Time-varying Conditional Correlations in Asia-Pacific Equity Markets

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Abstract This paper examines the risk correlation structure across equity markets for various Asia-Pacific markets. Pairwise correlations for Singapore, Malaysia, Thailand, Hong Kong, South Korea, Taiwan, Philippines, Indonesia, Japan and Australia between 1990 and 2001 are examined using daily data. A rolling estimation method is used to examine the significance of changes in the correlation structure across the markets over the sample period. The paper also examines the impact of diversification and industrial composition of the market indices on the correlation structure. Cross-market and cross-industry correlations, as well as pre- and post-crash correlations, are analysed to shed light on the correlation structure of these markets. Multivariate GARCH models of time-varying volatility impose restrictions on the parameters, such as constant conditional correlation. This paper provides insight into the nature of the correlation structure to assess the feasibility of models that require such parametric restrictions.

Keywords Time-varying correlations; Asia-Pacific equity markets; Pairwise correlations; GARCH models; Rolling regressions

1. INTRODUCTION

Volatility is an important characteristic in the analysis of financial asset returns. An important feature of financial volatility is the presence of serial dependence, or volatility clustering. This feature has led to numerous studies and the development of econometric techniques to analyse the time-varying nature of volatility, as well as its correlation structure. It is commonly accepted that volatility is time varying, so the correlation structure is also likely to be time varying.

The correlation coefficient is a measure of association between two variables, and a change in correlation would significantly impact on comovements between any two variables. For convenience, most multivariate time series techniques used in analysing returns and volatility assume the correlations to be constant, and possibly zero. If the non-constancy of correlation is significant, then models which assume constant correlations would be misspecified. It is, therefore, essential that we understand the nature and strength of this association as it plays an important role in modelling asset prices and analysing risk management.

The covariance between national markets is a very important consideration in international portfolio diversification. The lower the correlation between two individual markets, the lower is the risk of a portfolio of a mix of assets from the two markets. Although some earlier studies have concluded that correlations across markets are constant (and perhaps zero), recent studies have found that the correlations are indeed time varying.

Using a sliding window of 36 months, Solnik, et al. [1996] compute correlations between the US stock market and the markets of Germany, France, UK, Switzerland, Japan and an index comprising Europe, Asia and Far East (EAFE), and find that international correlations increase in periods of high volatility. Although they conclude that correlations between the US market and other markets are time varying, they also find that there has been a weakening in the correlations over the last decade. There is a growing emphasis in the literature that reports the increase in correlations during periods of high volatility [see Karolyi and Stulz, 1996; Ramchand and Susmel, 1998; Bracker and Koch, 1999].

Longin and Solnik [1995] use a multivariate GARCH (1,1) model to test the hypothesis of constant conditional correlation, and conclude that correlations across the markets of Germany, France, United Kingdom, Switzerland, Japan, Canada and the US are dynamic and exhibit

positive time trends in the conditional correlations, but not in the conditional variances. They also use a Threshold GARCH model and find that a positive or negative shock has the same impact on correlations. It is also found that when shocks to the US market are larger in absolute value than the unconditional US standard deviation, the correlation of the US with the German, French and Swiss markets increases. However, they were unable to establish asymmetry in responses to the correlations of these shocks, that is, there were no significant differences in the sensitivity of correlations between positive and negative shocks.

In understanding time-varying correlations, it also important to understand the factors that affect the cross-correlations between markets. Instead of analysing the time-varying nature of correlations, Bracker and Koch [1999] use daily data on ten markets to analyse the economic determinants of the correlation structure of these markets. They conclude that correlations are positively related to world market volatility, and negatively related to term structure differentials, real interest differentials and world market returns. Moreover, they detect a positive trend in the correlation across the markets and, as in Solnik, et al. [1996], find that this trend seems to be weakening.

Using daily returns between Japanese and US stocks, Karolyi and Stulz [1996] find strong evidence that covariances are higher when there are large contemporaneous returns shocks in national markets. They also demonstrate that there is a nonlinear relation between covariances and large market shocks, and explain this as evidence that large shocks to indices are more likely to be global shocks. Although they find that macroeconomic announcements and interest rate shocks do not significantly affect comovements, it is also found that correlations exhibit day-of-the-week effects, with Monday comovements being higher than on other days. As in Serra [2000], they find that controlling for industry effects has little or no impact on the comovements of markets.

Analysing cross-equity correlations for G7 countries, Erb, et al. [1994] conclude that correlations are also affected by business cycles. They report that correlations are highest when any two countries are in common recession, and are lower during recoveries and when business cycles in the two countries are out of phase. Such a finding is supported by Cheng [1998]. Using canonical correlation analysis, Cheng finds that the comovement between the US and the UK markets is very high and that the US economic cycle is highly capable of accounting for the comovement between the US and the UK markets.

Using a multivariate switching ARCH framework, Ramchand and Susmel [1998] conclude that correlation is both time- and state-varying. They argue that the traditional ARCH and GARCH models are seriously affected by the presence of structural breaks, so that a switching ARCH model is suggested. Far East and North American markets are studied and the market in each country is characterised by high and low variance regimes. As in most studies in this area, the increase in correlations during periods of high volatility is reported.

However, using extreme value theory, Longnin and Solnik [2001] argue that high volatility does not lead to an increase in conditional correlation. They find that correlation is primarily affected by market trends and that the correlation increases in bear but not in bull markets. In commenting on similar studies on correlations, they argue that it cannot be concluded that the 'true' correlation is changing over time by a simple comparison of estimated correlations conditional on different values of one return variable. The distribution of the conditional correlation must be clearly specified in order to test whether correlations increase in periods of high volatility.

The time-varying nature of correlation would result in the rejection of a certain class of econometric models, such as the constant-correlation multivariate GARCH model, that assume constant correlation [see Longin and Solnik, 2001; Tse, 2000].

Recent work in this area has focused on the markets of US and Europe, and little research is available on the correlation structure in the Asia-Pacific markets. Using the multidimensional scaling technique on time-varying correlations, Groenen and Franses [2000] report that, instead of a single world market, there seem to be three distinct clusters of markets, namely, US, European markets and the Asian countries. As the first two clusters of markets have been analysed extensively, the purpose of this paper is to explore the time-varying nature of the correlation structure across the equity markets of various Asia-Pacific markets.

2. DATA AND METHODOLOGY

Daily data for the sample period 1990 to 2001 are used for Singapore, Malaysia, Thailand, Hong Kong, South Korea, Taiwan, Philippines, Indonesia, Japan and Australia. The data are based on Datastream calculated Global Equity Indices for

the equity market and the industrial series for these countries. The Global Equity Indices are based on a representative sample of stocks covering up to 80% of the total market capitalisation.

This paper analyses three indices, namely Japan, $P_{JP,t}$, Singapore, $P_{SG,t}$, and Hong Kong, $P_{HK,t}$. The data are transformed into continuously compounded returns on each index, calculated as:

$$R_{i,t} = \log(P_{it}) - \log(P_{it-1}), \quad \text{for } i = JP, SG, HK \quad (1)$$

Visual inspection of the returns series indicates that the returns display volatility clustering associated with the generalised autoregressive conditional heteroskedasticity (GARCH) processes [see Engle, 1982; Bollerslev, 1986].

The AR(1) conditional mean equation is given by:

$$R_t = \phi_1 + \phi_2 R_{t-1} + \varepsilon_t, \quad |\phi_2| < 1 \quad (2)$$

and the GARCH (1,1) used to generate the conditional variance of ε_t is:

$$\varepsilon_t = \eta_t \sqrt{h_t}$$
$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \quad (3)$$

where $\eta_t \sim$ niid, $\omega > 0$, $\alpha \geq 0$, $\beta \geq 0$, and h_t is the conditional variance of R_t given all information at time $t-1$. Maximum likelihood estimates of the parameters of the GARCH (1,1) model are reported below.

3. EMPIRICAL RESULTS

Table 1 reports the summary data of the logarithmic returns for the three series. Although the unconditional density function is marginally skewed, the data display high kurtosis compared with the normal distribution, which is typical of financial data series. The Jarque-Bera Lagrange multiplier (LM) test for normality rejects normality for the three series.

Table 2 reports the estimates of the GARCH (1,1) model, where the robust t-ratios are given in parentheses.

The LM test applied to the standardised residual, η_t, indicates that there are no significant lagged squared standardised residuals. This confirms that there are no ARCH effects in the standardised errors and that the model is properly specified.

Table 1. Summary statistics of the logarithmic returns for Japan (JP), Hong Kong (HK) and Singapore (SG).

	Mean	Std. Dev.	Skewness	Kurtosis	JB
JP	-9.29E-05	0.012	0.313	7.417	2408
HK	4.99E-04	0.017	-0.095	12.29	10440
SG	1.97E-05	0.012	-0.054	9.963	5868

Note: JB is the Jarque-Bera Lagrange multiplier test statistic for normality of the returns, which follows a χ^2 distribution with two degrees of freedom.

Table 2. Parameters Estimates of the GARCH (1,1) Model.

	ω	α	β	$\alpha + \beta$	$(\alpha + \beta)^2 + 2\alpha^2$
JP	4.81E-06* (3.85)	0.111* (6.10)	0.860* (46.3)	0.971	0.967
HK	5.93E-06* (2.64)	0.109* (6.02)	0.873* (47.0)	0.982	0.988
SG	3.40E-06* (2.94)	0.149* (5.72)	0.837* (30.3)	0.986	1.017

*Significant at the 5% level. The t-ratios are based on Bollerslev-Wooldridge [1992] robust standard errors.

As shown in Table 2, all the estimated GARCH parameters are positive. The estimated ARCH (or short run persistence) effects are in the range (0.109, 0.149), while the GARCH effects are in the range (0.837, 0.873).

For all three indices, it is found that $\alpha + \beta < 1$, implying that the conditional variance, h_t, is finite and the process is strictly stationary and ergodic. This is also the estimate of the long run persistence, which is in the narrow range (0.971, 0.986). Hence, the effect of shocks on conditional volatility is small, but the long run persistence indicates a long memory process. The necessary and sufficient fourth moment condition for asymptotic normality, $(\alpha + \beta)^2 + 2\alpha^2 < 1$, is satisfied for Japan and Hong Kong, but not for Singapore.

Using a sliding window of 800 observations, pairwise conditional correlation estimates of cross-market indices and cross-industry indices are computed, where the conditional correlation for index 1 and index 2 is defined as:

$$\hat{\rho}_{12,t} = \frac{h_{12,t-1}}{\sqrt{h_{1,t-1}} \sqrt{h_{2,t-1}}} \quad (4)$$

where $h_{12,t-1}$ is the conditional covariance between indexes 1 and 2 at time $t-1$. Pairwise correlations are also estimated for the pre- and post-crash periods to ascertain changes in the correlation structure due to the Asian financial and economic crises.

Conditional volatility of returns and the conditional correlations between pairs of indices are shown in Figures 1 to 3. Table 3 reports the average correlations calculated for the period April 1993 to May 2001.

Table 3. Average correlations, April 1993 to May 2001

Country pairs	Average Correlations
Japan – Hong Kong	0.28
Singapore – Hong Kong	0.64
Japan – Singapore	0.24

The average correlation between Japan and Hong Kong is 0.28, between Singapore and Hong Kong is 0.64, and between Singapore and Japan is 0.24. Lowest and highest correlations between Japan and Hong Kong are 0.05 and 0.51, respectively, between Singapore and Hong Kong 0.37 and 0.90, respectively, and between Singapore and Japan 0.07 and 0.49, respectively.

Correlations between these markets are positive, on average, as they are calculated over 800 observations. This result is sensitive to the size of the chosen window, that is, a smaller window size could yield negative correlations. For example, correlations calculated using a window size of 100 provided some negative correlations between Singapore and Hong Kong. The correlation between the Singapore and Hong Kong markets is, on average, higher than the respective correlations of these two markets with Japan.

It is evident that the correlations between markets are time varying. There is a general tendency for correlations to increase in periods of high volatility, such as during the 1997 Asian financial crisis, which was characterised by especially high volatility. Pairwise correlations for all three countries increased during this period.

The 1997 Asian financial crisis was a defining moment in the history of the Asia-Pacific region as it exposed fundamental structural weaknesses, in particular, inadequate bank regulation, lack of transparency in business, and endemic cronyism in some economies, such as Indonesia and Thailand. Although the degree of severity varied, there was a decline in exchange rates, and in stock and property prices in all Asian countries. Thus, the increase in the correlations between these three countries is not surprising.
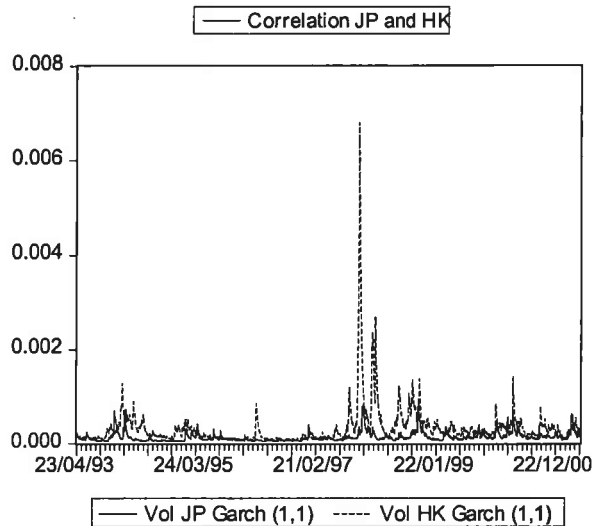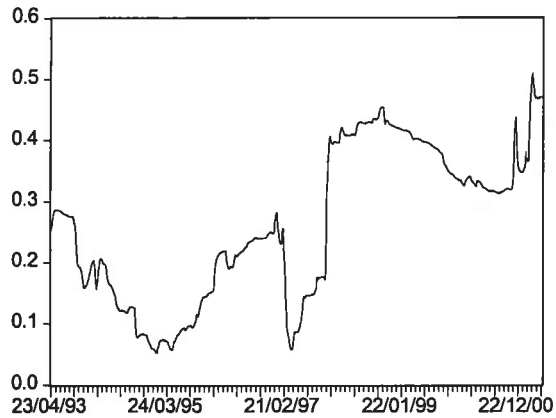

Figure1. Conditional correlations and conditional volatility of returns for Japan and Hong Kong.

Figure 1 shows the time-varying conditional correlations and conditional volatility between Japan and Hong Kong. The correlation spikes correspond to the volatility spikes in 1994 and 1997. There is a 'correlation smile' evident during 1993 and early 1997, that is, correlations declined during the first half of the period and increased during the second half. There is also a dramatic decline in the correlations just before the financial crisis in 1997.

The average correlation between Singapore and Hong Kong is much higher over the sample period than between Hong Kong and Japan. Figure 2 shows that during periods of high volatility in 1994 and 1997, there were corresponding increases in correlations between these two markets.

However, the spike in correlations in early 2001 does not correspond to any volatility spikes. As in Figure 1, there was a sharp decline in the correlations between the two markets just before the impact of the 1997 Asian financial crisis.
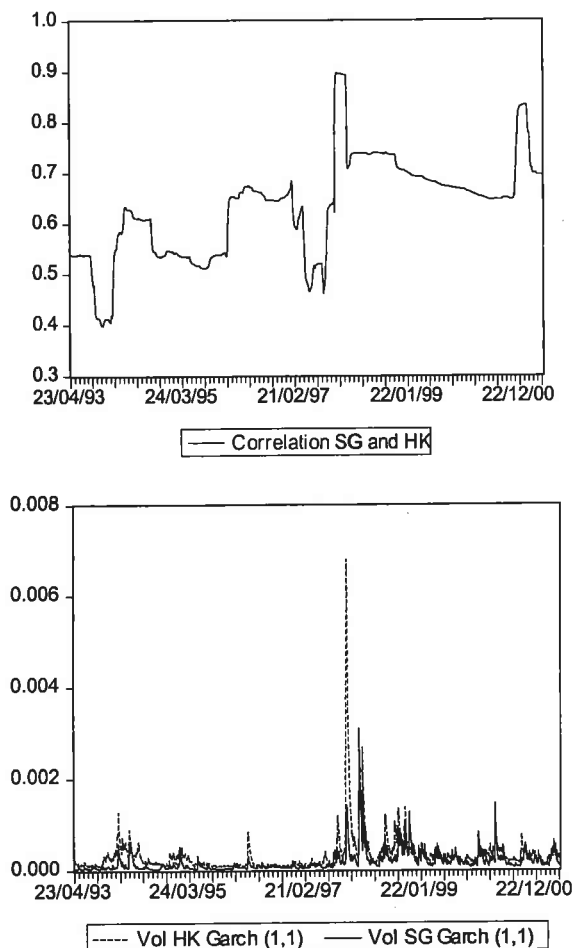

Figure 2. Conditional correlations conditional volatility for Singapore and Hong Kong.

There is a pronounced correlation smile between Singapore and Japan 1993 and 1998, in Figure 3. There are spikes in the correlations during the periods of high volatility in 1995, 1997, early 1999 and early 2001. Correlations between Singapore and Japan declined in 1993 and 1994, and increased from early 1997 to 1999. The average correlation between these two markets is lower than that between Singapore and Hong Kong, a result that is consistent with Tse and Tsui [2001].
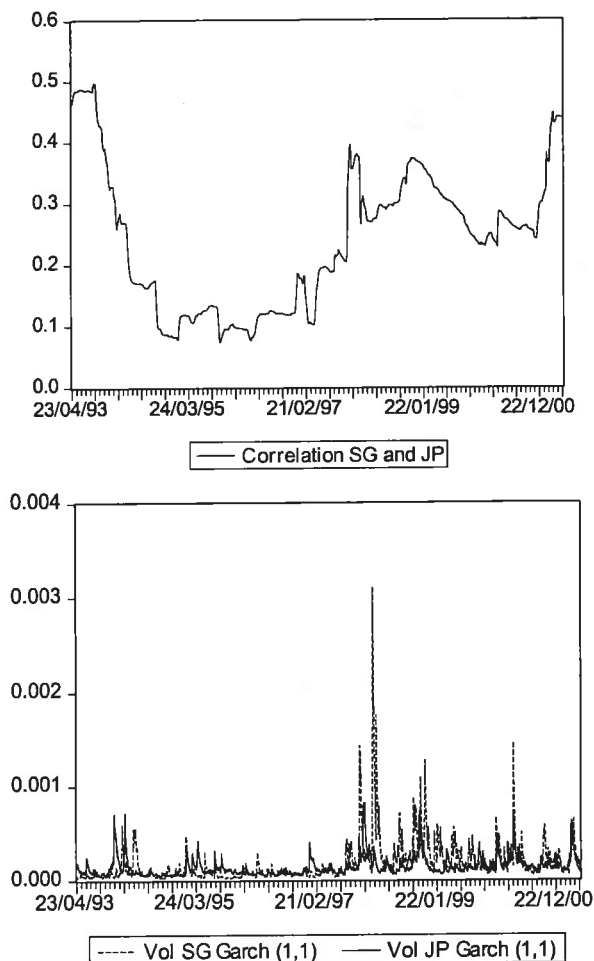

Figure 3. Conditional correlations and conditional volatility for Singapore and Japan.

A comparison of pre- and post-crash correlations shows a structural shift in the pair-wise correlations between the three countries. Computation of pre- and post-crash average correlations for these countries, as in Table 4, reveals a marked increase after the Asian financial crisis of 1997. The post-crash correlation between Japan and Hong Kong increased by a factor of 2.13, between Singapore and Hong Kong by a factor of 1.22, and between Singapore and Japan by a factor of 1.77.

Table 4. Average correlations for pre- and post-crash periods.

Country pairs	Pre-crash Apr 93-Apr 97	Post-crash Aug 97 – May 01
Japan/Hong Kong	0.185	0.394
Singapore/Hong Kong	0.579	0.706
Singapore/Japan	0.179	0.317

Portfolio theory dictates that there are benefits from international diversification if the correlations among assets are low. The increase in

the correlations between two assets would also result in the increase in the variance of the portfolio. The finding in this paper that there is a general increase in the correlations among the three markets after the Asian financial crisis is important. The Singapore and Hong Kong markets have become more integrated since the 90s, which is amplified by the cross-listing of many Hong Kong companies on the Singapore exchange.

As reported in Erb, et al. [1994] and Cheng [1998], correlations tend to be high when any two countries are in common recessions. There is a general increase in the correlations of the three markets in the first half of 2001. The markets have been experiencing a steady decline since the start of 2000, and the three countries recorded poor economic performances in the first quarter of 2001.

4. CONCLUDING REMARKS

Little attention has been paid in the literature to the risk correlation structure of Asia-Pacific markets. This paper investigated the nature of this structure to address the dearth of research on this topic. Empirical results for three markets have been reported. The paper reports positive pairwise correlations between the markets of Japan, Singapore and Hong Kong. The empirical estimates show that there is an increase in correlations between these markets during periods of high volatility. Moreover, there appears to have been a structural shift in the correlations between these markets after the Asian financial crisis of 1997. Further investigation is needed to understand the effects of extreme observations on the correlation structure and the effects of negative and positive shocks on the correlations.

5. ACKNOWLEDGEMENTS

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