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DETECTING SHIFT AND PURE CONTAGION IN EAST ASIAN EQUITY MARKETS: A UNIFIED APPROACH

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Abstract. We test for contagion between pairs of East Asian equity markets over the period 1990–2007. We develop an econometric methodology that allows us to test for both 'shift' and 'pure' contagion within a unified framework. Using both Hong Kong and Thailand as potential shock sources, we find strong evidence of both types of contagion. Therefore, during episodes of high volatility, equity returns are influenced by changes in the transmission of common shocks and additionally by the diffusion of idiosyncratic shocks through linkages that do not exist during normal times.

1. INTRODUCTION

The equity markets of East Asia have suffered much turbulence over the past two decades. Many episodes have been extreme and pervasive, as in the 1997–1998 crisis period, while others have been less widespread but still represent major downturns in equity returns. Frequently, these adverse shocks appear to exert excessive influence on neighbouring markets, given the existing levels of interdependence. This has led many observers to conclude that these simultaneous cross-country market depressions have been due to financial market contagion. However, in more recent times, the issue of the existence and prevalence of contagion has become contentious, with many contributors to the debate questioning whether contagion actually occurred during the crisis (e.g. Forbes and Rigobon, 2002).

Our aim is to test whether contagion has been a feature of East Asian equity markets over the past two decades. We test for two distinct channels of contagion within a unified framework. This facilitates the comparison of competing channels through which market volatility may be transmitted and, therefore, extends our understanding of the phenomenon of contagion. The extant literature distinguishes between 'shift' and 'pure' contagion. Shift contagion occurs when the interdependencies between pairs of markets increase during a crisis. The normal level of interdependence might be due to pre-existing market linkages, such as goods trade, financial flows or exposure to common shocks. The presence of shift contagion between markets implies that this existing or 'normal' relationship between market pairs becomes unstable during an episode of high volatility. In contrast, pure contagion reflects excess contagion suffered

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during a crisis that is not explained by market fundamentals or common shocks. Such contagion is a result of idiosyncratic shocks being transmitted to other countries through channels that could not have been identified before the event.[1] It is important to correctly identify the type of contagion that is present in markets before prescribing policy to deal with it. For example, if markets decline due to the effects of pure contagion, then policies such as capital controls aimed at breaking market linkages are unlikely to be successful. A better strategy would be to introduce policies aimed at reducing country-specific risks. We extend the methodology of Gravelle *et al*. (2006) to facilitate tests for both types of contagion within a bivariate regime-switching model in which both common and idiosyncratic shocks move between low-volatility and high-volatility states.

The question of whether contagion was present in East Asian equity markets during the 1997–1998 crisis period has already attracted much attention, but there is little consensus in the results. For example, Forbes and Rigobon (2002) reject the hypothesis that correlation coefficients between markets increased significantly during the crisis period, leading to the conclusion that there was 'no contagion, only interdependence'. Rigobon (2003b) fails to find evidence of a structural break in the propagation of shocks. These papers find no evidence for either shift or pure contagion. In contrast, Caporale *et al*. (2005), Bekaert *et al*. (2005) and Chiang *et al*. (2007) all find evidence of contagion between many pairs of Asian markets.

We re-examine the issue using a framework capable of detecting both types of contagion. We once again focus on equity markets within the region as comparing results from Dungey *et al*. (2003, 2004) suggests that the impact of contagion on return variation is more important for equity than for currency markets. We do not focus exclusively on the crisis of 1997–1998; rather, we analyse whether or not contagion has been a feature of high-volatility regimes over the past two decades. Ito and Hashimoto (2005) document many episodes of turbulence over this period for Asian equity markets. Consequently, our analysis does not suffer from the common problem of having very small crisis samples, which often leads to low power in the tests being used. Even with weekly data, we have sufficient observations in both low-volatility and high-volatility regimes to classify them accurately.

Our results show that contagion, both shift and pure, is a feature of East Asian equity markets over the sample. Using both Hong Kong and Thailand as potential shock sources, there is strong statistical evidence of changes in the transmission of common shocks between countries during periods of market turbulence, and also that the idiosyncratic shock of the source market impacts on the return generating process of its neighbours during high-volatility regimes. Contagion affects both developed and developing markets.

The present paper is organized as follows. Section 2 presents our model. Section 3 describes the data and reports our empirical findings using Hong Kong as the potential source of contagious effects. Section 4 presents a robustness

[1] For an overview of the various definitions of contagion, see Pericoli and Sbracia (2003).

check, replacing Hong Kong with Thailand as the source country. Section 5 contains our concluding remarks.

2. ECONOMETRIC METHODOLOGY

We extend the methodology of Gravelle *et al.* (2006) to test for both shift and pure contagion within a unified framework. Their model tests for shift contagion. We extend this to capture the potential effects of pure contagion, whereby country-specific shocks are transmitted to another market during episodes of high volatility. We use a bivariate factor model, which is attractive because we avoid debate regarding what the 'fundamentals' should be (see Karolyi, 2003). The model can be summarized as follows. Let r_{it} represent stock market returns from countries i. Returns can be decomposed into an expected, μ_i, and an unexpected component, u_{it}, reflecting the arrival of news to financial markets; that is,

$$r_{it} = \mu_i + u_{it},\ E(u_{it}) = 0,\ i = 1, 2 \text{ and } E(u_{1t}, u_{2t}) \neq 0. \tag{1}$$

The forecast errors are allowed to be contemporaneously correlated, implying that common structural shocks might be driving both returns. Therefore, we decompose the forecast errors into two structural shocks, one idiosyncratic and one common. Let z_{ct} and z_{it}, $i = 1,2$ denote the common and idiosyncratic shocks, respectively, and let their impacts on asset returns be σ_{cit} and σ_{it}, $i = 1,2$. Then, the forecast errors are written as:

$$u_{it} = \sigma_{cit} z_{ct} + \sigma_{it} z_{it},\ i = 1, 2. \tag{2}$$

Furthermore, the shock variances are normalized to unity, which means the impact coefficients may be interpreted as their standard deviations.

Following Gravelle *et al.* (2006), both the common and idiosyncratic shocks switch between two states: high volatility and low volatility.[2] The structural impact coefficients is given by:

$$\begin{aligned} \sigma_{it} &= \sigma_i(1 - S_{it}) + \sigma_i^* S_{it},\ i = 1, 2 \\ \sigma_{cit} &= \sigma_{ci}(1 - S_{ct}) + \sigma_{ci}^* S_{ct},\ i = 1, 2, \end{aligned} \tag{3}$$

where $S_{it} = (0,1)$, $I = 1,2c$ are state variables that take the value of zero in normal and unity in turbulent times. Variables with an asterisk belong to the high-volatility regime. Following the regime-switching literature, we complete the model by specifying the regime paths to be Markov switching and endogenously determined. Specifically, the conditional probabilities of remaining in the same state (i.e. not changing regime) are defined as follows:

[2] The heteroskedasticity inherent in the structural shocks ensures the identification of the system (see also Rigobon, 2003a). As argued by Gravelle *et al.* (2006), regime switching in the common shock alone is sufficient for this.

$$\begin{aligned} \Pr[S_{i,t} = 0 | S_{i,t-1} = 0] &= q_i, i = 1, 2, c \\ \Pr[S_{i,t} = 1 | S_{i,t-1} = 1] &= p_i, i = 1, 2, c \end{aligned} \tag{4}$$

Furthermore, we relax the assumption of constant expected returns in equation 1. These are allowed to be time-varying and depend on the state of the common shock. Hence, part of the stock market return represents a risk premium that changes with the level of volatility.[3] In particular, expected returns are modelled as follows:

$$\mu_{it} = \mu_i(1 - S_{ct}) + \mu_i^* S_{ct}, i = 1, 2. \tag{5}$$

Because idiosyncratic shocks are uncorrelated with common shocks and represent diversifiable risk, expected returns are not allowed to vary with the volatility state of these shocks.

Finally, in an extension to the Gravelle *et al.* (2006) model, we allow the idiosyncratic shock of the source country to potentially influence the other country return over and above that captured by the common shock during episodes of high volatility. This is 'pure contagion' and it is captured by augmenting the return equation of country 2 with the idiosyncratic shock of country 1 during the crisis period (see Dungey *et al.*, 2005 for a similar approach).

Although the entire model is estimated in a single step, it implies different features of the model in each of the eight possible regimes. For example, if we take the extreme states, returns during tranquil periods (all shocks in the low-volatility states) are given as follows:

$$\begin{aligned} r_{1t} &= \mu_1 + \sigma_{c1} z_{ct} + \sigma_1 z_{1t} \\ r_{2t} &= \mu_2 + \sigma_{c2} z_{ct} + \sigma_2 z_{2t}. \end{aligned} \tag{6}$$

The idiosyncratic shocks are assumed to be independent, so return comovements are solely determined by the common shock. Thus, the variance–covariance matrix of returns is:

$$\Sigma_1 = \begin{bmatrix} \sigma_1^2 + \sigma_{c1}^2 & \sigma_{c1}\sigma_{c2} \\ \sigma_{c1}\sigma_{c2} & \sigma_2^2 + \sigma_{c2}^2 \end{bmatrix}.$$

In contrast, during crisis periods (all shocks in high-volatility states), the corresponding return generating process during periods of turbulence is given by:

$$\begin{aligned} r_{1t} &= \mu_1^* + \sigma_{c1}^* z_{ct} + \sigma_1^* z_{1t} \\ r_{2t} &= \mu_2^* + \sigma_{c2}^* z_{ct} + \sigma_2^* z_{2t} + \delta\sigma_1^* z_{1t}. \end{aligned} \tag{7}$$

The variance covariance matrix of returns is:

[3] Gravelle *et al.* (2006) also relax this assumption when modelling the interdependence of bond returns.

$$\Sigma_8 = \begin{bmatrix} \sigma_1^{*2} + \sigma_{c1}^{*2} & \sigma_{c1}^{*}\sigma_{c2}^{*} + \delta\sigma_1^{*2} \\ \sigma_{c1}^{*}\sigma_{c2}^{*} + \delta\sigma_1^{*2} & \sigma_2^{*2} + \sigma_{c2}^{*2} + \delta^2\sigma_1^{*2} \end{bmatrix}.$$

The additional term in the return generating process of country 2 detects and measures pure contagion during episodes of high volatility in the idiosyncratic shock of country 1.

An extra assumption of normality of the structural shocks enables us to estimate the full model given by equations 1–7 via maximum likelihood along the lines of the methodology for Markov-switching models (see Hamilton, 1989).

2.1. *Testing for shift contagion*

The rationale behind testing for shift contagion lies on the argument that in its absence, a large unexpected shock that affects both countries does not change their interdependence. In other words, the observed increase in the variance and correlation of returns during crisis periods is a result of increased impulses stemming from the common shock and not of changes in its propagation mechanism. To empirically test for contagion, we perform a likelihood ratio test with the null and alternative hypotheses specified as follows:

$$H_0: \frac{\sigma_{c1}^{*}}{\sigma_{c2}^{*}} = \frac{\sigma_{c1}}{\sigma_{c2}} \text{ versus } H_1: \frac{\sigma_{c1}^{*}}{\sigma_{c2}^{*}} \neq \frac{\sigma_{c1}}{\sigma_{c2}} \quad (8)$$

The null hypothesis postulates that in the absence of shift contagion, the impact coefficients in both calm and crisis periods should move proportionately. This likelihood ratio test is commonly used for testing restrictions among nested models and follows a χ^2-distribution with one degree of freedom corresponding to the restriction of equality of the ratio of coefficients between the two regimes.

2.2. *Testing for pure contagion*

The final term of equation 7 in the return generating process of country 2 measures the effect of pure contagion. This only exerts an influence when the idiosyncratic shock of the source country is in the high-volatility regime. Now, our test for pure contagion is a simple *t*-test on the coefficient δ, where under the null $\delta = 0$ and there is no pure contagion.

3. EMPIRICAL RESULTS

3.1. *Data*

Our data set consists of weekly closing stock market indices from nine East Asian countries: Japan, Korea, Indonesia, Malaysia, the Philippines, Singapore, Taiwan, Thailand and Hong Kong. All indices are value-weighted, expressed in

US dollars and were retrieved from Datastream International.[4] Our sample spans a period of over 17 years from 4 April 1990 to 13 September 2007, yielding a total of 910 observations. Conducting the analysis with US dollar denominated returns allows us to take the perspective of a global investor that is concerned with possible contagion effects within the region. We prefer weekly returns to higher frequency data, in order to account for any non-synchronous trading in the countries under examination.[5] For each index, we compute the return between two consecutive trading periods, $t - 1$ and t, as $ln(p_t) - ln(p_{t-1})$, where p_t denotes the closing index on week t.

Table 1 presents descriptive statistics for the returns. Mean returns vary considerably across countries, ranging from 0.063% (Japan) to 0.292% (Hong Kong). Korea and Indonesia were the most volatile over this period, while the Singaporean market appears to be the least volatile. The Jarque–Bera test rejects normality for all markets, which is usual in the presence of both skewness and excess kurtosis. Return distributions are negatively skewed for half the countries, with Singapore being the most skewed. The most positively skewed returns are those for Indonesia. Indonesian and Malaysian returns exhibit considerable leptokurtosis. The high level of kurtosis in all markets is consistent with the presence of large shocks (of either sign) being a characteristic of the distribution of equity returns. Combined with the rejection of normality, this suggests that returns may be best modelled as a mixture of distributions, which is consistent with the existence of a number of volatility regimes.

3.2. *Estimates*

To simultaneously test for pure and shift contagion, it is necessary to select a 'ground-zero country' whose idiosyncratic risk might potentially be transmitted to other countries during periods of high volatility.[6] Initially we focus on Hong Kong, as it is often chosen as the shock source for studies of the 1997–1998 crisis (see, among others, Forbes and Rigobon, 2002; Chiang *et al.*, 2007). Furthermore, Hong Kong is an interesting market as it was subject to a great deal of political and financial change over our sample period.[7] We estimate the model for all pairs involving Hong Kong and perform diagnostic tests to ensure that our model adequately captures the returns behaviour before proceeding to formally test for contagion.

Table 2 reports results from a number of diagnostic tests. We report the Lagrange Multiplier test for serial correlation in the standardized residuals. For

[4] The Datastream codes have the following structure: TOTMKXX, where XX represents the country code; that is, JP (Japan), KO (Korea), ID (Indonesia), MY (Malaysia), PH (Philippines), SG (Singapore), TA (Taiwan), TH (Thailand) and HK (Hong Kong).

[5] Forbes and Rigobon (2002) use a 2-day moving-average return but this introduces serial correlation into the return-generating process. Because we focus on episodes of high volatility over a longer time period and are, consequently, less restricted by sample size, we work with weekly returns.

[6] The test for shift contagion does not require us to specify the source of the shock (see Gravelle *et al.*, 2006).

[7] Billio and Pelizzon (2003) warn about the sensitivity of choice of source country, so for robustness, we repeat the analysis using Thailand as the base market in Section 4.

Table 1. Summary descriptive statistics

	Japan	Korea	Indonesia	Malaysia	Philippines	Singapore	Taiwan	Thailand	Hong Kong
Mean	0.063	0.248	0.257	0.185	0.169	0.165	0.094	0.189	0.292
Median	0.000	0.176	0.071	0.275	0.213	0.161	0.145	0.099	0.441
Maximum	12.50	30.73	70.92	36.24	17.34	16.96	29.42	26.47	15.12
Minimum	−12.14	−44.13	−41.52	−32.28	−25.46	−20.34	−21.98	−24.11	−18.25
Standard deviation	3.139	5.129	5.244	4.057	3.965	2.887	4.710	4.999	3.337
Skewness	0.375	−0.053	2.410	0.344	−0.218	−0.285	0.507	0.298	−0.247
Kurtosis	4.526	13.957	44.614	22.657	7.316	8.553	8.011	6.684	5.922
Jarque–Bera	109.5	4547.8	66469.7	14652.6	712.8	1180.4	990.1	527.4	332.5
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 2. Diagnostic tests on standardized residuals and model specification

Country	*LM(1)*	*LM(4)*	*ARCH(1)*	*ARCH(4)*	*NORMALITY*	RCM_1	RCM_2	RCM_3
Japan	0.853	4.419	0.294	3.881	0.056	54.58	60.49	23.38
	2.823	6.184	3.677	7.024	0.078			
Korea	0.319	3.914	0.145	5.008	0.029	24.47	3.47	30.06
	0.036	7.839	7.220*	10.526	0.042			
Indonesia	0.734	4.084	0.001	8.132	0.063	94.51	20.26	32.64
	0.406	15.467*	54.107*	7.054	0.191*			
Malaysia	0.173	2.903	0.494	8.112	0.061	33.10	11.67	27.03
	5.936	11.880	2.462	24.203*	0.041			
Philippines	0.239	1.329	0.026	0.627	0.124	25.01	28.97	39.58
	3.637	12.794	0.046	2.019	0.029			
Singapore	0.155	5.741	0.099	5.561	0.038	32.71	53.13	22.89
	0.809	11.784	15.259*	82.430*	0.144			
Taiwan	0.824	3.961	0.224	8.367	0.046	34.38	13.97	31.17
	0.000	8.378	0.602	9.256	0.085			
Thailand	0.158	2.287	0.540	1.476	0.025	11.38	55.77	25.04
	0.515	11.587	25.872*	45.360*	0.067			

Notes: LM(k) is the Breusch–Godfrey Lagrange Multiplier test for no serial correlation up to lag k. ARCH(k) is the Lagrange Multiplier test for no autoregressive conditional heteroskedasticity effects of order k, normality is the Cramer-von-Mises test for the null of Normality. RCMi is the regime classification measure, where $i = 1, 2, 3$ for the idiosyncratic shock of the first, second and the common shock, respectively. * denotes significance at the 1% level. LM(k) and ARCH(k) have a $x^2(k)$ distribution under the null hypothesis. The Cramer-von-Mises test has a non-standard distribution and the cut-off value for RCM is 50.

the majority of country pairs, we cannot reject the null of no serial correlation at both one and four lags. Likewise, we find little evidence of autoregressive conditional heteroskedasticity effects. To test for normality, we use the Cramer-von Mises test. Our results suggest that all the country residuals are normally distributed.[8] Hence, we argue that our regime-switching model adequately captures the distribution of asset returns.

The ability of our model to define regimes is assessed using the regime classification measure (RCM) of Ang and Bekaert (2002). According to this statistic, a good regime-switching model should classify regimes accurately; that is, the smoothed regime probabilities, p_t, are close to either one or zero. For a model with two regimes, the RCM is given by:

$$RCM = 400 * \frac{1}{T}\sum_{t=1}^{T} p_t(1-p_t),$$

where the constant serves to normalize the statistic to be between 0 and 100. A lower RCM statistic implies better model performance. A perfect model will have an RCM close to zero, whereas poorly-specified models produce statistics close to 100. Our regimes are generally well-defined. In particular, those for the

[8] We also employed the Kolmogorov-Smirnov, Lilliefors, Anderson-Darling and Watson empirical distribution tests, which yielded similar results. Alternatively, tests for skewness and excess kurtosis or the joint Jarque–Bera test point to normality of the standardised residuals. These results are available upon request.

Table 3. Estimates of mean returns across regimes

Country	μ_1	μ_2	μ^*_1	μ^*_2	*LR*	*p-val*
Japan	0.410 (0.109)	0.080 (0.167)	0.161 (0.207)	–0.002 (0.020)	1.010	0.603
Korea	0.481 (0.102)	0.246 (0.169)	0.097 (0.143)	0.180 (0.204)	2.939	0.230
Indonesia	0.469 (0.102)	0.646 (0.153)	–0.003 (0.025)	–0.673 (0.236)	4.857*	0.088
Malaysia	0.412 (0.105)	0.329 (0.092)	0.034 (0.052)	–0.106 (0.179)	5.597*	0.061
Philippines	0.563 (0.108)	0.662 (0.144)	–0.311 (0.441)	–1.035 (0.315)	4.595	0.101
Singapore	0.509 (0.104)	0.479 (0.102)	0.175 (0.048)	0.115 (0.096)	4.756*	0.093
Taiwan	0.466 (0.111)	0.293 (0.177)	0.072 (0.135)	–0.205 (0.344)	14.573***	0.001
Thailand	0.447 (0.101)	0.301 (0.136)	0.163 (0.152)	0.284 (0.122)	1.628	0.443

Notes: Standard errors in parentheses next to coefficients. Likelihood ratio statistic is for the null of equality of mean returns across the regimes. The test statistic has a $x^2(2)$-distribution under the null hypothesis. *** denotes significance at the 1% level, ** denotes significance at the 5% level and * denotes significance at the 10% level.

common shock are accurately distinguished, with statistics all less than 40. Likewise, the majority (69%) of idiosyncratic shocks have RCM statistics below 40, but there are some notable exceptions – in particular, the Hong Kong/ Indonesia pair.

Table 3 reports the estimated parameters for expected returns, with columns 2 and 3 (4 and 5) referring to calm (turbulent) periods. Country 1 always refers to Hong Kong.

Table 3 presents a number of striking features. First, the low volatility regime is characterized by positive mean returns in all cases, and the majority are statistically significant at conventional levels. High volatility regimes are associated with lower returns. In some cases, they become negative, although admittedly many of these are not statistically different from zero. Second, we compute a likelihood ratio statistic to test the hypothesis of equal means between regimes. However, the results are not conclusive and, hence, we conduct the analysis with and without the restriction of equal expected returns across regimes. The results do not differ qualitatively, so we report results in the subsequent analysis where expected returns are allowed to be regime-dependent.[9]

3.3. *Conditional correlations*

Given that much of the early literature on contagion focuses on changes in the pair-wise comovement of assets, we analyse the time-varying conditional correlations produced by our model. These are depicted in Figure 1 for each pair of markets.[10]

It is clear from visual inspection that the correlation coefficients exhibit considerable time variation. For many markets (e.g. Korea), there is a large increase

[9] Guidolin and Timmermann (2005) for UK assets and Flavin and Panopoulou (2009) for G-7 equity markets reject the hypothesis of equal means across regimes.

[10] To economize on space, our figures contain a set of representative countries. The entire set may be viewed in the associated working paper at http://economics.nuim.ie/research/workingpapers/ documents/N1890208.pdf

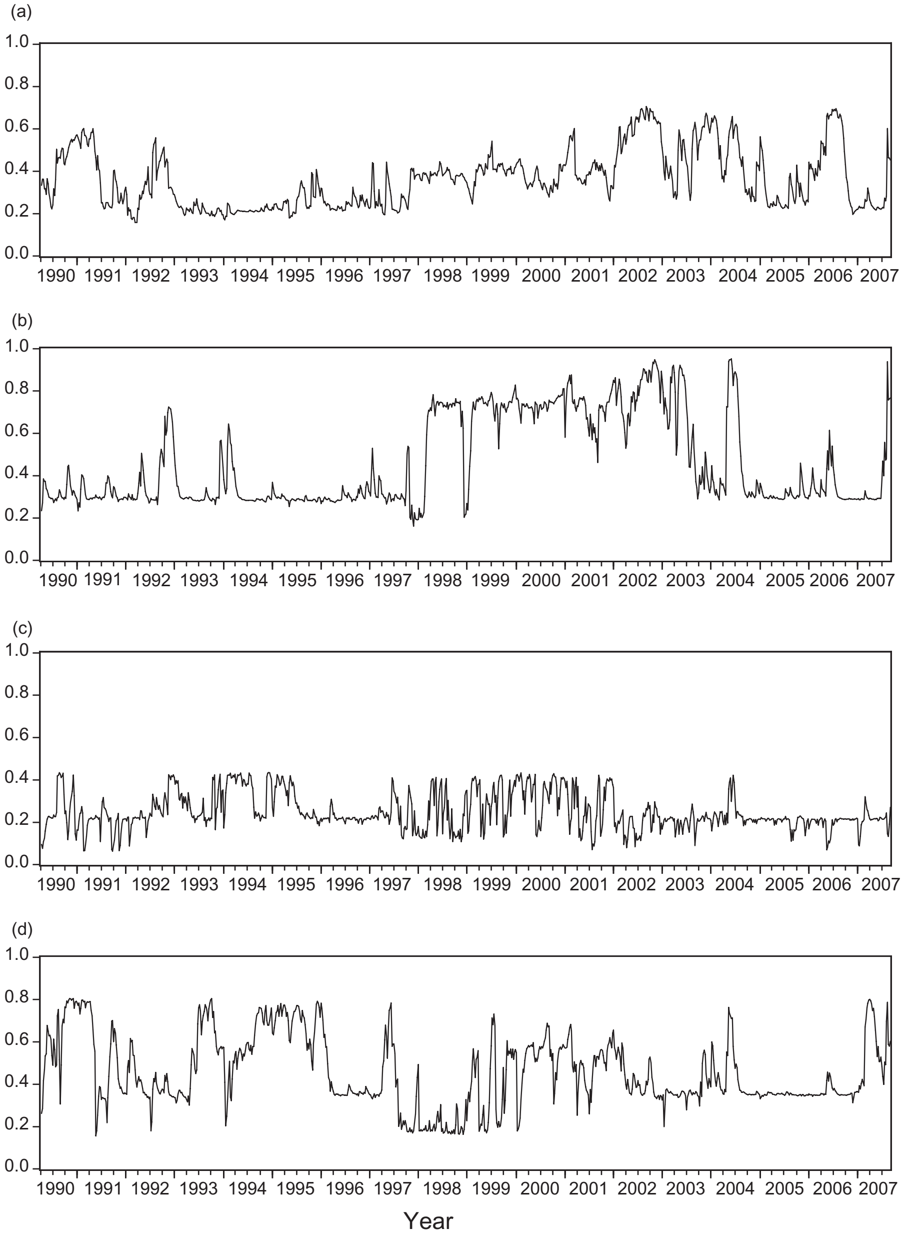

Figure 1. Conditional correlations: (a) Japan, (b) Korea, (c) Indonesia and (d) Malaysia

in the coefficient around the Asian crisis, but high correlations are by no means exclusive to this period. In contrast, the correlation of Hong Kong/Malaysia declines during the crisis. Billio and Pelizzon (2003) refer to a possible 'loss of interdependence', which may be captured here. We also observe a pattern similar to that documented by Chiang *et al.* (2007), whereby there is a gradual increase in the correlation in the first phase of the crisis and then a sustained second phase, which they surmise to be driven by herding behaviour in the market. However, it is clear that one cannot detect contagion without performing formal statistical tests for its presence.

3.4. *Tests for shift contagion*

Following Gravelle *et al.* (2006), our test for shift contagion focuses on changes in the transmission mechanism of the common shock between low-volatility and high-volatility regimes for pairs of markets. Therefore, we begin with an in-depth analysis of the common shock.

Figure 2 presents the filtered probabilities of the common shock being in the high-volatility regime. We observe a similar pattern across most pairs, with the common shock often in the turbulent regime, especially around the Asian crisis of 1997–1998. In many cases, the turbulent regime persists for much longer and continues into the next decade. The early 1990s are also characterized by high-volatility common shocks, which is consistent with events documented in Ito and Hashimoto (2005).

Table 4 presents more detailed results for the common shock. First, the 'frequency' statistic tells us the proportion of time that the common shock is in the high volatility state.[11] It varies from a high of 58% (Singapore/Hong Kong) to a low of 30% (Philippines/Hong Kong). It is clear that all pairs are prone to high-volatility common shocks. Averaging across all, we see that the common shock is in the turbulent regime approximately 45% of the time. Therefore, we have ample observations in this regime with which to precisely estimate parameters.

'Duration' gives the length of time (in years) for which a common shock persists. It ranges from 6 months (Philippines/Hong Kong) to over 3.5 years (Singapore/Hong Kong). The average duration across pairs is almost 2 years, with all pairs being vulnerable to persistent, high-volatility common shocks over the sample. This persistence is largely driven by regional and global market conditions from 1997–2001. All markets suffer high-volatility common shocks arising from first the Asian crisis, which is regional and subsequent common turbulence due to global events such as the Russian crisis, the near-collapse of the LTCM hedge fund and the terrorist threat following 9/11. Therefore, it is important to recognize that to test for shift contagion, common shocks do not have to be exclusively sourced in the countries sampled.

[11] Frequency is calculated as $(1 - Q)/(2 - P - Q)$, where P and Q are as defined in equation 4 and Duration $= 1/(1 - P)$.

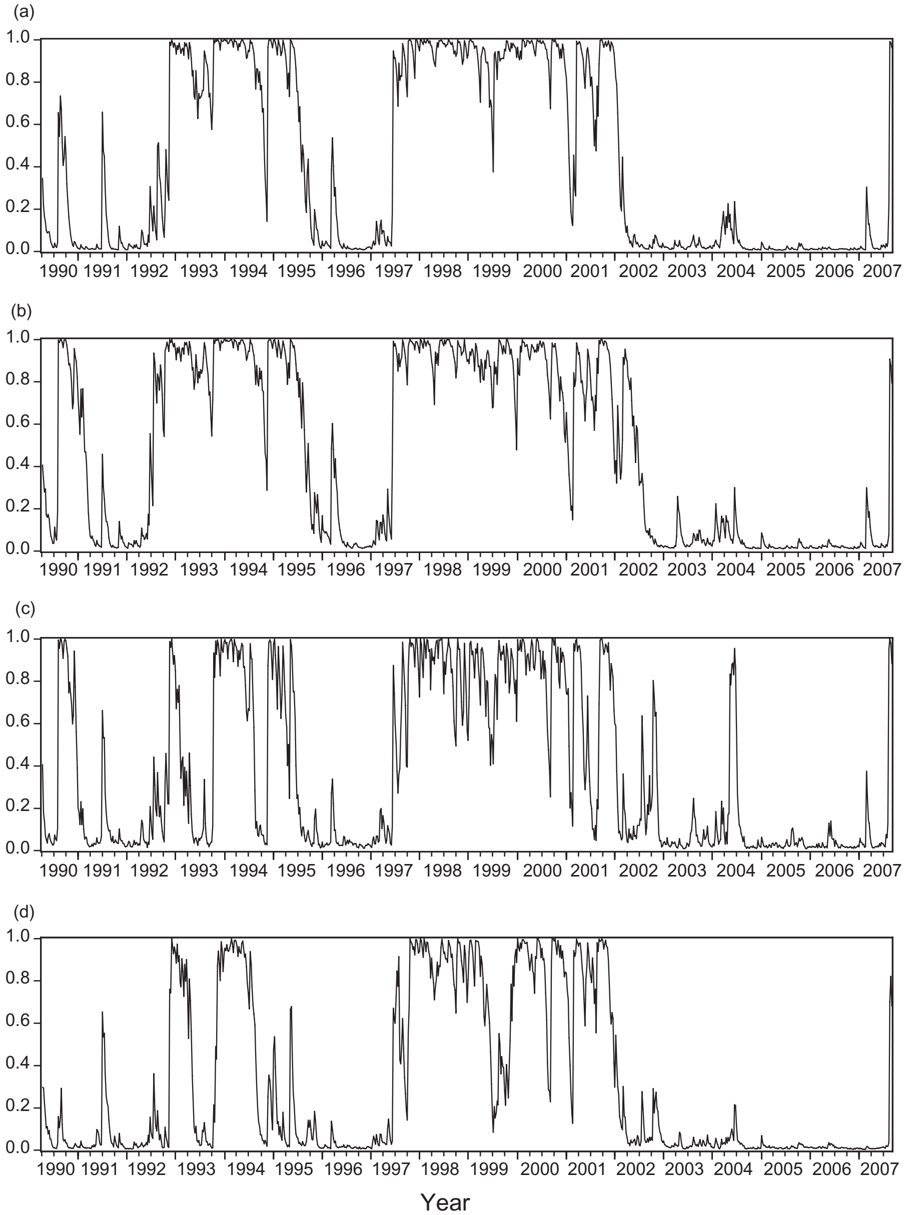

Figure 2. Filter probabilities of high volatility common shocks: (a) Japan, (b) Korea, (c) Indonesia and (d) Malaysia

The remainder of Table 4 presents estimates of the impact coefficients of common shocks for calm (σ) and turbulent (σ^*), times as well as the ratio, γ, which facilitates our test of shift contagion. Focusing on the structural impact coefficients, we find that those in the low-volatility state are generally lower and

Table 4. Estimates of impact coefficients of common shocks

Country	σ_{c1}	σ_{c2}	σ^*_{c1}	σ^*_{c2}	γ	Frequency (%)	Duration (years)
Japan	1.949 (0.093)	0.386 (0.142)	4.108 (0.183)	0.386 (0.142)	2.107	50.27	2.62
Korea	2.024 (0.082)	0.846 (0.144)	3.777 (0.170)	0.846 (0.144)	1.866	51.01	2.09
Indonesia	2.214 (0.051)	0.704 (0.034)	4.585 (0.183)	1.594 (0.174)	1.094	39.51	0.70
Malaysia	2.252 (0.078)	0.550 (0.088)	4.461 (0.228)	0.550 (0.088)	1.981	33.94	1.19
Philippines	2.210 (0.090)	0.738 (0.158)	3.961 (0.264)	0.738 (0.158)	1.792	30.00	0.52
Singapore	1.742 (0.118)	1.003 (0.014)	3.528 (0.118)	1.003 (0.014)	2.025	57.73	3.64
Taiwan	2.191 (0.088)	1.249 (0.182)	4.359 (0.185)	1.921 (0.262)	1.293	48.14	1.51
Thailand	2.154 (0.092)	1.195 (0.267)	4.073 (0.213)	1.743 (0.342)	1.297	54.40	3.02

Notes: Standard errors in parentheses next to coefficients. 'Duration' refers to the duration of the high volatility common shock expressed in years. 'Frequency' measures the proportion of time that the shock is in the high volatility regime and is expressed as a percentage.

display less dispersion than their counterparts in the more turbulent regime. The former has an average response of 1.46 across all market pairs, as opposed to 2.61 in the latter. Likewise, the average dispersion increases twofold. However, all parameters are statistically significantly different from zero. Furthermore, it is informative to distinguish between the response of Hong Kong and the other countries to a common shock. In both regimes, Hong Kong is more sensitive to the shock, but particularly in the high-volatility regime. Often, the response of its partner to entering a high-volatility regime is largely unchanged. Therefore, without any formal test, we can surmise that the heightened sensitivity of Hong Kong might result in shift contagion.

To test for shift contagion, we report the ratio of the estimated impact coefficients of common structural shocks in column 6 of Table 4. We construct the following statistic:

$$\gamma = \max\left\{\left|\frac{\sigma^*_{c1}\sigma_{c2}}{\sigma^*_{c2}\sigma_{c1}}\right|, \left|\frac{\sigma^*_{c2}\sigma_{c1}}{\sigma^*_{c1}\sigma_{c2}}\right|\right\}.$$

It reveals whether impact coefficients in the high volatility regime are proportional to their corresponding values in the low volatility regime. A ratio of unity indicates that there is no difference in the transmission mechanism of shocks between the high-volatility and low-volatility regimes, whereas deviations from unity would imply shift contagion. Given the difference in common shock sensitivities between Hong Kong and its partners, it is unsurprising that this ratio is often greater than unity. To test if it is statistically different from unity, we perform a likelihood ratio test, and Table 5 presents the results.[12]

We find strong evidence of shift contagion between Hong Kong and five markets: Japan, Korea, the Philippines, Singapore and Thailand. When the

[12] Given general support for our model specification, including the normality assumption, the likelihood ratio statistic has a $\chi^2(1)$ distribution under the null hypothesis of no shift-contagion (see Gravelle *et al*., 2006).

Table 5. Likelihood ratio tests for shift contagion

Country	*LR*	*p*-value
Japan	4.918**	0.027
Korea	9.404***	0.002
Indonesia	0.061	0.806
Malaysia	1.229	0.268
Philippines	6.905***	0.009
Singapore	15.633***	0.000
Taiwan	2.031	0.154
Thailand	29.900***	0.000

Notes: The likelihood ratio (LR) statistic is for the null of no shift contagion against the alternative of shift contagion between Hong Kong and the indicated countries. The test statistic has a $x^2(1)$-distribution under the null hypothesis. *** denotes significance at the 1% level, ** denotes significance at the 5% level and * denotes significance at the 10% level.

common shock enters the high-volatility regime, they experience a structural shift in their interdependencies and, hence, the diffusion of such shocks is regime-dependent. Evidence of shift contagion is observed for both developed markets (Japan) and emerging markets (Thailand). With the exception of Thailand, the change in the transmission mechanism is driven by the response of Hong Kong to the shock entering the high-volatility regime. For the other markets, there is no additional response to the regime change. As Hong Kong is already experiencing domestic turbulence, its increased sensitivity to the common shock is sufficient to generate shift contagion. The response of its partner country to entering the high-volatility regime seems to depend on the coincidence of the high-volatility regimes for the common and Hong Kong's idiosyncratic shocks. For example, let us contrast the cases of Japan and Thailand. Comparing Figures 2 and 3, we observe that when the common shock of Hong Kong/Japan is in its high-volatility regime, the idiosyncratic shock of Hong Kong is usually also in the high-volatility regime. Given that it is our source country, its idiosyncratic shock potentially impacts on the Japanese equity return during these periods. It appears that when the high-volatility regimes are roughly coincident (the 'frequency' statistics for the common and Hong Kong idiosyncratic shock are 50% and 48%, respectively), then the idiosyncratic shocks impacting on Japanese equity swamp the effect of the common shock, leaving its response unchanged between regimes. In contrast, the common shock for Hong Kong/Thailand is more frequently in the turbulent state than the idiosyncratic shock of Hong Kong for this pair is (54% *vs* 12%). Hence, the high-volatility common shock exerts additional influence on the Thai equity return relative to its normal level, causing the parameters governing the common shock to increase.

The presence of shift contagion has important implications for both investors and policy-makers. Investors will be reluctant to simultaneously hold equities in Hong Kong and in each of these markets because market linkages are not robust to changes in market conditions. Policy-makers who want to implement appropriate strategies to limit the spread of contagion should adopt measures to

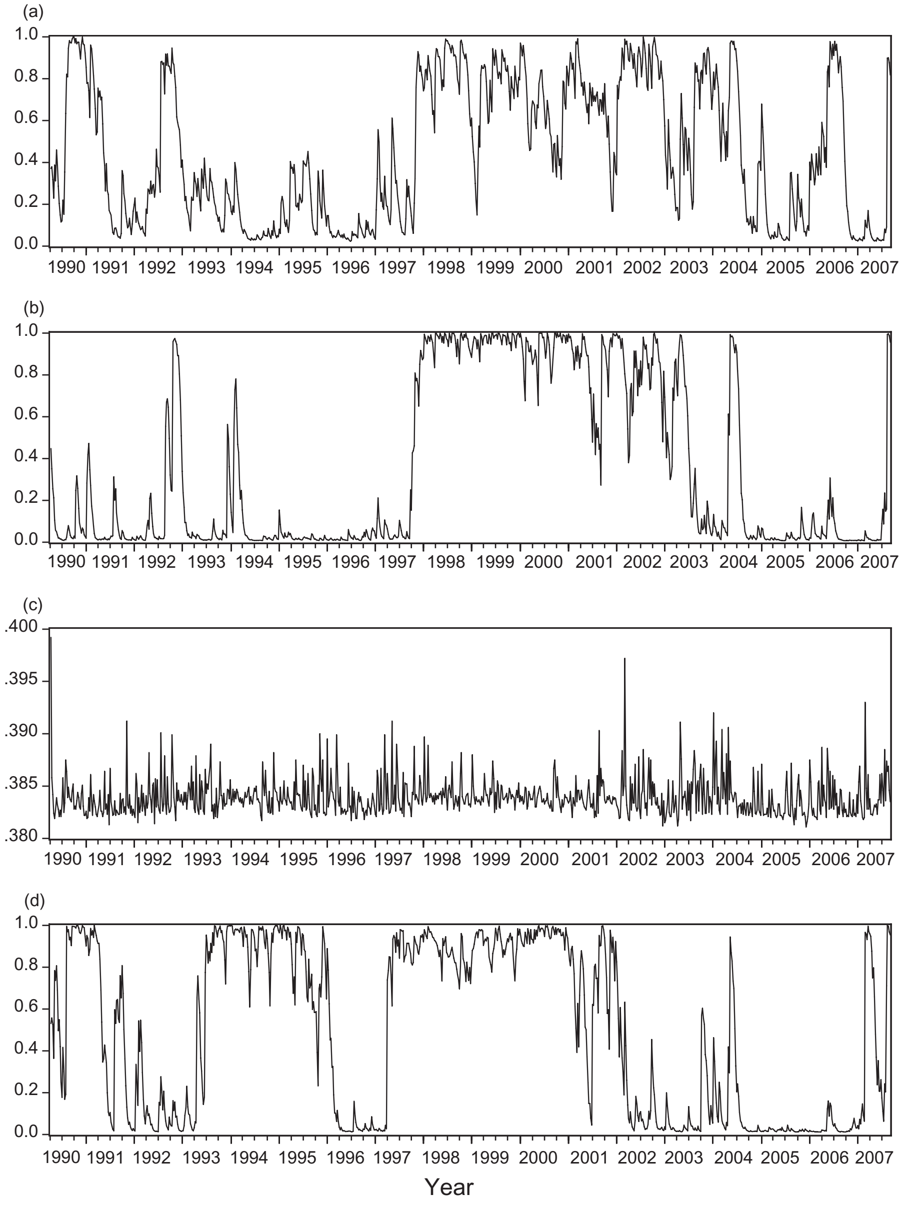

Figure 3. Filter probabilities of idiosyncratic shock for Hong Kong with other market: (a) Japan, (b) Korea, (c) Indonesia and (d) Malaysia

strengthen existing linkages and reduce vulnerability to common shocks. In contrast, there is no evidence of shift contagion between Hong Kong and the markets of Indonesia, Malaysia and Taiwan. The degree of interdependence observed in normal market conditions continues during turbulent periods.

3.5. *Tests for pure contagion*

Pure contagion refers to the phenomenon whereby the idiosyncratic shock of one country (Hong Kong in our case) is transmitted to others through channels that only exist during periods of market turbulence in the source country. We now focus on the idiosyncratic shocks and statistical tests of pure contagion.

Figures 3 and 4 present the filtered probabilities of being in the turbulent regime for the idiosyncratic shock of Hong Kong and each of its partners, respectively. We observe a great deal of high-volatility idiosyncratic risk associated with Hong Kong, the only exception being with Indonesia. In all other cases, there is a large probability of being in the turbulent state, especially during the period of regional and global downturns. This is very evident from 1997 onwards, which lends support to Hong Kong being the shock source for the Asian crisis. As stated, turbulent conditions for the Hong Kong shock often coincide with similar conditions for the common shock. In contrast, Figure 4 portrays a less consistent pattern. Some countries, like Korea and Malaysia, have relatively few periods when there is a high probability of being in the turbulent regime, whereas others, like Japan and Singapore, have many periods when their idiosyncratic shock is likely to experience high volatility.

Table 6 provides a more in-depth analysis of these idiosyncratic shocks. Compared to the common shock, impact coefficients are larger and more variable. 'Frequency' and 'duration' statistics for Hong Kong and its partners are reported in the final two columns, respectively. For the Hong Kong shock, frequency varies from a low of 12% (Thailand) to 68% (Taiwan). Duration is short relative to the common shock. For the pair with Indonesia, it persists for only a couple of weeks. In contrast, it persists for over 2 years for the Taiwanese pair. There is sufficient variation to suspect that Hong Kong's idiosyncratic shock might cause pure contagion. For the other markets, there is large variation in the prevalence of the diversifiable shock and its duration is generally short: less than 1 year.

Table 6 also reports the estimated coefficients (with standard errors) for the δ parameter, which detects and measures the strength of pure contagion. The high-volatility Hong Kong shock has adverse repercussions for its neighbouring markets and exerts a strong influence on their return generating process. δ is positive for all countries and statistically different from zero in six out of eight cases. With the exception of Indonesia and Taiwan, we find evidence that the Hong Kong shock is transmitted to each of the other markets. These pure contagion effects were felt most strongly in the developing markets of Thailand and Korea, but were also suffered in developed markets like Japan. Therefore, this additional transmission channel during periods of high-volatility idiosyncratic shocks in the source market plays a key role in spreading volatility across markets.

3.6. *Summary of results*

Combining the results of the previous two subsections, we conclude that our sample is characterized by significant contagion from Hong Kong to many of its

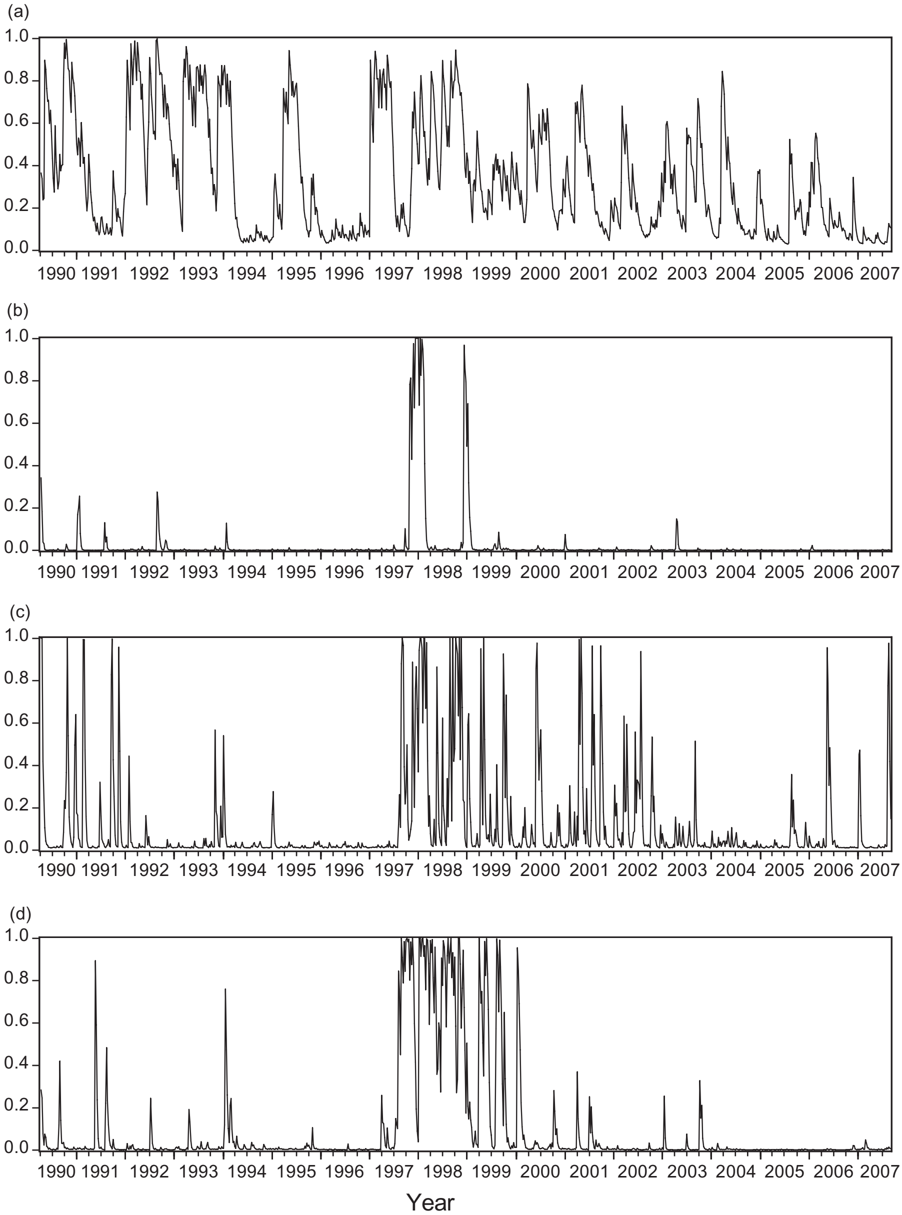

Figure 4. Filter probabilities of country idiosyncratic shock: (a) Japan, (b) Korea, (c) Indonesia and (d) Malaysia

neighbouring East Asian equity markets. We find statistically significant evidence of both shift and pure contagion in the majority of market pairs. Only Taiwan (consistent with Bekaert *et al.*, 2005) and Indonesia appear to be immune from contagious effects, with no evidence of either type of contagion. In

Table 6. Estimates of impact coefficients of idiosyncratic shocks-pure contagion

Country	σ_1	σ_2	σ^*_1	σ^*_2	δ	Frequency/duration (1)	Frequency/duration (2)
Japan	0.000 (0.000)	1.846 (0.123)	1.913 (0.333)	3.348 (0.361)	1.448 (0.296)	47.70% 0.97	32.83% 0.40
Korea	0.003 (0.009)	2.896 (0.096)	2.390 (0.282)	16.617 (3.036)	2.202 (0.241)	41.39% 1.66	2.50% 0.16
Indonesia	0.275 (0.440)	3.048 (0.138)	0.385 (0.593)	12.012 (1.235)	0.372 (0.371)	38.39% 0.04	11.81% 0.07
Malaysia	0.001 (0.032)	1.486 (0.072)	1.922 (0.269)	9.014 (0.834)	1.590 (0.202)	50.36% 1.41	10.79% 0.27
Philippines	0.002 (0.008)	2.518 (0.116)	4.217 (0.515)	5.138 (0.417)	1.080 (0.194)	17.21% 0.35	21.32% 0.63
Singapore	0.945 (0.173)	1.045 (0.078)	3.316 (0.320)	1.998 (0.098)	1.278 (0.078)	26.05% 0.29	56.31% 0.98
Taiwan	0.000 (0.000)	1.946 (0.112)	0.000 (0.000)	9.489 (1.044)	5.57 (29.58)	68.38% 2.25	8.49% 0.17
Thailand	0.002 (0.019)	2.617 (0.133)	2.861 (0.497)	4.644 (0.290)	3.108 (0.490)	12.07% 0.91	44.54% 0.68

Notes: Standard errors in parentheses next to coefficients. 'Duration' refers to the duration of the high volatility regime of the idiosyncratic shock expressed in years. 'Frequency' measures the proportion of time that the shock is in the high volatility regime and is expressed as a percentage.

addition, it is clear from Figure 4 that Indonesia suffered from many problems of its own, and that even if it did not suffer from contagion, it still had sufficient domestic volatility, making it a high-risk market. Indonesia suffered many country-specific problems due to low world oil prices and a drought that badly affected its agricultural produce. Furthermore, the financial crisis triggered political upheaval and mass violent protests, which inhibited potential recovery. Malaysia suffered pure but not shift contagion. Interestingly, Malaysia was the only country to introduce capital controls during the 1997–1998 crisis, thus reducing the impact of common shocks. Indeed, it would seem that Malaysia and Hong Kong had a 'loss of interdependence' during this period. All other markets, both developed and emerging, feature both types of contagion. Much of the shift contagion resulted from the heightened sensitivity of Hong Kong to common shocks during periods when it was already experiencing large idiosyncratic problems. Policy-makers need to formulate appropriate strategies to deal with simultaneous occurrences of shift and pure contagion in Asian markets as policies that focus exclusively on either form are unlikely to eliminate contagion.

4. ROBUSTNESS

Other studies of the Asian crisis contend that Thailand, and not Hong Kong, was the source of the shock (e.g. Baur and Schulze, 2005). Furthermore, the Thai equity market also has a history of adverse shocks (Ito and Hashimoto, 2005). Therefore, we replicate our analysis using Thailand as our base country. The main results are reported in Table 7. Rather than presenting a detailed discussion of the results, we focus on some key points.

First, we examine the common shock. The 'frequency' is lower than in the previous analysis. Its duration is much shorter and is always less than 1 year. However, we still detect statistically significant evidence of shift contagion between Thailand and its partner in 50% of the pairs. Once more, its presence is predominantly due to the reaction of the source country, with most other markets not changing their response. The case of Hong Kong is interesting as we now fail to reject the null hypothesis of no shift contagion. In the previous section, this was reversed as the influence of the Hong Kong idiosyncratic shock outweighed the response of Thai equity returns to the high-volatility common shock, suggesting that shift contagion had taken place. However, when the source country is specified as Thailand, its idiosyncratic shock does not impact upon Hong Kong (see below) and, therefore, all the increased equity volatility comes through the common shock.

The prevalence and persistence of the idiosyncratic shocks show great variation across market pairs. In contrast to the previous case, idiosyncratic shocks display far greater persistence than the common shock. This might be due to the existence of more commonality between Hong Kong and the other markets. Once more, there is evidence of pure contagion effects running from Thailand to many other markets. In particular, Indonesia and Korea are vulnerable to such contagion from their Thai neighbour. Indonesia, which was immune to contagious effects from Hong Kong, is severely exposed to Thai shocks (see Cerra and

Table 7. Test of shift and pure contagion using Thailand as source of shock

	Common shock			Idiosyncratic shocks		
Country	γ	Frequency	Duration	δ	Frequency/ duration (1)	Frequency/ duration (2)
Japan	2.309*	28.38%	0.64	0.733 (0.134)	13.73% 0.27	47.65% 0.37
Korea	1.276	19.39%	0.82	1.943 (0.244)	38.60% 1.23	1.00% 0.15
Indonesia	2.356***	31.84%	0.65	3.245 (0.593)	35.89% 0.17	0.60% 0.06
Malaysia	1.882***	18.78%	0.43	2.352 (13.482)	71.07% 2.38	13.77% 1.96
Philippines	1.178	11.15%	0.82	0.225 (0.053)	42.63% 0.69	22.96% 0.63
Singapore	2.090***	28.31%	0.49	0.726 (0.055)	20.75% 0.27	59.97% 1.68
Taiwan	2.360	28.58%	0.97	0.94 (0.296)	34.54% 0.50	14.52% 0.22
Hong Kong	1.056	11.83%	0.70	0.000 (0.001)	40.89% 0.69	55.63% 2.94

Notes: γ captures shift contagion and δ measures pure contagion. 'Duration' refers to the duration of the high volatility common shock expressed in years. 'Frequency' measures the proportion of time that the shock is in the high volatility regime and is expressed as a percentage. We perform a likelihood ratio test for shift contagion. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level. Standard errors are shown in parentheses next to δ coefficients.

Saxena, 2002). Only Malaysia and Hong Kong appear to be unaffected by the high volatility of the Thai shock. Therefore, Hong Kong is unaffected by Thailand but the reverse is not true.

5. CONCLUSIONS

We test for both shift and pure contagion effects within a unified framework. Our methodology builds on the contribution of Gravelle *et al.* (2006). We have a bivariate model in which the unexpected element of equity returns is decomposed into a common and an idiosyncratic shock. Both shocks switch between volatility regimes, yielding a model in which each pair of returns may transit between eight states. We apply our model to the equity markets of East Asia, which have experienced many periods of turbulence over the past two decades.

We test for both changes in the transmission of common shocks between market pairs (shift contagion) and for the influence of idiosyncratic shocks from the base country on neighbouring markets (pure contagion). Using Hong Kong as our shock source, there is statistical evidence of both types of contagion in five markets. Most often shift contagion results from the response of Hong Kong to the high-volatility common shock. Malaysia suffers pure contagious effects but no change in the diffusion process governing the common shock. Only Indonesia and Thailand are immune to contagion from Hong Kong. Using Thailand as our base country reinforces the conclusion that contagion has been a major feature of East Asian equity markets over the past two decades.

Our results have implications for both investors and policy-makers. Investors should be cautious about simultaneously holding equities from two countries that exhibit shift contagion. The promised portfolio benefits are likely to disappear when most needed, given that they are not robust to regime changes in the common shock. Policy-makers tasked with curbing the spread of contagion across the region should take account of the fact that there are two distinct types of contagion operating simultaneously. Policies designed to exclusively treat one form of contagion without due regard for the other are unlikely to be successful.

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