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Price Linkages in Asian Equity Markets: Evidence Bordering the Asian Economic, Currency and Financial Crises

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Abstract. This paper examines price linkages among Asian equity markets in the period surrounding the recent Asian economic, financial and currency crises. Three developed markets (Hong Kong, Japan and Singapore) and six emerging markets (Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand) are included in the analysis. Multivariate cointegration and level VAR procedures are conducted to examine causal relationships among these markets. The results indicate that there is a stationary relationship and significant causal linkages between the Asian equity markets. Nevertheless, lower causal relationships that exist between the developed and emerging equity markets suggest that opportunities for international portfolio diversification in Asian equity markets still exist.

Keywords: Financial integration, international portfolio diversification, market efficiency.

1. Introduction

Following the massive devaluation of the Thai baht in July 1997, most East Asian and South-East Asian financial markets, particularly in Korea, Malaysia, Indonesia and the Philippines, experienced similarly dramatic devaluations in exchange rates. In these markets managed currencies were allowed to move in a wider band or abandoned altogether, capital control measures were introduced, bank and sovereign ratings were downgraded, and inflationary

expectations revised upward along with unemployment. As the crises intensified, foreign exchange and stock market turmoil spread across Asia. News of economic and political distress, particularly bank and corporate fragility, became commonplace, and modest recoveries in some markets were repeatedly assailed by deteriorating conditions in others. Only by mid 1999 was Asian recovery becoming a reality, and only after extensive microeconomic reform, fiscal contraction and international financial assistance. Nevertheless, the pace of Asian recovery is exceedingly slow and uneven. While some economies, such as Korea, made moderate gains in 1999/2000, they are followed at a distance by many, including Thailand, the Philippines, Hong Kong and Singapore, and yet further behind by several of the markets most distressed by the regional collapse, especially Malaysia and Indonesia.

Quite apart from the posited macroeconomic, structural and policy origins of the Asian economic, currency and financial crises, the manner in which these crises reverberated across national stock markets has created considerable interest in the study of linkages among regional capital markets. This is especially noteworthy since Asian capital markets have been traditionally viewed as being relatively isolated from each other. However, with the Asian crises came the realisation that the several capital markets had becomes so integrated that the more developed markets, including Singapore and Hong Kong, exerted a strong influence on the smaller markets, especially Indonesia, Malaysia and Thailand. Indeed, the more developed markets themselves were no longer isolated from conditions in these emerging markets.

The growing integration of Asian financial markets has obvious implications for international portfolio diversification. Starting with the seminal studies of Levy and Sarnat (1970) and Solnik (1974) a voluminous empirical literature has arisen concerned with establishing the degree of correlation in international capital (equity) markets. If, and as has been hypothesised, low correlations of returns exist, diversifying across national markets allows investors to reduce portfolio risk while holding expected return constant. This would appear to have been a major factor in the interest international investors expressed in Asian emerging markets before the crises. As an indication, net portfolio investment flows averaged $US10.5 billion for the period 1991 to 1996 across Asia, and $US11.75 billion in the five economies most affected by the crises (namely, Indonesia, Korea, Malaysia, the Philippines and Thailand) (Baig and Goldfajn, 1998, p. 93).

Unfortunately, little empirical evidence exists concerning linkages among Asian capital markets and the concomitant prospects for international portfolio diversification. International studies concerned with market linkages are relatively commonplace [see, for example, Arshanapalli and Doukas (1993), Masih and Masih (1999) and Cheung and Lai (1999)]. And

regional markets, especially in Europe (Abbott and Chow, 1993; Espitia and Santamaria, 1994; Akdogan, 1995; Meric and Meric, 1997) and Latin America (Chaudhuri, 1997; Christofi and Pericli, 1999) are subject to increasing attention. However, few studies have adopted an Asian regional perspective. Moreover, even where Asian markets are examined in a broader multilateral context (that is, along with North American and European markets) there is generally an emphasis on the more developed Asian economies. For example, Lai *et al.* (1993), Richards (1995) Solnik *et al*. (1996), Darbar and Deb (1997), Yuhn (1997) and Francis and Leachman (1998) only incorporated Japan in their studies of international stock market linkages, Ramchand and Susmel (1998) added Singapore and Hong Kong, while Kwan *et al*. (1995) also included Taiwan and Korea. As far as the authors are aware, no study to date has examined capital market linkages across the broad spectrum of Asian developing and developed economies, irrespective of any changes arising from the recent economic, currency and financial crises.

The paper itself is divided into four main areas. The second section briefly surveys the empirical literature concerning price linkages and international portfolio diversification in the Asian milieu. The third section explains the methodology and data employed in the present analysis. The results are dealt with in the fourth section. The paper ends with some brief concluding remarks.

2. Asian Equity Market Linkages

Despite their generally small size in terms of global market capitalisation, Asian equity markets have increasingly attracted non-Asian investors – particularly from the U.S. – to the potential benefits of international diversification. However, it has been cogently argued [see, for example, Roca (1999) and Masih and Masih (1999)] that comparatively recent developments in these markets, including increasing levels of trade interaction and the easing of regulatory restrictions governing the movement of capital, have diminished the prospects for diversification by these groups. Combined with the pace of global financial integration, and innovations such as the October 1987 stock market crash and the more recent Asian crises, these factors suggest that Asian capital markets have become increasingly integrated.

Several studies have been undertaken which focus upon the relationships between developed and emerging Asian markets. In one of the earlier studies, Bailey and Stulz (1990) examined the prospects for international portfolio diversification among Pacific Basin stock markets. Using daily returns for the Hong Kong, Japan, Malaysia, Philippines, Singapore, Korea, Taiwan and Thailand stock market indexes over the period January 1977 to December

1985, and specifying their analysis in US dollars, Bailey and Stulz (1990) employed simple correlation analysis to detect significant interrelations among markets. The results indicated that the degree of correlation between US and Asian equity returns depended upon the periodic specification, whether daily, weekly or monthly. For example, with daily returns only the correlations between the US and Hong Kong, Japan and Taiwan were significant, while for monthly returns all Asian market correlations were significant, with the exception of the Philippines and Thailand. Using this evidence Bailey and Stulz (1990, p. 61) concluded that the benefits for US investors diversifying into the Pacific Basin were "…substantial and yet they are easily overestimated [when] using daily data [or] for investors with holding periods longer than one day".

Specifying a similar set of Asian equity markets, Cheung and Mak (1992) also used national share market indices to analyse financial integration, though defined in terms of weekly returns over the period January 1977 to June 1988. The approach taken to international portfoio diversification was likewise from a US investor perspective. Employing an ARIMA model Cheung and Mak (1992, p. 46) found:

> [O]ur study provides evidence that the US stock market leads most of the Asian-Pacific stock markets with the exception of the three relatively closed markets [Taiwan, Korea and Thailand]. Similar testing procedures are also performed to examine the causal relationship between the Japanese market and other smaller Asian emerging markets…the regional factor [Japanese market] seems to have a less significant impact on the Asian-Pacific markets.

Upon this basis, Cheung and Mak (1992) concluded that opportunities still existed for portfolio diversification in Asia by international investors. Janakiramanan and Lamba (1998) also examined Asian emerging markets in the broader context of the Pacific-Basin [that is, along with the United States, Australia and New Zealand]. The results of a vector autoregression (VAR) model provided evidence "…that markets that are geographically and economically close and/or have large numbers of cross-border listings exert significant influence over each other". Importantly, while the US market was obviously the most influential market, Janakiramanan and Lamba (1998) found that its effect had diminished over more recent years in favour of regional influences.

In contrast to the work of Bailey and Stulz (1990) and Cheung and Mak (1992), more recent analyses of Asian financial market interrelationships have employed cointegration techniques. For example, Chung and Liu (1994) used weekly national index data from the Japanese, Taiwanese, Hong Kong, Singaporean and Korean markets in conjunction with cointegration tests to examine long-run relationships over the period January 1985 to May

1992. Chung and Liu (1994, p. 257) found that "…stochastic trends dictated by the four common unit roots are important to the long-run movement of the stock prices". The results also indicated that Taiwan (along with the US) did not belong to the same common stock region as the remaining four countries (namely, Japan, Singapore, Hong Kong and Korea) (Chung and Liu, 1994).

Kwan *et al*. (1995) also used cointegration analysis to examine long-term links between world equity markets (including Japan, Taiwan, Korea, Singapore and Hong Kong) as well as Granger (1969) non-causality tests to quantify short-term causal relationships. The sample spanned the period January 1982 to February 1991 and like much of the work in this area used commonly available stock market indices. For example, the four Asian indices used were the Nikkei Dow (Japan), Hang Seng (Hong Kong), Taiwan Weighted, South Korea Composite and Singapore Strait Times. Focusing on the 'four little tigers' Kwan *et al*. (1995) concluded "…a (uni-directional) causal sequence is found in all but 4 of 12 cases considered and that the existence of significant lead-lag relationships between equity markets points to a rejection of the informational market efficient hypothesis". Roca (1999) used similar techniques to investigate short and long-term price linkages between Asian equity markets over the period December 1974 to December 1995, and made allowance for the structural shifts associated with the 1987 stock market crash. However, contrary to the findings of Kwan *et al*. (1995), Roca (1999, p. 510) found evidence suggesting that "the lack of cointegration between the equity markets of Australia and the US, UK, Hong Kong, Singapore, Taiwan and Korea means that the latter markets could serve as good avenues for long-term portfolio diversification".

Nevertheless, evidence concerning Asian financial market integration has been more mixed when studies have included smaller emerging markets. For example, Elyasiani *et al.* (1998) examined the interdependence and dynamic linkages between the Sri Lankan stock market and its trading partners. The Asian trading partners were comprised of Taiwan, Singapore, Japan, South Korea, Hong Kong and India. Elyasiani *et al*. (1998, p. 100) concluded:

> Overall, the results on the dynamic responses to external shocks demonstrate that the Sri Lankan market is very much immune to shock originating form the US and six Asian countries considered here with whom it has a trading relationship. It appears that the emerging capital market of Sri Lanka is scantily integrated with those of the larger and stronger economies of the region.

Accounting for these differences between emerging markets and larger regional economies, Elyasiani *et al*. (1998) reasoned that low levels of capitalisation, a lack of market liquidity,

high concentration in blue chips and barriers to investment were possible reasons for the lack of interdependence. And these therefore provided opportunities for diversification benefits to global investors.

Lastly, there is some evidence that there is strong regional perspective to Asian capital market interrelationships. For instance, Masih and Masih (1999, p. 275) found that "…other advanced countries did not appear to have any pronounced effect on the Asian regional markets (compared to the intra-regional impact of the Asian markets". Put differently, "…the results tend to lend strong support to the view that the stock market fluctuations in all these Asian markets are explained mostly by their regional markets (rather than the advanced economies) (Masih and Masih, p. 251). Masih and Masih (1999) attributed the increasingly strong Asian intra-regional stock market dependency to *inter alia* growing shares of intra-regional trade and investment and common monetary policies pursued since the October 1987 crash

The existing literature regarding the degree of Asian financial market interdependence and the concomitant potential for international portfolio diversification may be summarised as follows. First, most empirical studies to date have indicated that the major equity markets (ie. Japan, Hong Kong, Taiwan and Korea) are closely integrated, thereby diminishing the potential for Asian portfolio diversification. This holds for both studies with a specific Asian focus and those examined in a broader international context [see, for example, Kwan *et al*. (1995), Elyasiani *et al*. (1998) and Masih and Masih (1999)]. However, evidence concerning financial integration in some of the smaller Asian equity markets (ie. Thailand, the Philippines, Indonesia and Malaysia) is less conclusive.

Second, evidence also exists that the degree of financial interrelationship among Asian markets has increased dramatically in recent years. Key aspects of this process have been increasing shares of intra-regional trade and investment, and the impact of innovations in the form of market shocks such as the October 1987 stock market crash (Roca, 1998; Masih and Masih, 1999). However, no study to date has addressed the possible impact of the 1997 Asian crises on these relationships. Third, while some evidence exists concerning financial integration in other regional markets, especially Europe, far less is known about financial interrelationships in the Asian region. This is particularly pertinent because of the large number of emerging markets in the region and the generally strong growth potential, but also because of the hitherto unexpected contagion effects that characterised the regional economy in 1997/98.

Finally, while more recent work has taken advantage of the sizeable advances in cointegration techniques, much of the work on Asian financial market interrelationships has been constructed using simple correlation techniques. Moreover, most of the data used in these analyses are drawn from national stock market indices that may exhibit particular problems associated with the degree of comparability with respect to index breadth, liquidity and construction. Combined together, these factors may serve to compromise existing work in this area.

3. Empirical Methodology

The data employed in the study is composed of value-weighted equity market indices for nine Asian markets; namely, Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. Three of these markets are categorised as 'developed' (Hong Kong, Japan and Singapore) and the remainder is regarded as 'emerging'. All data is obtained from Morgan Stanley Capital International (MSCI) and encompasses the period 1 January 1988 to 18 February 2000. MSCI indices are widely employed in the financial integration literature on the basis of the degree of comparability and avoidance of dual listing [see, for instance, Meric and Meric (1997), Yuhn (1997), Roca (1999) and Cheung and Lai (1999)]. Weekly data is specified. On one hand, it has been argued "daily return data is preferred to the lower frequency data such as weekly and monthly returns because longer horizon returns can obscure transient responses to innovations which may last for a few days only" (Elyasiani *et al*. 1998: 94). However, Roca (1999, p. 505), amongst others, have countered that "…daily data are deemed to contain 'too much noise' and is affected by the day-of-the-week effect".

Within this time-series, three sub-periods are identified. The sub-periods consist of the period leading up to the onset of the Thai currency crisis (1/1/1988–25/7/97), a period since this event (1/8/1997–18/2/2000), and the entire sample (1/1/1988–18/2/2000). The overall hypothesis is that existing price linkages have strengthened in the period since the beginning of the Asian crises period, and that regional financial interrelationships are also more extensive in this period. The paper investigates the integration among Asian equity markets as follows. To start with, since the variance of a nonstationary series is not constant over time, conventional asymptotic theory cannot be applied for those series. Unit root tests of the null hypothesis of nonstationarity are conducted in the form of an Augmented Dickey-Fuller (ADF) regression equation:

$$\Delta Y_{it} = \alpha_0 + \alpha_1 t + \rho_0 Y_{it-1} + \sum_{i=1}^{p} \rho_i \Delta Y_{it-i} + \varepsilon_{it} \tag{1}$$

where Y_{it} denotes the index for the *i*-th country at time *t*, $\Delta Y_{it} = Y_{it} - Y_{it-1}$, ρ are coefficients to be estimated, *p* is the number of lagged terms, *t* is the trend term, α_1 is the estimated coefficient for the trend, α_0 is the constant, and ε is white noise. The critical values in MacKinnon (1991) are used in order to determine the significance of the test statistic associated with ρ_0. ADF tests are performed on both the levels and first differences of the indices.

Following Engle and Granger (1987) suppose we have a set of *m* indices $y_t = [Y_{1t,} Y_{2t}, \cdots, Y_{mt}]'$ such that all are I(1) and $\beta' y_t = u_t$ is I(0), then β is said to be a cointegrated vector and $\beta' y_t = u_t$ is called the cointegrating regression. The components of y_t are said to be cointegrated of order (*d*, *b*) and is denoted by $y_t \sim$ CI(*d*, *b*) where $d > b > 0$, if (i) each component of y_t is integrated of order (*d*, *b*) and (ii) there exists at least one vector $\beta = (\beta_1, \beta_2, \ldots, \beta_m)$, such that the linear combination is integrated of order (*d* - *b*). Toda and Yamamoto (1995) propose a level VAR procedure, principally for the purpose of Granger non-causality testing, in which the relationships between cointegrated variables may be analysed **(**Masih and Masih, 1999: 266). Essentially, the level VAR is based on VAR for the level of variables with the lag order *p* in the VAR equations given by $p=k+d_{max}$, where *k* is the true lag length and d_{max} is the possible maximum integration order of variables (Masih and Masih, 1999). The estimated VAR is expressed as:

$$y_t = \hat{\gamma}_0 + \hat{\gamma}_1 t + \cdots + \hat{\gamma}_q t^q + \hat{J}_1 y_{t-1} + \cdots + \hat{J}_k y_{t-k} + \cdots + \hat{J}_p y_{t-p} + \hat{\varepsilon}_t, \tag{2}$$

where $t = 1, \ldots, T$ is the trend term and $\hat{\gamma}_i, \hat{J}_j$ are parameters estimated by OLS. Note that d_{max} does not exceed the true lag length *k*. Equation (2) can be written as:

$$Y' = \hat{\Gamma}\Lambda + \hat{\Phi}X + \hat{\Psi}Z' + \hat{\mathrm{E}}' \tag{3}$$

where $\hat{\Gamma} = (\hat{\gamma}_0, \ldots, \hat{\gamma}_q)$, $\Lambda = (\tau_1, \ldots, \tau_T)$ with $\tau_t = (1, t, , \ldots, t^q)'$, $\hat{\Phi} = (\hat{J}_1, \ldots, \hat{J}_k)$, $\hat{\Psi} = (\hat{J}_{k+1}, \ldots, \hat{J}_p)$, $X = (x_1, \cdots, x_T)$ with $x_t = (y'_{t-1}, \ldots, y'_{t-k})'$, $Z = (z_1, \cdots, z_T)$ with $z_t = (y'_{t-k-1}, \ldots, y'_{t-p})'$ and $\hat{\mathrm{E}}' = (\hat{\varepsilon}_1, \ldots, \hat{\varepsilon}_T)$. As restrictions in parameters, the null hypothesis $H_0 : f(\phi) = 0$ where $\phi = vec(\Phi)$ is tested by a Wald statistic defined as:

$$W = f(\hat{\phi})' \left[F(\hat{\phi}) \left\{ \hat{\Sigma}_\varepsilon \otimes (X'QX)^{-1} \right\} F(\hat{\phi})' \right]^{-1} f(\hat{\phi}) \tag{4}$$

where $F(\phi) = \partial f(\phi)/\partial\phi', \hat{\Sigma}_\varepsilon = T^{-1}\hat{E}'\hat{E},\ Q = Q_\tau - Q_\tau Z(Z'Q_\tau Z)^{-1}Z'Q_\tau$ and $Q_\tau = I_T - \Lambda(\Lambda'\Lambda)^{-1}\Lambda'$ where I_T is a $T\times T$ identity matrix and $\hat{\Lambda}$ is the estimator of $\Lambda = (\tau_1,\ldots,\tau_T)$. Under the null hypothesis, the Wald statistic (4) has an asymptotic chi-square distribution with *m* degrees of freedom that corresponds to the number of restrictions.

The order of cointegration must be known so as to implement this model. A useful statistical test for determining the cointegrating rank *r* is proposed by Johansen (1991) and Johansen and Juselius (1990). The test is based on the MLE and the rank of Π (denoted by *r*) is tested based on its eigenvalues. Two tests viz. the maximum eigenvalue test and the trace test are proposed. In the trace test, the test statistic is:

$$\lambda(r) = -T\sum_{i=r+1}^{m}\ln(1-\lambda_i) \tag{5}$$

where T is the number of useable observations, λ_i is the eigenvalues of $|\lambda S_{kk} - S_{k0}S_{00}^{-1}S_{0k}| = 0$ where $S_{ij} = \frac{1}{n}\sum_{t=1}^{T}R_{it}R'_{jt}$ where *i* and *j* can take the value of *0* or *k*, R_{0t} and R_{kt} are $m\times 1$ vectors whose *t*-th element is the residual obtained when Δy_t and y_{t-1} are regressed on $\Delta y_{t-1},\ldots..,\ \Delta y_{t-k+1}$, respectively. The test statistic (5) tests the null hypothesis of the number of distinct cointegrating vectors as $r = 0$ versus $r > 0$, $r \le 1$ versus $r > 1$, and so on. For example, to test for no cointegrating relationship, *r* is set to zero and the null hypothesis is $H_0 : r = 0$ and the alternative is $H_1 : r > 0$. In the maximum eigenvalue test, the test statistic is:

$$\lambda(r) = -T\ln(1-\lambda_{r+1}) \tag{6}$$

For the maximum eigenvalue test statistic (6) the hypotheses to be tested are $r = 0$ versus $r = 1$, $r \le 1$ versus $r = 2$, and so on. In both tests the testing hypotheses are conducted sequentially until we encounter an insignificant result. Note that these two tests are not independent and we can calculate one test statistic from the other. However, in practice the conclusions reached by these two tests are not always the same.

The optimal lag order must also been known in order to implement this model. The lag order is determined by using both the likelihood ratio (LR) test and information criteria in VAR. The optimum number of lags to be used in the VAR models is determined by the likelihood ratio (LR) test statistic:

$$LR = (T-K)\ln(|\Sigma_0|/|\Sigma_A|) \tag{7}$$

where T is the number of observations, K denotes the number of restrictions, Σ denotes the determinant of the covariance matrix of the error term, and subscripts 0 and A denote the restricted and unrestricted VAR, respectively. LR is asymptotically distributed χ^2 with degrees of freedom equal to the number of restrictions. The test statistic in (7) is used to test the null hypothesis of the number of lags being equal to $k - 1$ against the alternative hypotheses that $k = 2, 3, \ldots$ and so on. The test procedure continues until the null hypothesis fails to be rejected, thereby indicating the optimal lag corresponds to the lag of the null hypothesis.

4. Empirical Results

Table I presents the ADF unit root tests (1) for the nine Asian equity indices in price level and price-differenced forms. The first column (A) for each form presents tests carried out for the period 1/1/1988 to 25/7/1997 (prior to the onset of the Asian currency crises). The second column (B) details the tests for the period since this event; that is, 1/8/1997 to 18/2/2000. The final column (C) provides the tests for the entire sample period (1/1/1988 to 18/2/2000). In all instances, the null hypothesis of nonstationarity is tested. Analysis of the price levels series indicates non-stationarity for all markets in the three sample periods except Indonesia, the Philippines and Thailand in the post-crises period.

<TABLE I HERE>

However, all of the ADF test statistics are significant in first differenced form for Period A, indicating stationarity and the suggestion that each index series is integrated of order 1 or I(1). A similar indication is obtained for the longest time-series (Period C). For the time-series since the onset of the Asian currency crisis (Period B) the ADF tests indicate that all series are stationary in first-differenced form with the exception of Indonesia, the Philippines and Thailand which are integrated of order zero. This would indicate that in the post-crisis period, the equity prices became mean (or deterministic time trend) reverting. Put differently, this would suggest that stock prices became more predictable than previously, inferring reduced profit opportunities for international investors in the post-crises period. The finding of non-stationarity in levels and stationarity in differences provides comparable Asian evidence to Elyasiani *et al.* (1998) and Masih and Masih (1999), amongst others.

As discussed, Johansen cointegration and maximum eigenvalue tests are used to obtain the cointegrating rank. Trace and maximum eigenvalue test statistics are detailed in Parts (i) and

(ii) of Table II respectively. As multivariate cointegration tests the results cover all markets simultaneously rather than simple bivariate combinations. They therefore consider the wide range of portfolio diversification options available to non-Asian investors, as well as the scope of financial integration that may not be reflected in pairwise combinations. Also include in Table II are the eigenvalues and normalised cointegrating coefficients in Part (iii).

<TABLE II HERE>

Three sets of trace and maximum eigenvalue tests are included in Table II. These correspond to the three periods under examination; that is, a pre-crisis period (A), the post-crises period (B) and the entire sample period (C). For all three periods, the trace test statistics are greater than the critical values (5% level) for the null hypotheses of $r = 0$ thereby rejecting the null hypothesis. However, the null hypothesis of $r \leq 1$ fails to be rejected in favour of $r > 1$ thereby indicating a cointegrating rank of 1. The trace and maximum eigenvalue tests are in agreement during periods A and B regarding the number of cointegrating vectors, however in period C there is a contradiction in which case the number of cointegrating vectors is decided on the basis of the trace test. In all three time periods the null hypothesis of $r = 0$ is rejected in favour of $r = 1$ (at the 5% level) though the null hypothesis of $r \leq 1$ fails to be rejected in favour of $r = 2$ indicating a cointegrating rank of 1. The primary finding obtained from both sets of Johansen cointegration tests is that a statistical relationship or linkage exists between Asian equity markets in all three time periods; that is, before, after and surrounding the Asian crises.

The causality Wald test statistics and *p*-values based on Toda and Yamamoto's (1995) level VAR procedure are presented in Table III. The model is estimated for the levels, such that a significant Wald test statistic indicates a causal relationship. The first matrix of test statistics in Table III relates to the pre-crisis period 1/1/1988 to 25/7/1997. Among the nine markets, sixteen significant causal links are found (at the 5% level or lower). For example, column 5 shows that the Japanese, Korean, Philippine and Singaporean markets affect the Malaysian market; and the Taiwan market (column 8) is influenced by Korea. Further insights are gained by examining the rows in Table III indicate the effects of a particular market on all markets. It is evident that the Hong Kong market is again one of the most influential markets in the Asian regional area, influencing Indonesia, the Philippines and Singapore. The least influential markets in the pre-crises period include Indonesia, Malaysia, Taiwan and Thailand. There is also an indication that there is feedback at play in pairwise combinations: for

example, the Philippines market Granger-causes Thailand and Thailand Granger-causes the Philippines.

<TABLE III HERE>

The second set of test statistics and *p*-values in Table III relate to the period since the onset of the Asian crises, while the third set relates to the entire sample period (i.e. before and after the onset of the Thai currency crisis). Thailand and Taiwan Granger-cause two other markets in the post-crises period, while Japan, the Philippines and Thailand Granger-cause two other markets over the total sample. These results appear plausible in terms of quantifying the well-known 'contagion' effect in Southeast Asian markets. One important change in the post-crisis period is that the number of causal links has fallen from sixteen to eight. The relative influence of the Hong Kong market has declined substantially in the post-crises period.

One plausible implication of the results in Table III is that there may be no gains from pairwise portfolio diversification between those countries where a significant causal relationship exists. Also since we have a finding of causality these markets must be seen as violating weak-form efficiency since one of the markets can help forecast the other. In all other cases, the absence of Granger causality implies that there are differences between the markets for non-Asian investors to gain by portfolio diversification. However, we should remember that Granger causality only indicates the most significant direct causal relationship. For example, it may be that markets such as Hong Kong influence non-Granger caused markets indirectly through other markets.

All of these results appear sensible in terms of the relative importance of these markets in the Asian region. One of the most interesting findings concerns the change in the most influential markets, as measured by causal links, in the post-crisis period as compared to the pre-crisis period. In the pre-crisis period, Hong Kong, Japan, Korea and Singapore account for nine of the sixteen significant causal relationships. In the post-crisis period these markets account for far fewer significant causal relationships, with markets such as Thailand and Taiwan increasing in relative importance. Once again, this is largely consistent with the notion of 'contagion effects' following the onset of the Asian crises and the greater degree of market interdependence in the post-crisis regional economy.

Overall, these findings are comparable to most other work in this area. In the only other known study of Asian financial integration in the post-crisis period, Baig and Goldfajn (1998, p. 42) likewise concluded:

> The Asian crises suggest that during a period of financial market instability, market participants tend to move together across a range of countries. Shocks originating from one market readily get transmitted to other markets, thus becoming a source of substantial instability.

Nevertheless, while Baig and Goldfajn (1998, p. 42) found evidence of substantial contagion in the foreign debt markets, "…the evidence on stock market contagion is more tentative". The results obtained in this paper complement this work in quantifying the interdependencies among Asian equity markets.

5. Concluding Remarks

This paper investigates price relationships among nine Asian equity markets during the period 1988 to 2000. Three of these markets are regarded as developed (Hong Kong, Japan and Singapore) while the majority are categorised as emerging markets (namely, Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand). Wald test statistics in a level VAR approach are used to measure causality in order to avoid some of the pre-test biases discussed by Toda and Yamamoto (1995). The results indicate, as expected, that the Asian equity markets are highly integrated, both before and after the recent crises. Possible reasons include long-standing trends in trade and investment interaction, the more recent convergence in monetary policies and the almost universal process of microeconomic reform flowing from the crises themselves. However, this interdependency by some measures also appears to be have decreased in the period during and after the Asian crises. This suggests that at least some markets have become more isolated following these macroeconomic shocks.

The findings obtained in this paper have obvious implications, amongst other things, for the purported benefits of international portfolio diversification among the several Asian equity markets. In effect, the strong linkages among the national markets would indicate that the returns from such a strategy have diminished markedly. However, the results also suggest that opportunities for diversification may still exist, especially in some of the smaller markets. In the pre-crisis period most Asian equity markets were relatively isolated from each other or were subject to only a few direct causal links. One of the most interesting findings concerns the change in the most influential markets, as measured by causal links, in the post-crisis period as compared to the pre-crisis period. This is at least one indication of an increasingly interdependent Asian regional market.

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Table I. Augmented Dickey-Fuller (ADF) unit root tests

		Levels series			First differenced series		
		A	B	C	A	B	C
Hong Kong	HON	-2.5795	-1.9312	-2.8746	-6.9105[a]	-2.9437[a]	-7.1262[a]
Indonesia	IND	-2.7211	-3.7192[b]	-2.4410	-6.4757[a]		-7.0875[a]
Japan	JAP	-2.1192	-2.3755	-2.1658	-7.2469[a]	-14.5092[c]	-8.1327[a]
Korea	KOR	-1.8657	-2.6841	-1.7695	-14.0435[c]	-2.4851[a]	-15.8945[c]
Malaysia	MAL	-2.8945	-2.6151	-2.0403	-6.2751[a]	-2.5191[a]	-6.3719[a]
Philippines	PHI	-1.3166	-3.5319[a]	-1.6580	-6.7603[a]		-6.7372[a]
Singapore	SIN	-1.4345	-2.1468	-1.7305	-6.5006[a]	-5.0328[a]	-6.3812[a]
Taiwan	TAI	-2.0913	-1.8606	-2.8309	-6.6831[a]	-5.1834[a]	-7.7779[a]
Thailand	THA	-1.4924	-3.5295[a]	-1.1541	-6.3907[a]		-6.973[a]

Notes: Period A 1/1/1988–25/7/1997, Period B 1/8/1997–18/2/2000, Period C 1/1/1988–18/2/2000. Hypotheses H_0: unit root, H_1: no unit root (stationary). The lag orders in the ADF equations are determined by the significance of the coefficient for the lagged terms. Specification in the ADF equations is determined by the significance of the constant or constant and trend terms, therefore the critical values vary and are not presented. Superscripts indicate significance at: [a] –1% level, [b] – 5% level and [c] – 10% level.

Table II. Cointegration tests, eigenvalues and cointegrating coefficients

			A		B		C	
	H_0	H_1	Statistic	Critical value	Statistic	Critical value	Statistic	Critical value
(i). Trace tests	r = 0	r > 0	215.6179	202.92	124.9132	102.14	204.2625	202.92
	r ≤ 1	r > 1	157.6597	165.58	67.5746	76.07	152.7714	165.58
	r ≤ 2	r > 2	112.1762	131.70	39.7290	53.12	108.3435	131.70
	r ≤ 3	r > 3	77.3764	102.14	24.5222	34.91	74.6145	102.14
	r ≤ 4	r > 4	51.9066	76.07	11.6764	19.96	51.2676	76.07
	r ≤ 5	r > 5	31.3558	53.12	1.7607	9.24	32.2452	53.12
	r ≤ 6	r > 6	17.4207	34.91			18.0952	34.91
	r ≤ 7	r > 7	9.8933	19.96			7.0959	19.96
	r ≤ 8	r = 9	3.7088	9.24			2.4193	9.24
(ii). Maximum eigenvalue tests	H_0	H_1	Statistic	Critical value	Statistic	Critical value	Statistic	Critical value
	r = 0	r = 1	57.9582	57.42	57.3385	40.30	51.4911	57.42
	r ≤ 1	r = 2	45.4835	52.00	27.8457	34.40	44.4278	52.00
	r ≤ 2	r = 3	34.7998	46.45	15.2067	28.14	33.7290	46.45
	r ≤ 3	r = 4	25.4698	40.30	12.8458	22.00	23.3469	40.30
	r ≤ 4	r = 5	20.5507	34.40	9.9157	15.67	19.0224	34.40
	r ≤ 5	r = 6	13.9351	28.14	1.7607	9.24	14.1500	28.14
	r ≤ 6	r = 7	7.5274	22.00			10.9993	22.00
	r ≤ 7	r = 8	6.1845	15.67			4.6766	15.67
	r ≤ 8	r = 9	3.7088	9.24			2.4193	9.24
(iii). Eigenvalues and cointegrating coefficients			Eigenvalues			Cointegrating coefficients		
			A	B	C	A	B	C
			0.1103	0.3481	0.0785	1.0000	1.0000	1.0000
			0.0876	0.1876	0.0681	0.0686		0.1893
			0.0678	0.1073	0.0521	-1.8771	-20.5570	-1.0554
			0.0501	0.0914	0.0364	54.0488	-28.9126	34.6778
			0.0406	0.0713	0.0297	4.9251	789.3686	-3.2381
			0.0277	0.0131	0.0222	5.4407		6.1203
			0.0151		0.0173	-4.5489	-4.0370	-3.4257
			0.0124		0.0074	-7.6818	-594.5626	-5.7734
			0.0075		0.0038	-2.7382		-1.9391

Notes: Period A 1/1/1988–25/7/1997, Period B 1/8/1997–18/2/2000, Period C 1/1/1988–18/2/2000.Critical values are at the 5% level. The optimal lag order of each VAR model was selected using LR tests for the significance of the coefficient for maximum lags. In each cointegrating equation, the intercept (no trend) is included, which is selected by AIC for the three samples. Cointegrating coefficients are ordered according to the order of markets in Table I and the vector is normalised with the element of HON equal to one.

Table III. Causality tests by level-VAR for nine Asian markets

	Market	HON	IND	JAP	KOR	MAL	PHI	SIN	TAI	THA	Causes
Period A: 1/1/1988–25/7/1997	HON	-	14.3970	3.0023	3.9930	5.1812	14.3545	12.3643	1.0999	6.1314	3
			(0.0061)	(0.5574)	(0.4070)	(0.2692)	(0.0062)	(0.0148)	(0.8943)	(0.1895)	
	IND	2.7168	-	10.5349	3.6154	6.9232	9.4687	2.1980	1.3944	1.3654	1
		(0.6063)		(0.0323)	(0.4605)	(0.1400)	(0.0504)	(0.6994)	(0.8452)	(0.8502)	
	JAP	4.3787	7.2267	-	13.2819	19.3517	1.5929	0.5445	2.0930	1.7548	2
		(0.3572)	(0.1244)		(0.0100)	(0.0007)	(0.8101)	(0.9690)	(0.7187)	(0.7807)	
	KOR	8.3244	8.5034	6.8482	-	16.4176	1.3213	3.3389	14.1394	0.0930	2
		(0.0804)	(0.0748)	(0.1441)		(0.0025)	(0.8577)	(0.5028)	(0.0069)	(0.9990)	
	MAL	9.9792	2.0086	2.3388	7.3209	-	5.0852	2.2590	3.4256	5.2433	1
		(0.0408)	(0.7342)	(0.6737)	(0.1199)		(0.2787)	(0.6882)	(0.4893)	(0.2632)	
	PHI	3.6485	17.0492	5.3726	1.4477	15.5844	-	5.4539	9.1687	14.8761	3
		(0.4557)	(0.0019)	(0.2512)	(0.8359)	(0.0036)		(0.2438)	(0.0570)	(0.0050)	
	SIN	7.5175	3.8064	5.1526	5.4409	10.7631	9.6265	-	6.0244	1.7370	2
		(0.1109)	(0.4328)	(0.2720)	(0.2450)	(0.0294)	(0.0472)		(0.1973)	(0.7840)	
	TAI	1.9892	13.1694	3.0745	2.2844	1.9198	3.5518	0.7809	-	5.6920	1
		(0.7377)	(0.0105)	(0.5454)	(0.6836)	(0.7505)	(0.4700)	(0.9410)		(0.2234)	
	THA	3.6648	6.3152	3.5675	5.0978	5.0529	15.6311	4.1764	8.1404	-	1
		(0.4533)	(0.1768)	(0.4677)	(0.2774)	(0.2819)	(0.0036)	(0.3827)	(0.0866)		
	Caused	1	3	1	1	4	3	1	1	1	16
Period B: 1/8/1997–18/2/2000	HON	-	1.2468	6.4495	1.0399	1.9184	2.0822	0.9250	2.8407	1.8693	1
		-	(0.5361)	(0.0398)	(0.5945)	(0.3832)	(0.3531)	(0.6297)	(0.2416)	(0.3927)	
	IND	0.7817	-	1.1781	0.3325	0.2331	1.6790	1.6077	0.5214	0.4521	0
		(0.6765)	-	(0.5548)	(0.8468)	(0.8900)	(0.4319)	(0.4476)	(0.7705)	(0.7977)	
	JAP	1.1257	1.1913	-	2.9832	12.3715	2.1543	4.7105	5.8045	0.4707	1
		(0.5696)	(0.5512)	-	(0.2250)	(0.0021)	(0.3406)	(0.0949)	(0.0549)	(0.7903)	
	KOR	3.3096	0.8453	5.9986	-	0.1777	0.4589	0.3746	3.1038	0.8311	1
		(0.1911)	(0.6553)	(0.0498)	-	(0.9150)	(0.7950)	(0.8292)	(0.2118)	(0.6600)	
	MAL	1.5523	1.8619	0.3791	5.7251	-	3.2571	4.4551	0.8646	0.9901	0
		(0.4602)	(0.3942)	(0.8273)	(0.0571)	-	(0.1962)	(0.1078)	(0.6490)	(0.6096)	
	PHI	1.0644	6.8430	0.1473	2.5714	3.5847	-	0.4134	1.2061	0.6285	1
		(0.5873)	(0.0327)	(0.9290)	(0.2765)	(0.1666)	-	(0.8133)	(0.5471)	(0.7303)	
	SIN	0.7768	2.1585	5.4871	0.5823	1.6209	0.1955	-	1.8172	2.4939	0
		(0.6781)	(0.3398)	(0.0643)	(0.7474)	(0.4447)	(0.9069)	-	(0.4031)	(0.2874)	
	TAI	5.5879	0.5925	0.8247	1.4570	7.0876	0.1311	6.2366	-	0.1837	2
		(0.0612)	(0.7436)	(0.6621)	(0.4826)	(0.0289)	(0.9365)	(0.0442)	-	(0.9122)	
	THA	4.8647	3.1396	0.8214	3.0935	15.2914	14.3783	4.0067	4.2633	-	2
		(0.0878)	(0.2081)	(0.6632)	(0.2129)	(0.0005)	(0.0008)	(0.1349)	(0.1186)	-	
	Caused	0	1	2	0	3	1	1	0	0	8
Period C: 1/1/1988–18/2/2000	HON	-	6.5831	3.9318	2.0867	5.6829	7.9897	9.1863	0.8009	4.3671	0
			(0.1596)	(0.4153)	(0.7198)	(0.2241)	(0.0920)	(0.0566)	(0.9383)	(0.3586)	
	IND	2.3004	-	10.2414	2.7649	3.7793	5.2810	4.3042	1.7175	0.4237	1
		(0.6807)		(0.0366)	(0.5979)	(0.4367)	(0.2597)	(0.3664)	(0.7875)	(0.9805)	
	JAP	0.5010	6.6271	-	12.5698	11.8076	0.4041	2.4780	3.4448	2.4000	2
		(0.9734)	(0.1570)		(0.0136)	(0.0188)	(0.9821)	(0.6486)	(0.4863)	(0.6626)	
	KOR	3.5809	6.0254	16.0486	-	6.4352	0.8591	2.2303	8.2883	0.4976	1
		(0.4657)	(0.1973)	(0.0030)		(0.1689)	(0.9304)	(0.6935)	(0.0816)	(0.9737)	
	MAL	6.6894	4.7541	3.0162	3.7636	-	2.6949	5.0923	1.5469	4.2784	0
		(0.1532)	(0.3135)	(0.5551)	(0.4389)		(0.6101)	(0.2780)	(0.8183)	(0.3696)	
	PHI	2.3370	21.1729	7.4285	3.5037	8.2203	-	4.3817	8.7711	14.7418	2
		(0.6740)	(0.0003)	(0.1149)	(0.4773)	(0.0838)		(0.3568)	(0.0671)	(0.0053)	
	SIN	8.0381	7.0912	3.9880	0.5187	10.7111	5.4290	-	3.0657	3.2567	1
		(0.0902)	(0.1311)	(0.4076)	(0.9717)	(0.0300)	(0.2460)		(0.5469)	(0.5158)	
	TAI	3.0525	7.9758	5.8148	2.8938	6.2381	2.5252	6.3955	-	6.7199	0
		(0.5491)	(0.0925)	(0.2134)	(0.5758)	(0.1821)	(0.6401)	(0.1715)		(0.1515)	
	THA	6.3025	9.2437	5.0916	4.7683	6.1657	13.1703	6.6224	13.8171	-	2
		(0.1777)	(0.0553)	(0.2780)	(0.3119)	(0.1871)	(0.0105)	(0.1572)	(0.0079)		
	Caused	0	1	2	1	2	1	0	1	1	9

Notes: Unbracketed figures in table are Wald statistics for Granger non-causality tests. Figures in brackets are *p*-values. The level VARs are estimated with lag order of $p = k + d_{max}$; k is selected by the LR test in (7) and d_{max} is set to one. Tests indicate Granger causality by row to column and Granger caused by column to row. For example, in the period 1/1/1988 – 25/7/97 Hong Kong (row) Granger causes three markets (Indonesia, Philippines and Singapore) and is Granger-caused by Malaysia.