table 2. To conserve space only correlations of lag orders from 0 to 3 are presented. The figures show the extent the markets in the column lead the markets in the row, with statistical significance denoted by asterisks. The contemporaneous cross-correlations are statistically significant between Hong Kong–Shanghai, Hong Kong–Taiwan and Shanghai–Shenzhen stock returns. In the first-lag cross-correlation matrix, there are eight correlations out of the total of sixteen elements are significant. Shanghai is a quite passive market. It is led by all the other markets included in this study. On the other hand, Hong Kong is leading Shanghai and Taiwan markets. There are also significant higher lags interactions between two stock markets in Mainland China (Shanghai and Shenzhen).

Following the Tiao-Box approach outlined in the second section, a fifth order vector autoregressive time series model has been tentatively specified. In order to achieve parsimonious in parameters, insignificant elements of the parameter matrices should be deleted. The model estimation procedure was carried out in three stages. First, the model was estimated without constraints. Second, the parameter estimates with absolute t-values less than 1.64 were deleted. Finally, the critical value was set to the typical 1.96. This is to avoid deleting too many parameters in the second stage. The final model, computed by the SCA system (Liu and Hudak, 1995), is given as follows:

$$
\begin{aligned}
H_t &= .077H_{t-1} \\
S_t &= .178H_{t-1} + .194S_{t-1} + .107Z_{t-1} \\
&\quad -.065S_{t-3} + .085H_{t-4} \\
&\quad +.074H_{t-5} + .065W_{t-5} \\
Z_t &= .245Z_{t-1} + .084S_{t-2} + .078Z_{t-4} \\
W_t &= .069H_{t-1} + .072H_{t-5} \qquad (3)
\end{aligned}
$$

We performed a detailed diagnostic analysis of the residuals from the above fitted model. The $M(l)$ statistics for $l = 1, \ldots, 5$, are, respectively, 7.36, 7.17, 8.16, 12.34 and 15.72, which are insignificant at the 5% level (The critical value at the 5% level is $\chi^2_{16,0.05} = 26.3$). Inspection of the cross-correlation matrices of the residuals (not reported here) showed that there is no residual serial correlation. Therefore, the fitted model is adequate to represent the multivariate structures for the return transmission among the Greater China stock markets.

Table 3 summarizes the lead-lag relationship among the four Greater China stock markets as given in equation (3). Returns in the Hong Kong market follow an AR(1) model. They move independently and do not lag behind the markets in Shanghai, Shenzhen and Taiwan. It might be due to the fact that Hong Kong has the most mature and the largest stock market compared with the others. Using the univariate time series modelling approach by Box and

Jenkins (1976), a random walk model was fitted to the stock index in Taiwan. However, when the other markets are jointly considered, returns in the Taiwan market are no longer a white noise. The Taiwan market lags behind the Hong Kong market by one and five days. The Shanghai market is rather passive. It lags behind all the other markets for various durations. There are also some lead-lag interactions between the Shanghai and Shenzhen markets.

Table 3: Estimated Return Transmission among Greater China Stock Markets

Return Transmission	Lag Order
H $\longrightarrow$ H	1
H $\longrightarrow$ S	1, 4, 5
H $\longrightarrow$ W	1, 5
S $\longrightarrow$ S	1, 3
S $\longrightarrow$ Z	2
Z $\longrightarrow$ Z	1, 4
Z $\longrightarrow$ S	1
W $\longrightarrow$ S	5

5. CONCLUSION

We have examined the return transmission among the four Greater China stock markets. The estimation results show that the markets do not generally follow a random walk. There are multivariate return transmission structures, and incorporating these structures can reduce the residual standard error and improve the fit over the univariate models.

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