Return and Volatility Spillovers from Developed to Emerging Capital Markets: The Case of South Asia

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Abstract

This study examines return and volatility spillovers from the US and Japanese stock markets to three South Asian capital markets – (i) the Bombay Stock Exchange, (ii) the Karachi Stock Exchange, and (iii) the Colombo Stock Exchange. We construct a univariate EGARCH spillover model which allows the unexpected return of any particular South Asian market to be driven by a local shock, a regional shock from Japan, and a global shock from the USA. The study discovers return spillovers in all three markets, and volatility spillovers from the US to the Indian and Sri Lankan markets, and from the Japanese to the Pakistani market. Regional factors seem to exert an influence on these three markets before the Asian financial crisis but the global factor becomes more important in the post-crisis period.

JEL Classification: G14; G15

Key Words: Integration; Spillover; EGARCH Model; Asymmetric Effect.

I. Introduction

The theme of integration among international capital markets and the mechanism whereby information is transmitted among different stock exchanges has been extensively researched in the modern finance literature. This topic has attracted the attention of financial economists as the turmoils which occur in some capital markets have far reaching consequences on security prices on their counterparts in other countries. For example, the October 1987 crash not only eliminated more than 20 per cent of the market value of US equities but also sent shock waves around the world. The Asian financial crisis had a similar impact on many other emerging markets in Latin America as well as in Eastern Europe. The liberalization of capital movements together with advances in computer technology and the improved world-wide processing of news have improved the possibilities for national financial markets to react rapidly to new information from international stock exchanges.

Early investigations in this area analysed the interrelatedness among developed capital markets using correlations of stock returns. For example, Hilliard (1979) examined indices for ten international equity markets (Amsterdam, Frankfurt, London, Milan, New York, Paris, Sydney, Tokyo, Toronto, and Zurich) during the world-wide financial crisis created by the OPEC embargo in the period of 1973-1974 and found that the most intra-continental prices move simultaneously. More recently, Eun and Shim (1989) applied vector autoregression (VAR) methodology to study daily index data for nine of the largest stock exchanges in the world (Australia, Canada, France, Germany, Hong Kong, Japan, Switzerland, the UK, and the US) and discovered a substantial amount of multi-lateral interaction among these markets; the US stock market was the most influential and none of the other markets explained any movements in US returns. Joen and von Furstenberg (1990) arrived at a similar view;

they highlighted evidence of growing international integration among the four major equity markets of Germany, Japan, the UK and the US in the 1980s. Becker *et al.* (1990) concluded that the information from the US market could be used to trade profitably in the Japanese market as there was a high correlation between the open-to-close returns of US shares in the previous trading day and the returns of Japanese equities in the current period. Koch and Koch (1991), who used a dynamic simultaneous equations model to investigate the contemporaneous and lead-lag relationships among eight national stock exchanges (Australia, Germany, Hong Kong, Japan, Singapore, Switzerland, the UK, and the US), discovered a growing level of market interdependence within the same geographical regions over time; an increasing influence of the Japanese market at the expense of the US market was also detected.

Another branch of research concentrates on the transmission of international equity movements by studying the spillover of return and volatility across markets. For example, Hamao *et al.* (1990), who studied three major stock markets (London, New York and Tokyo,) using univariate GARCH-in-mean models, found volatility spillovers (i) from New York to Tokyo and London and (ii) from London to Tokyo. Theodossiou and Lee (1993) used multivariate GARCH-in-mean models to analyse the markets in Canada, Germany, Japan, the UK and the US; they discovered that the US market was the major exporter of volatility. More recently, Scheicher (2001) analysed three Eastern European markets (Czech Republic, Hungary and Poland) and reported that although the equity returns were affected by both regional and global factors, the volatilities were impacted by only regional influences. Fratzscher (2002) and Baele (2002) arrived at a similar conclusion; they documented evidence that shock transmissions from the aggregate European Union market to domestic European equities had become more pronounced in recent years[1].

A number of researchers have addressed the question of whether the quantity of news (i.e. the size of an innovation) and the quality of the information (i.e. the sign of an innovation) are important determinants of the degree of volatility spillover across markets. This question has been motivated by findings of an 'asymmetric' or 'leverage' effect associated with equity returns; bad news has a different degree of predictability on future volatility compared to its good news counterpart[2]. This asymmetric effect has been examined in studies of volatility spillovers across markets. For example, Bae and Karolyi (1994), who examined the joint dynamics of overnight and daytime return volatility for the New York and Tokyo stock markets over the period 1988-1992, noted that the magnitude and persistence of shocks originating in New York or Tokyo that transmitted to the other market were significantly understated if this asymmetric effect was ignored; bad news from domestic and foreign markets appeard to have a much larger impact on subsequent return volatility than good news. Koutmos and Booth (1995) investigated the asymmetric impact of market advances and market declines (i.e. good and bad news respectively) on volatility transmission across the New York, Tokyo and London stock markets. Using daily open-to-close returns, they found unidirectional price spillovers (i) from New York to Tokyo, (ii) from New York to London, and (iii) from Tokyo to London. They also uncovered bidirectional volatility spillovers among the three markets. In all

[1] Some researchers have extended this investigation to foreign exchange and spot and future markets and uncovered evidence for the existence of spillovers among major currency markets (Baillie and Bollerslev, 1990; Engle *et al.*, 1991; Chin *et al.*, 1991; Cheung and Fung, 1997).

[2] This phenomenon was originally motivated by the work of Black (1976), Christie (1982), French *et al.* (1987) and Nelson (1991) and its significance was evaluated by Pagan and Schwert (1990), Braun *et al.* (1992), Glosten *et al.* (1993) and Engle and Ng (1993) by employing different variations of volatility models. Nelson (1991), Cheung and Ng (1992), Koutmos (1992) and Poon and Taylor (1992), among others, provide empirical evidence for the existence of a leverage effect.

instances, the volatility transmission mechanism was asymmetric - *i.e.* negative innovations in one market increased volatility in the other market considerably more than their positive counterparts. Booth *et al.* (1997) looked at the four Scandinavian markets and found significant and asymmetric volatility spillovers among Swedish, Danish, Norwegian, and Finnish securities. Similar evidence has been reported for other European markets - London, Paris, and Frankfurt – by Kanas (1998).

Only a minority of studies have focussed on the return and volatility spillovers from developed to emerging capital markets[3]. In particular, the evidence on market interactions and information transmissions in South Asian capital markets is hard to find. The Capital markets in South Asia have generated a considerable interest among local and foreign investors as a result of the increased economic activity in these countries arising from economic reforms and the liberalisation of capital markets. In this research exercise, we investigate how information is transmitted from developed capital markets to three recently libaralised South Asian capital markets – the Bombay Stock Exchange (BSE) of India, the Karachi Stock Exchange (KSE) of Pakistan and the Colombo Stock Exchange (CSE) of Sri Lanka; return and volatility spillover models are tested on market index data. Our study differs from the previous research on this topic in three respects. First, unlike many existing studies which focus on how a single international market (often the US or a world market) influences other stock markets[4], we consider the innovations from both the US and Japanese markets in an attempt to analyse the impacts of both regional and world shocks on South Asian equities. Second, we recognise that volatility transmission may be asymmetric in

[3] See, Ng (2000), Chan-Lau and Ivaschenko (2002) and Worthington and Higgs (2004) for some evidence on this topic.

[4] Many early studies failed to distinguish between world and regional factors as they were predominantly occupied with testing the influence of the world market (often US) on other markets. For example, see Hamao *et al.* (1990), Campbell and Hamao (1992), Bekaert and Hodrick (1992), Bekaert and Harvey (1995), Harvey (1995), Karolyi (1995) and Karolyi and Stulz (1996).

character – i.e. the negative innovations in one market may produce higher volatility spillovers in another market, than the positive innovations of equal magnitude. Finally, we address the possible effect of the Asian financial crisis[5] on the transmission mechanism by disaggregating the data into three sample periods: (i) pre-crisis, (ii) in-crisis and (iii) post-crisis.

The reminder of this paper is organized as follows. Section II provides a brief overview about the South Asian stock markets. Section III describes the spilover models used to analyse the data in this study. Section IV outlines the data employed in the study and presents the empirical results. The final section offers some conclusions.

II. An Overview of South Asian Capital Markets

The South Asian region is notable for its large population (more than one-fifth of the world total's inhibitants) which continues to grow rapidly. India is by far the largest South Asian country, in terms of population, GDP, and land area. Sri Lanka has the most open economy. Indian, Pakistan, and Sri Lankan stock exchanges are also the three biggest markets in this region in terms of market capitalization. South Asia has experienced fast economic growth in recent years because of the economic reforms implemented by these countries' governments; it was the fastest growing region of the world in 1998. The emerging capital markets in this region have generated considerable interest among regional as well as global investors because of the rapid growth of these countries' economies and the concessions provided to foreign investors through radical liberalization processes.

The Bombay Stock Exchange is the oldest stock market in Asia - even older than the Tokyo Stock Exchange - and was established in 1875 as a voluntary non-

[5] Bollerslev *et al.* (1992) suggest that the asymmetric response of volatility to innovations may be the

profit making association. It is one of 25 stock markets throughout India. With over 20 million shareholders, India has the third largest investor base in the world after the US and Japan. India's market capitalization was the 6^{th} highest among the emerging markets. Share trading on Colombo Stock Exchange dates back to the 19^{th} century; in 1896 Colombo Brokers Association commenced the trading of shares in limited liability companies. By contrast, the stock market in Pakistan is relatively new. The Karachi Stock Exchange only came into existence in 1947. These capital markets exhibit a number of common features; they did not play a prominent role in the economic development of their countries until the respective governments started a programme of deregulation and economic liberalization. For example, India initiated financial reforms in conjunction with economic deregulation and permitted foreign companies to own a majority stake in quoted Indian firms from many different industries. The liberalization policies of the Pakistan government have led to rapid deregulation of the economy and the removal of impediments to private investment. The secondary stock market in Pakistan is now open to foreign investors; non-nationals are treated equally with local participants when trading shares. The Sri Lankan government took a number of steps including the opening of the banking sector to foreign owners, repealing the business acquisition act and privatizing government-owned business undertakings in an attempt to create a well-functioning capital market in the country.

TABLE 1 ABOUT HERE

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result of a few extreme observations such as those associated with the October 1987 crash.

As a result of these changes, share markets in these three South Asian countries recorded a remarkable rate of growth in their trading activities. Table 1 reports some market statistics for the stock exchanges in these countries. According to this table, during the 10-year period ending 2003, these markets have reported a phenomenal growth in market capitalization: BSE 341.93 per cent, KSE 1,268.57 per cent and CSE 112.10 per cent. Similar growth patterns can be observed with respect to market capitalization as a percentage of GDP, annual turnover, the number of listed companies, and the market price index. The number of companies listed on the BSE at the end of December 1998 was 5,860. This was more than the aggregate total of companies listed in 9 emerging markets (Malaysia, South Africa, Mexico, Taiwan, Korea, Philippines, Thailand, Brazil and Chile) at the same date. The number of listed companies was also larger than that in several developed markets: Japan, UK, Germany, France, Australia, Switzerland, Canada and Hong Kong. The KSE has also grown quickly, especially in recent years. It was declared the "best performing stock market of the World for the year 2002" by Business Week. The findings of this study will be interesting as little evidence appears in the finance literature on South Asian capital markets.

III. Methodology

EGARCH Model Estimation

GARCH (generalized autoregressive conditional heteroskedasticity) models are generally used to explore the stochastic behavior of several financial time series and, in particular, to explain the behavior of volatility over time. However, such models do not work with negative data. The exponential GARCH (EGARCH) model developed by Nelson (1991)[6] overcomes this limitation and allows researchers to capture the leverage effect or asymmetric impact of shocks on volatilities. It therefore, avoids the imposition of non-negativity restrictions on the values of the GARCH parameters to be estimated. Specifically, time series of share returns are modeled in EGARCH (*p, q*) as follows:

$$R_t = \alpha_0 + \sum_{i=1}^{r} \alpha_i R_{t-i} + \varepsilon_t \quad [1]$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2) \quad [2]$$

$$\log(\sigma_t^2) = a_0 + \sum_{i=1}^{q} a_i f(z_{t-i}) + \sum_{i=1}^{p} b_i \log(\sigma_{t-i}^2) \quad [3]$$

$$f(z_{t-i}) = \theta\, z_{t-i} + \left[|z_{t-i}| - \mathrm{E}(|z_{t-i}|) \right] \quad [4]$$

$$\mathrm{E}(|z_{t-i}|) = \left[\frac{2}{\pi} \right]^{0.5} \quad [5]$$

where R_t is the return series in time *t* (i.e. continuously compounded returns generated taking the natural logarithm of the ratio of current price to the lagged price), ε_t is the stochastic error, Ω_{t-1} is the information set at time *t*-1, σ_t^2 is the conditional (time varying) variance, and z_t is the standardized residual which is derived from ε_t / σ_t conditional on Ω_{t-1}. The term ε_t is assumed to be normally distributed with a zero mean and variance (σ_t^2). The term $\left[\frac{2}{\pi} \right]^{0.5}$ is a constant employed to make sure that the integral under the curve of the normal distribution of the residual from negative to positive infinity is equal to one.

[6] A competing model which also captures the asymmetric leverage effect is the Quadratic GARCH model proposed by Engle (1990). However, Engle and Ng (1993) find that the EGARCH performs better. Moreover, a significant body of previous evidence, summarized by Hamilton (1994, P. 672), supports the use of the EGARCH model. On the basis of this evidence, the EGARCH model is employed in this study.

Equation [1] (the conditional mean equation) is modeled as an autoregressive process of order *r* [AR (*r*)], following Theodossiou and Lee (1993), and Karolyi (1995). To specify the lag length *r* for each return series, the autocorrelation function (ACF) and partial autocorrelation function (PACF) of each series are considered, and residuals from the mean equations are then tested for whiteness using the Ljung-Box statistic. For the entire period (01/01/ 1993 – 31/12/2003), we use 1 lag for the US, Japanese and Indian return series and 2 lags for Pakistan and Sri Lankan series to yield uncorrelated residuals. For the sub-periods, whiteness in the residuals for each series is achieved using 1 lag except for the Pakistan series in the pre-crisis period and Indian series in the post-crisis period; in each of these two exceptions, 2 lags are needed.

Equation [3] (the conditional variance equation) reflects the EGARCH (*p,q*) representation of the variance of ε_t. According to this EGARCH representation, the variance is conditional on its own past values as well as on past values of a function of z_t, or the standardized residuals (ε_t / σ_t). The persistence of volatility implied by Equation [3] is measured by $\sum_{i=1}^{p} b_i$. The unconditional variance is finite if $\sum_{i=1}^{p} b_i$ <1 in absolute terms (see Nelson, 1991). If $\sum_{i=1}^{p} b_i$ =1, then the unconditional variance does not exist and the conditional variance follows an integrated process of order one. As noted by Hsieh (1989), the exponential specification is less likely to produce integrated variances. The smaller the $\sum_{i=1}^{p} b_i$, the less persistent the volatility is after a shock.

In equation [4], asymmetry is present if θ is negative and statistically significant. Asymmetry in volatility transmission can be conveniently examined using its partial derivatives:

$$\frac{\partial f(z_t)}{\partial z_t} = \begin{cases} 1+\theta, & \text{for } z_t > 0 \\ -1+\theta, & \text{for } z_t < 0 \end{cases} \qquad [6]$$

The term $\left[\left|z_t\right| - E\left(\left|z_t\right|\right)\right]$ measures the size effect of an innovation whereas θz_t measures the corresponding sign effect. If θ is negative, a negative z_t tends to reinforce the size effect, whereas a positive z_t tends to partially offset it. If $\theta = 0$, a positive shock has the same effect as a negative shock of the same magnitude. If $-1<\theta<0$, a negative shock increases volatility more than a positive shock and, thus, θ measures the asymmetric effect of shocks on volatility. If $\theta < -1$, a negative (positive) shock increases (reduces) volatility. The relative importance of the asymmetry or the leverage effect can be measured by the ratio $\frac{\left|-1+\theta\right|}{1+\theta}$. Lag truncation lengths, *p* and *q*, are determined using likelihood ratio (LR) tests of alternative specifications[7]. Based on these tests, EGARCH (1, 1) models were determined to be optimal.

The Univariate EGARCH Models of Price and Volatility Spillovers Estimation

In this study, the univariate EGARCH model is used to test for return and volatility spillovers from the two developed stock markets of the US and Japan to a third small stock market (India, Pakistan, and Sri Lanka respectively). We assume unidirectional return and volatility spillovers to be relevant because these small stock

[7] Likelyhood ratios are calculated as follows:

$$LR = 2 * [\ln(\log \textit{likelihood of unrestricted model}) - \ln(\log \textit{likelihood of restricted model})]$$

The unrestricted model refers to either the EGARCH(1,2) or EGARCH(2,1) model and the restricted model refers to the EGARCH(1,1) model. Since we have a very small LR statistic for all markets, the markets are not thought to have a substantial impact on the two developed markets considered. To test for spillovers from a foreign market to the domestic market, the approach adopted by Hamao *et al*. (1990) and Theodossiou and Lee (1993) is followed. According to this approach, the most recent squared residuals from the conditional mean–conditional variance formulation of the foreign market are introduced as an exogenous variable in the conditional variance equation of the domestic market. The univariate EGARCH (1, 1) models of return and volatility spillovers for market j are specified as follows:

The conditional mean equation for India, Pakistan and Sri Lanka becomes;

$$\begin{aligned} R_{IND,t} &= \alpha_{IND,0} + \alpha_{IND,1} R_{IND,t-1} + \beta_{IND,1} R_{US,t-1} \\ &\quad + \beta_{IND,2} R_{JAP,t-1} + \varepsilon_{IND,t} \end{aligned} \qquad [7a]$$

$$\begin{aligned} R_{PAK,t} &= \alpha_{PAK,0} + \alpha_{PAK,1} R_{PAK,t-1} + \alpha_{PAK,2} R_{PAK,t-2} + \beta_{PAK,1} R_{US,t-1} \\ &\quad + \beta_{PAK,2} R_{JAP,t-1} + \varepsilon_{PAK,t} \end{aligned} \qquad [7b]$$

$$\begin{aligned} R_{SRI,t} &= \alpha_{SRI,0} + \alpha_{SRI,1} R_{SRI,t-1} + \alpha_{SRI,2} R_{SRI,t-2} + \beta_{SRI,1} R_{US,t-1} \\ &\quad + \beta_{SRI,2} R_{JAP,t-1} + \varepsilon_{SRI,t} \end{aligned} \qquad [7c]$$

The conditional variance equation for these three markets is:

$$\begin{aligned} \log\left(\sigma^2{}_{IND,t}\right) &= a_{IND,0} + a_{IND,1} f(z_{IND,t-1}) + b_{IND,1} \log(\sigma^2{}_{IND,t-1}) \\ &\quad + c_{IND,1} \log(U_{US,t}) + c_{IND,2} \log(U_{JAP,t}) \end{aligned} \qquad [8a]$$

$$\begin{aligned} \log\left(\sigma^2{}_{PAK,t}\right) &= a_{PAK,0} + a_{PAK,1} f(z_{PAK,t-1}) + b_{PAK,1} \log(\sigma^2{}_{PAK,t-1}) \\ &\quad + c_{PAk,1} \log(U_{US,t}) + c_{PAK,2} \log(U_{JAP,t}) \end{aligned} \qquad [8b]$$

$$\begin{aligned} \log\left(\sigma^2{}_{SRI,t}\right) &= a_{SRI,0} + a_{SRI,1} f(z_{SRI,t-1}) + b_{SRI,1} \log(\sigma^2{}_{SRI,t-1}) \\ &\quad + c_{SRI,1} \log(U_{US,t}) + c_{SRI,2} \log(U_{JAP,t}) \end{aligned} \qquad [8c]$$

where,

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lag truncation lengths $p = 2$ or $q = 2$ are not statistically significant. Based on these tests, we fit EGARCH(1,1) models for all markets.

$$f\left(z_{IND,t-1}\right)=\theta_{IND}\ z_{IND,t-1}+\left[\left|z_{IND,t-1}\right|-\mathrm{E}\left(\left|z_{IND,t-1}\right|\right)\right] \quad [9a]$$

$$f\left(z_{PAK,t-1}\right)=\theta_{PAK}\ z_{PAK,t-1}+\left[\left|z_{PAK,t-1}\right|-\mathrm{E}\left(\left|z_{PAK,t-1}\right|\right)\right] \quad [9b]$$

$$f\left(z_{SRI,t-1}\right)=\theta_{SRI}\ z_{SRI,t-1}+\left[\left|z_{SRI,t-1}\right|-\mathrm{E}\left(\left|z_{SRI,t-1}\right|\right)\right] \quad [9c]$$

$U_{US,t}$ and $U_{JAP,t}$ are the contemporaneous squared residuals (from the AR(1) – EGARCH(1,1) models) for the US and Japanese returns respectively, and z_{t-1} is the lagged standardized residuals.

Return spillovers occur when past information about the US and Japanese markets have persistent effects on small market returns, and volatility spillovers are related to the present information flows from the foreign markets. The univariate EGARCH model permits us to differentiate between the relative influence of the US and Japan on the three small markets. Existence of return spillovers is indicated by the statistical significance of β_1 (return spillovers from the US) and β_2 (return spillovers from Japan). Existence of volatility spillovers is indicated by the statistical significance of c_1 (volatility spillovers from the US) and c_2 (volatility spillovers from Japan). Statistical inference regarding c_1 and c_2 is based on robust standard errors derived by Bollerslev and Wooldridge (1992)[8]. A significant c_1 (or c_2) coupled with a significantly negative θ implies that negative innovations in the US market (or Japanese market) have a higher impact on the volatility of market *j* than positive innovations, *i.e.* the volatility spillover mechanism is asymmetric.

Given a sample of *T* observations and conditional normality for the stock returns in each market, the log likelihood function for the univariate EGARCH can be written as:

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[8] Conventional standard errors tend to underestimate the true standard errors, especially for the parameters in the conditional variance equation (Susmel and Engle, 1994).

$$L(\Theta) = (-T/2)\log(2\pi) - 0.5\sum_{t=1}^{T}\log(\sigma_t^2) \qquad [10]$$

where Θ is the parameter vector ($\alpha_0 \ \ \alpha_1 \ \ \alpha_2 \ \ a_0 \ \ a_1 \ \ b_1 \ \ c_1 \ \ c_2 \ \ \theta$) to be estimated.

IV. Empirical Findings

Data and Preliminary Statistics

The data used in the study consist of daily stock indices for five countries - the USA, Japan, India, Pakistan, and Sri Lanka for the period 1 January 1993 to 31 December 2003; a total of 2869 observations are employed for each market. The sample period is divided into three sub-periods – pre-crisis (01/01/1993- 31/06/1997), in-crisis (01/07/1997-31/12/1999), and post-crisis (01/01/2000-31/12/2003). The index data are obtained from Datastream. The stock market indices used in this study are the S&P 500 (the US), the Nikkei 500 (Japan), the BSE National Price Index (India), the Karachi 100 Price Index (Pakistan), and the Colombo All Share Price Index (Sri Lanka). In each market, we choose the most comprehensive and diversified stock index. The S&P 500 index consists of the 500 largest, publicly-held companies representing approximately 76 percent of total market capitalization. The Nikkei 500 index incorporates 500 Japanese companies listed in the First Section of the Tokyo Stock Exchange. The BSE National Index comprises 100 stocks listed at five major Indian stock exchanges (Mumbai, Calcutta, Delhi, Ahmedabad and Madras). The Karachi 100 includes the largest 100 companies in the exchange (27 companies representing 27 sectors and 73 companies representing the entire market) covering about 83 percent of market capitalization of the exchange. The Colombo All Share

Price Index consists of all the shares traded on the stock exchange[9].With the exception of the Nikkei 500, all indices are calculated on a value-weighted basis. The Japanese index is a share price-weighted index which does not take dividend reinvestment into account. However, cash dividends paid on most Japanese stocks are relatively small, so this dividend omission is of little consequence. [10] The variable analysed in the study is the daily return which is calculated by taking the natural logarithm of the ratio of current price to the lagged price[11].

TABLE 2 ABOUT HERE

Table 2 reports summary statistics for the daily returns of the five national stock markets. The mean returns are positive for four markets with the exception of Japan. The Pakistan market earned the highest mean return but with the largest risk as measured by the standard deviation. However, the sample means for all five markets are not statistically different from zero. The measures for skewness show that with the exception of the distribution of returns for the Sri Lankan market, the return series are negatively skewed. The excess Kurtosis measures indicate that the distributions of all the return series are highly leptokurtic. Likewise, the Jarque-Bera statistics reject normality for each of the return series at the 1 percent level of significance.

The Ljung-Box *q*-statistics - LB(k) and $LB^2(k)$ - for lag lengths of 6 and 12 days are used to test for serial correlation in the return and squared return series. The

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[9] Even though the CSE had a "blue chips" index representing the top companies in the market, its composition changed in 1998. Therefore, it was decided to use the All Share Price Index.

[10] See Campbell and Hamao (1989) for evidence on the dividend-price ratio for the Tokyo market.

[11] Since Eastern trading time leads Western trading time by one day, we consider US returns with a one day lag in order to overcome problems associated with non-synchroneous trading across five markets analysed. All three South Asian markets have overlapping trading hours with the Japanese market but not with the US market. Recent spillover investigations deal with this problem using open-to-close returns (Hamao et al. 1990; Bae and karolyi, 1994; and Koutmos and Booth, 1995). However, this

null hypothesis of uncorrelated returns is rejected at the 1 percent level of significance for the markets of Japan, India, Pakistan, and Sri Lanka at both lag lengths used. The null hypothesis of homoskedastic returns (uncorrelated squared returns) is also rejected at the 1 percent level for all markets at both lag levels. Linear dependencies may be due either to non-synchronous trading of the stocks that make up each index[12] or to some form of market inefficiency. Non-linear dependencies may be due to autoregressive conditional heteroskedasticity, as documented by several recent studies for both the US and foreign stock markets[13]. The ARCH Lagrange Multiplier (*LM*) tests (Engle, 1982) indicate that each market's returns strongly depend on their past values and exhibit strong ARCH effects, implying that the ARCH model is appropriate for data analysis in this study[14]. The ARCH effects may explain (at least partially) the observed thicker than normal distributional tails. Since the Jarque-Bera normality tests show that all the return series are not normally distributed, we examine the relationship among returns using nonparametric correlations. All return series are positively correlated, but the cross-correlations among returns are relatively low.

Univariate EGARCH Model Estimation

We first estimate a univariate EGARCH (1, 1) model for each of the five indices by restricting all cross-market coefficients measuring return and volatility spillovers to be zero. An EGARCH (1, 1) model was determined to offer the best fit for the data series. The resulting coefficients from these models are presented in Table

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option was not available to us due to the difficulty of obtaining opening and closing prices for the South-Asian capital markets.

[12] See Scholes and Williams (1977) and Lo and MacKinley (1988).

[13] See, for example, Nelson (1991), Akgiray (1989) and Booth *et al.* (1992).

[14] The LM test approach requires the estimation of the auxiliary regression model of $e_t^2 = cons\tan t + \sum_{i=1}^{p} \delta_i e_{t-i}^2 + error$, where e_ts are the OLS residuals, i =1,2,..p;and t = p_{+1}, p_{+2}, …,

3. Panel A provides estimates for equation [1]. The first order autoregressive coefficient, α_1, is statistically significant for the Japanese, Indian, Pakistan, and Sri Lankan markets, indicating that either non-synchronous trading or market inefficiency induces autocorrelation in the return series. The second order autoregressive coefficient, α_2, is also statistically significant for the Pakistan and Sri Lankan markets. However, for the US market, α_1, is insignificant; this finding is consistent with previous studies such as Theodossiou and Lee (1993) and Koutmos and Booth (1995), indicating that the US market is more efficient than other markets. Conditional hetreoskedasticity is perhaps the single most important property describing the short-term dynamics of all markets.

TABLE 3 ABOUT HERE

The conditional variance is a function of past innovations and past conditional variances. Panel B provides estimates for equation [3]. The relevant coefficients, a_1 (measuring the ARCH effect) and b_1 (measuring the degree of volatility persistence) are all statistically significant for all the markets. Furthermore, the values of b_1 coefficients are all close to one indicating a high degree of persistence in volatility. This volatility persistence is highest for the US, followed by the Japanese, Indian, Pakistan, and Sri Lankan markets. The leverage effect, as measured by θ, or the asymmetric impact of past innovations on current volatility, is negative and statistically significant for the US, Japanese, and Indian markets indicating that the volatility spillovers may also be asymmetric. The relative importance of the

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m. From the results of this auxiliary regression, a test statistic is calculated as $(N-p)*R^2$ which is expected to be distributed as Chi-squared (p) under the null hypothesis of no ARCH effects.

asymmetry, or leverage effect, can be measured by the ratio $\frac{|-1+\theta|}{1+\theta}$. Thus, the degree of asymmetry, on the basis of the estimated θ coefficients, equals -1.23 for the US market, -1.13 for Japanese market, and -1.06 for Indian market. These ratios indicate that the degree of asymmetry is highest for the US market (negative innovations increase volatility 1.23 times more than positive innovations), followed by the Japanese market (1.13 times) and the Indian market (1.06 times). The hypothesis that the return series are homoskedastic (*i.e.* $a_1 = b_1 = \theta$) is rejected at any significance level on the basis of the Wald test[15].

Panel C reports the diagnostics on standardized and squared standardized residuals. The estimated Ljung-Box statistics show that the EGARCH model fully captures all linear and non-linear dependencies present in the US and Japanese return series, but only successfully accounts for the non-linear dependencies of the Indian, Pakistan and Sri Lankan return series. Our autoregressive formulations of the conditional mean and conditional variance equations appear to absorb all the non-linear serial correlations present in the original return series[16]. On the basis of Jarque-Bera statistics, the hypothesis of univariate normality is rejected for the all markets.

Price and Volatility Spillovers

We next estimate the univariate EGARCH (1, 1) model given by equations [7], [8], and [9] for each market to test for return and volatility spillovers. The results are shown in Table 4. Panels A, B and C report the return spillover coefficients, volatility spillover coefficients, and the diagnostics on standardized and squared

[15] A non-linear Wald test is used to test for the joint significance of the EGARCH model, as standard *t*-statistics do not work since we have a non-linear ML. The very large Wald statistic indicates the presence of an EGARCH volatility model.

standardized residuals respectively. The full model considers both return and volatility spillovers from the world source of shocks (the US) and the regional source of shocks (Japan) to the three small emerging markets. In terms of first moment interdependencies (return spillovers), there are positive significant return spillovers from the US to India, Pakistan, and Sri Lanka respectively; all three US return spillover coefficients (0.0989, 0.0382, and 0.0269) are statistically significant at conventional levels. There is a positive significant return spillover from Japan to Pakistan, but there are negative significant return spillovers from Japan to India and Sri Lanka. Again, all three Japanese return spillover coefficients (-0.0346, 0.0600, and -0.0376) are statistically significant. Moreover, the magnitude of the spillover coefficients varies from a low of 0.0269 from the US to Sri Lanka to a high of 0.0989, from the US to India.

TABLE 4 ABOUT HERE

Turning to second moment interdependencies (volatility spillovers), a statistically significant spillover effect exists from US to India at the 10 per cent level of significance, from US to Sri Lanka at the 1 per cent level, and from Japan to Pakistan at the 5 per cent level. The magnitude of the volatility spillover coefficients also varies. Specifically, the coefficient from the US to Sri Lanka (0.0209) is greater than its counterparts from Japan to Pakistan (0.0097), and from the US to India (0.0056); these findings indicate that the US, proxying for the world factor as a source of shocks, has more impact on the Asian small markets. In addition, the coefficient measuring asymmetry, θ, is significant for the Indian and Sir Lankan markets, which

[16] Higher-order lags could not eliminate the linear serial correlation present in the Indian, Pakistan and

means that any negative news (innovations) from the US market increase volatility more than positive news of similar size from the same market. Thus, both the Indian and Sri Lankan markets present evidence consistent with an asymmetric response of volatility to innovations from the US market. Numerically, bad news from the US market for Indian and Sri Lankan markets have 1.06 times, and 1.07 times the impact of good news as indicated by the relative asymmetry ratio. The spillovers are symmetric for the Pakistan market since the coefficient measuring asymmetry is insignificant.

Comparing the coefficients from the univariate EGARCH model (restricted model) with those of the spillover model (unrestricted model) (*i.e.* Tables 3 and 4, respectively), we can see that both sets of results are consistent. The coefficients α_1, α_2 (for the one-lag and two-lag conditional means) and b_1 (for the one-lag conditional variances) all are highly significant; b_1 is close to unity as well. These findings clearly indicate that both the returns and volatility of all three small markets respond to their own past information. Thus, current information for a market remains important for all future forecasts of the conditional mean and conditional variance of that market.

Conditional volatilities of the returns in the Pakistan and Sri Lankan markets respond symmetrically to their own past innovations; the θ coefficients reported in Table 3 for these two markets are insignificant. Also, evidence of asymmetric volatility transmission from either of the developed markets to the Pakistan market is not present; the θ coefficient reported in Table 4 for this market is insignificant. However, after taking into account volatility spillover, the Sri Lankan market becomes sensitive to news originating from the US market more strongly when the news is 'bad' than when the news is 'good'. The Indian market also responds

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Sri Lankan return series.

asymmetrically to its own past innovations and also to world shocks; both the θ coefficients reported in Tables 3 and 4 are negative and significant. We use the likelihood ratio (LR) statistic to test the hypothesis that return and volatility spillovers from the two developed markets to three small markets are jointly zero (*i.e.* the univariate EGARCH model versus the spillover model). The null hypothesis cannot be rejected at any significance level, implying the importance of return and volatility spillovers. The Ljung-Box statistics for the standardized and squared standardized residuals reported in this unrestricted model indicate the presence of limited spillover effects as the values reported in the table are very close to those calculated for the restricted model. The Jarque-Bera normality test statistics indicate that standardized residuals for all three indices exhibit strong deviations from normality. In short, the existence of first and second moment interdependencies points to the presence of a global marketplace; however, the degree of interdependencies is limited.

Subperiod Price and Volatility Spillovers

The Asian financial crisis started in mid-1997 and lasted until the end of 1999. The most directly affected nations were from Southeast Asia, namely Malaysia, Thailand, the Philippines and Indonesia. However, other countries soon became affected. Due to “financial contagion”, markets fell across the globe and the implications of the Asian financial turmoil became far-reaching. For example, in the US the Dow Jones Industrial Average fell by 554 points on October 27, 1997. The crisis badly affected Japan which was the biggest trading partner of the main Asian countries affected and the main supplier of foreign capital to Asian markets.

TABLE 5 ABOUT HERE

The results for the unrestricted model (*i.e.* univariate EGARCH(1,1) with spillover effect) for the three sub-periods are reported in Table 5. Coefficient a_1 (measuring ARCH effect) and b_1 (measuring volatility persistence) are significant for almost all markets in the three periods. The α_1 coefficient (measuring the return persistence) is significant on average, except for India during in-crisis period and for Pakistan during in- and post-crisis periods. The findings are consistent with the results reported in Table 4 for the entire period; that is, for these small emerging markets, past information can be used to forecast both stock market returns and variance. Finally, the Ljung-Box statistics for the standardized and squared standardized residuals indicate that the univariate EGARCH model with spillover effects are correctly specified.

For the pre-crisis period, there is evidence of return spillovers from Japan to all three small markets. There is also evidence of volatility spillovers from Japan to the Pakistan and Sri Lankan markets. However, these spillovers are symmetric since the θ coefficients (measuring the asymmetry) for both markets are insignificant. For the in-crisis period, the Indian market shows evidence of return spillovers from both the US and Japanese markets; the Pakistan market also shows signs of return spillovers from the Japanese market. There is no evidence of return spillovers for Sri Lankan markets and also no evidence of volatility spillovers for any market. However, the θ coefficient is significant for the Indian and Pakistan markets, implying both markets respond asymmetrically to their own past innovations. For the post-crisis period, there is evidence of both return spillovers and volatility spillovers from the US market to the Indian, Pakistan, and Sri Lankan markets. In addition, there is some evidence of return spillovers from the Japanese to the Pakistan market and volatility spillovers from the Japanese to the Indian market. However, the volatility spillovers are only asymmetric in the Indian market as the coefficient θ is only significant for India. Thus, the Indian market appears to respond asymmetrically to its own past innovations and to innovations from the two developed markets as well.

A comparison of the results from the three sub-periods reveals that during the crisis the small markets are comparatively isolated. In more recent years, however, these markets have grown more interdependent in the sense that information affecting asset prices has become more global in nature. We also find that during the pre-crisis period, these small markets are more responsive to price changes in the Japanese market which suggests that a regional factor dominates the source of spillovers. However, during the post-crisis period, the small markets have become more sensitive to news originating in the US market which indicates that the world factor is the source of spillovers. Even though we find significant volatility spillovers in these markets, the volatility transmission is not all asymmetric in the sense the bad news (a market decline) in one market has a greater impact on the volatility of the next market to trade.

Discussion

Since governments have implemented financial liberalisation policies, the capital markets in South Asian countries have become more dependent upon news from their developed market counterparts which are often the sources of capital outflows. This fact is confirmed by the findings of significant return spillovers from both the world's largest (the US) and the region's largest (the Japanese) stock markets to all three South Asian stock markets.

The return and volatility spillovers observed from the US market to the Indian market are hardly surprising as the US is India's biggest foreign trade partner as well as its largest cumulative investor - both in Foreign Direct Investment (FDI) and Foreign Portfolio Investment (FPI). According to the International Financial Statistics Yearbook, for example, the FDI inflows from the US constituted about 16 percent of the total actual inflow into the economy in 2001. Out of the 538 Foreign Institutional Investors (FIIs) registered with the BSE, 220 were from the US. An investment of nearly USD7 billion out of a total of USD13 billion by FIIs in the Indian capital markets was from the US. This accounts for about 47 percent of the net investments made by the FIIs since 1993. However, FPI inflows are very volatile. For example, in 1998, FDI inflows from the US were negative. As Granger *et al.* (1999) highlighted, foreign investments to emerging markets are extremely volatile and depend on changing economic conditions. Since independence, Pakistan has had to depend on foreign assistance in its development efforts. Japan is its largest donor and the biggest investor. According to the International Financial Statistics Yearbook, the share of financial flows from Japan to Pakistan amounted to 91.9 percent, 39 percent, and 59 percent of total donations in 1998, 1999, and 2000 respectively. The total cumulative amount of net disbursement from Japan's Official Development Assistance (ODA) to Pakistan reached USD4 billion through 1999. As a result, it is not too surprising to find that the volatility of the Japanese capital market influences the volatility of Pakistan equity values. Due to the small size of Sri Lankan economy, export-oriented industries are extremely important. Sri Lanka and the US enjoy cordial trade relations. Since the proportion of exports to the US as a percentage of total exports has reached an average of 40 percent during 1993-2001, according to International Trade Statistics

Yearbook, we would therefore expect the volatility of the US economy to be transmitted to the Sri Lankan market.

It is interesting to see that the South Asian stock markets do not show any volatility spillovers from the US and/or Japan during the in-crisis period. The South Asian countries that were examined in this study have been relatively insulated from the 1997 financial crisis. One reason might be that the financial sectors of these counties might not have been libaralised to the extent that is evident in East Asian countries. Also, these countries, and in particular their companies, are less exposed to foreign debt.

V. Conclusion

This study investigates the magnitude and changing nature of the return and volatility spillovers from the US and Japan to the three small South Asian stock markets: namely India, Pakistan and Sri Lanka. We use a univariate Exponential Generalized Autoregressive Conditionally Heteroskedastic (EGARCH) spillover model to account for asymmetries in the volatility transmission mechanism, *i.e.* the possibility that bad news in a given market has a greater impact on the volatility of the returns of an other market than good news. We also attempt to distinguish world forces (the US) from regional factors (Japan). The tests cover the period 01/01/1993-31/12/2003. To examine whether or not there are structural shifts in the international market dynamics, the tests are also conducted for three sub-periods – pre-crisis, in-crisis, and post-crisis.

A number of findings emerge from the analysis. First, for the entire period analysed, both world and regional factors are important in explaining returns and volatility in the three South Asian countries examined, although the world market influence tends to be greater. We find evidence of significant return spillovers from the US and Japan to all three small markets. We also document evidence of volatility spillovers from the US to Sri Lanka and from Japan to Pakistan at the 5 per cent significance level and from the US to India at the 10 per cent significance level. Second, the volatility transmission mechanism is asymmetric but only from the US stock market, *i.e.* negative innovations in US equity prices increase volatility in the Indian and Sri Lankan stock markets considerably more than positive innovations. Third, no volatility spillovers existed during the period of Asian crisis. More spillovers, and spillovers of greater intensity, were uncovered during the post-crisis period. In most cases, spillovers during the post-crisis period were not asymmetric. Finally, the relative importance of the world and regional market factors was influenced by the Southeast Asian financial crisis. The sub-period analysis revealed that before the crisis, regional factors were more important than their world factor counterparts; in other words, the Japanese stock market was the source of price and volatility spillover for the South Asia region. However, after the crisis, the world factors dominate the regional factors; that is, the US stock market has had a larger impact on small South Asian stock markets.

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Table 1

Growth in South Asian Stock Markets

Market	Levels			Growth(%)	
	1993	1998	2003	93-98	93-03
Panel A: Market Capitalization (billion)					
BSE	3,050	4,770	13,479	56.40	341.93
KSE	70	266	951	280	1,268.57
CSE	124	117	263	-5.65	112.10
Panel B: Market capitalization as % of GDP					
BSE	35.54	27.43	49.00	-22.82	37.87
KSE	5.22	16.20	18.62	210.35	256.71
CSE	24.85	11.46	15.73	-53.88	-36.70
Panel C: Annual Turnover (billion)					
BSE	675	2,662	4,094	294.37	506.52
KSE	27	427	696	1,481.48	2,477.78
CSE	35	18	74	-48.57	111.43
Panel D: Number of Listed Companies					
BSE	3,263	5,860	5,644	79.59	72.97
KSE	630	773	701	22.70	11.27
CSE	201	240	244	19.40	21.39
Panel E: Value of the Price Index					
BSE	1,614	1,359	3,075	115.79	90.52
KSE	2,170	945	4,472	-56.45	106.08
CSE	979	597	1,062	-39.02	8.48

Note: This table reports market statistics for the Bombay Stock Exchange (BSE), the Karachi Stock Exchange (KSE) and the Colombo Stock Exchange (CSE). Market capitalization and the annual value of turnover are in local currencies. Source: Emerging Stock Markets Factbook, www.bseindia.com, www.kse.com.pk, and http://www.cse.lk.

Table 2

Preliminary Statistics on Stock Market Returns

Summary Statistics	US	JAP	IND	PAK	SRI
Panal A: Descriptive Statistics for the Daily Returns					
Sample Mean	0.0326	-0.0053	0.0332	0.0445	0.0196
	(1.6131)	(0.2325)	(1.1512)	(1.4199)	(0.9603)
Standard Deviation	1.0826	1.2207	1.5449	1.6784	1.0931
Skewness	-0.1122***	-0.1383***	-0.1894***	-0.3319***	1.1984***
	(-2.4348)	(-3.0000)	(-4.1087)	(-7.2174)	(26.0652)
Kurtosis	3.7728***	2.8248***	3.1798***	7.0057***	44.1719***
	(41.5495)	(31.1209)	(35.0220)	(77.1429)	(486.2747)
Jarque-Bera statistics	1707.6	963.0	1225.8	5919.8	233930.8
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
LB(6)	10.34	35.67	57.66	26.31	302.07
	[0.1110]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
LB(12)	20.61	41.58	72.75	49.81	328.63
	[0.0560]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
$LB^2(6)$	475.46	275.94	430.33	496.85	220.04
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
$LB^2(12)$	779.11	375.62	574.03	656.46	265.32
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
ARCH(12) *LM* statistics	298.57	198.53	263.62	321.87	218.70
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Panel B: Nonparametric Cross-correlations of Market Returns					
Countries	US	Japan	India	Pakistan	Sri Lanka
US	1	0.0880	0.0279	0.0071	0.0181
Japan		1	0.1232	0.0382	0.0393
India			1	0.0651	0.0501
Pakistan				1	0.0702
Sri Lanka					1

Note: The sample spans from January 01, 1993 to December 31, 2003 and includes 2869 daily observations. Returns and Standard Deviations are expressed in percentages. The Jarque-Bera statistic tests the normality of large samples using both skewness and kurtosis measures. LB(k) and $LB^2(k)$ are the Ljung-Box *q*-statistics for returns and squared returns respectively distributed as χ^2 with k degrees of freedom. For the autoregressive-conditional heteroscedasticity (ARCH) *LM* test, the null hypothesis is that ARCH effects are not present in the first 12 lags. Cross-correlation coefficients are measured by nonparametric Spearman's correlation coefficients. The *t*-statistics and *p*-values are provided in parentheses ( ) and [ ] respectively. The *** denotes the statistical significance at the 1 per cent level.

Table 3

EGARCH Model Estimation Results

Parameters	US	JAP	IND	PAK	SRI
Panel A: Conditional Mean Equation Coefficients					
α_0	0.0003*	-0.0003	0.0002	0.0002	0.0002
	(0.0001)	(0.0002)	(0.0003)	(0.0002)	(0.0001)
α_1	0.0239	0.0956***	0.1700***	0.1015***	0.4273***
	(0.0175)	(0.0165)	(0.0197)	(0.0085)	(0.0208)
α_2				0.0425**	0.0417**
				(0.0187)	(0.0208)
Panel B: Conditional Variance Equation Coefficients					
a_0	-0.1609***	-0.1924***	-0.2026***	-0.3666***	-0.9019***
	(0.0293)	(0.0423)	(0.0566)	(0.0617)	(0.1045)
a_1	0.1174***	0.1649***	0.1811***	-0.0116	0.4836***
	(0.0133)	(0.0162)	(0.0218)	(0.0101)	(0.0234)
b_1	0.9823***	0.9776***	0.9750***	0.9537***	0.9046***
	(0.0032)	(0.0047)	(0.0067)	(0.0074)	(0.0106)
θ	-0.1047***	-0.0622***	-0.0270***	-0.0116	-0.0030
	0.0118	(0.0098)	(0.0094)	(0.0101)	(0.0157)
Log Likelihood	9368.6	8822.2	8176.5	8038.5	9833.9
Wald Statistic	175668.4	55691.9	42299.4	26000.5	12592.7
Panel C: Diagnostics on Standardized and Squared Standardized Residuals					
Jarque-Bera statistic	332.0	331.2	1268.4	2627.0	20766.5
LB(6)	11.3219	3.4443	13.9290	22.4325	29.0984
	[0.0790]	[0.7510]	[0.0300]	[0.0010]	[0.0000]
LB(12)	20.0903	12.2238	26.7866	35.1847	40.4759
	[0.0650]	[0.4280]	[0.0080]	[0.0000]	[0.0000]
$LB^2(6)$	1.3605	7.0264	8.7173	3.5142	1.8959
	[0.9680]	[0.3180]	[0.1900]	[0.7420]	[0.9290]
$LB^2(12)$	2.1665	11.7111	13.2885	6.0631	5.3730
	[1.0000]	[0.4690]	[0.3480]	[0.9130]	[0.9440]

Note: α_1 and α_2 are the coefficients on the first order and second order autoregressive process specified for the mean equations. a_1 is the measure of the autoregressive conditional heteroskedasticity (ARCH) effect. b_1 is the measure of volatility persistence. θ is the measure of asymmetric effect. The null hypothesis for Wald test is $a_1 = b_1 = \theta$. Jarque-Bera statistic tests the normality of the standardized residual series. LB(k) and $LB^2(k)$ are the Ljung-Box *q*-statistics for the standardized residuals and squared standardized residuals distributed as χ^2 with k degrees of freedom. The standard errors and *p*-values are provided in parentheses ( ) and [ ] respectively. The *** denotes statistical significance at the 1 per cent level, the ** denotes at the 5 per cent level, and the * denotes at the 10 per cent level.

Table 4

Univariate EGARCH(1,1) Model of Return and Volatility Spillovers Results

Parameters	IND	PAK	SRI
Panel A: Return Spillover Coefficients			
α_0	0.0001	-0.0001	-0.0005
	(0.0002)	(0.0002)	(0.0001)
α_1	0.1684***	0.1053***	0.3864***
	(0.0195)	(0.0203)	(0.0205)
α_2		0.0439***	0.0682***
		(0.0152)	(0.0204)
β_1(from US)	0.0989***	0.0382**	0.0269***
	(0.0232)	(0.0180)	(0.0096)
β_2(from Japan)	-0.0346*	0.0600***	-0.0376***
	(0.0187)	(0.0185)	(0.0098)
Panel B: Volatility Spillover Coefficients			
a_0	-0.2149***	-0.2572***	-1.3001***
	(0.0615)	(0.0671)	(0.2050)
a_1	0.1872***	0.2584***	0.4569***
	(0.0218)	(0.0198)	(0.0226)
b_1	0.9729***	0.9472***	0.8459***
	(0.0076)	(0.0080)	(0.0194)
θ	-0.0282***	-0.0146	-0.0349**
	(0.0096)	(0.0105)	(0.0170)
c_1(from US)	0.0056*	0.0056	0.0209***
	(0.0029)	(0.0038)	(0.0064)
c_2(from JAP)	-0.0007	0.0097**	0.0096
	(0.0034)	(0.0045)	(0.0057)
Log Likelihood	8183.1	8048	9880
Wald statistic	36643.6	23930.8	11929.5
Likelihood Ratio (LR)	0.0016	0.0025	0.0094
Panel C: Diagnostics on Standardized and Squared Standardized Residuals			
Jarque-Bera statistic	1410.0	2271.1	18821.1
LB(6)	14.3324	22.195	26.346
	[0.0260]	[0.0001]	[0.0000]
LB(12)	27.7540	34.885	44.627
	[0.0060]	[0.0000]	[0.0000]
$LB^2(6)$	8.1119	2.937	1.612
	[0.2300]	[0.8170]	[0.9520]
$LB^2(12)$	12.6056	5.575	4.837
	[0.3980]	[0.9360]	[0.9630]

Note: α_1 and α_2 are the coefficients on the first order and second order autoregressive processes specified for the mean equations. a_1 is the measure of the autoregressive conditional heteroskedasticity (ARCH) effect. b_1 is the measure of volatility persistence. θ is the measure of asymmetric effect. The null hypothesis for Wald test is $a_1=b_1=\theta=c_1=c_2$. LR=2*[ln(log likelihood of unrestricted model)-ln(log likelihood of restricted model)]. The unrestricted model refers to the spillover model and restricted model refers to the univariate EGARCH(1,1) model. Jarque-Bera statistic tests the normality of the standardized residual series. LB(k) and LB^2(k) are the Ljung-Box *q*-statistics for the standardized residuals and squared standardized residuals distributed as χ^2 with k degrees of freedom. The standard errors and *p*-values are provided in parentheses ( ) and [ ] respectively. The *** denotes statistical significance at the 1 per cent level, the ** denotes at the 5 per cent level, and the * denotes at the 10 per cent level.

Table 5

Subperiod Return and Volatility Spillovers Results

Parameters	Pre-Crisis(1172 Observations)			In-Crisis(654 Observations)			Post-Crisis(1043 Observations)		
	IND	PAK	SRI	IND	PAK	SRI	IND	PAK	SRI
Panel A: Return Spillover Coefficients									
α_0	-0.0002	-0.0004	-0.0001	0.0005	-0.0003	0.0002	0.0002	0.0009**	0.0001
	(0.0005)	(0.0003)	(0.0001)	(0.0006)	(0.0007)	(0.0003)	(0.0004)	(0.0004)	(0.0002)
α_1	0.2817***	0.2227***	0.5988***	0.0572	0.0632	0.3804***	0.1096***	0.0011	0.3973***
	(0.0282)	(0.0332)	(0.0277)	(0.0389)	(0.0446)	(0.0393)	(0.0344)	(0.0349)	(0.0343)
α_2		0.0394							0.0066
		(0.0334)							(0.0351)
β_1 (from US)	-0.0005	0.0451	0.0292	0.1941***	0.1095	0.0352	0.1280***	0.0517*	0.0371***
	(0.0384)	(0.0475)	(0.0201)	(0.0531)	(0.0698)	(0.0258)	(0.0294)	(0.0274)	(0.0140)
β_2 (from Japan)	0.0770**	0.0577*	-0.0219*	-0.1064**	0.1175*	-0.0103	-0.0346	0.0368*	-0.0235
	(0.0387)	(0.0342)	(0.0127)	(0.0494)	(0.0648)	(0.0163)	(0.0284)	(0.0190)	(0.0147)
Panel B: Volatility Spillover Coefficients									
a_0	-0.1633*	-0.9776***	-1.0115***	-0.9785	-0.2762	-1.2784	-0.6184	-1.1255	-0.8053
	(0.0917)	(0.3355)	(0.2657)	0.4558	0.1616	0.4107	0.1822	0.2765	0.2061
a_1	0.1705***	0.3137***	0.5600***	0.0913	0.2003***	0.4254***	0.3496***	0.3410***	0.5784***
	(0.0282)	(0.0428)	(0.0482)	(0.0592)	(0.0354)	(0.0683)	(0.0567)	(0.0446)	(0.0412)
b_1	0.9762***	0.8645***	0.8784***	0.8858***	0.9352***	0.8544***	0.9266***	0.8882***	0.9127***
	(0.0093)	(0.0358)	(0.0191)	(0.0560)	(0.0205)	(0.0412)	(0.0224)	(0.0243)	(0.0146)
θ	0.0063	0.0299	0.0463	-0.0893***	-0.0569***	-0.0092	-0.0913***	-0.0329	-0.0467
	(0.0143)	(0.0243)	(0.0304)	(0.0293)	(0.0241)	(0.0359)	(0.0248)	(0.0248)	(0.0320)
c_1 (from US)	0.0068	-0.0106	-0.0030	-0.0036	0.0173	0.0152	-0.0222***	-0.0235**	-0.0232*
	(0.0056)	(0.0095)	(0.0113)	(0.0108)	(0.0109)	(0.0164)	(0.0095)	(0.0105)	(0.0122)
c_2 (from Japan)	-0.0039	0.0301***	0.0208**	0.0012	0.0163	-0.0194	0.0222**	0.0032	0.0073
	(0.0050)	(0.0090)	(0.0098)	(0.0160)	(0.0127)	(0.0168)	(0.0103)	(0.0100)	(0.0109)
Log Likelihood	3557.1	3585.0	4362.9	1754.8	1601.9	2278.7	2941.1	2918.5	3356.7
Wald statistic	18907.7	1291.3	3415.6	392.3	3494.8	1052.9	4538.4	2777.6	5517.5
Panel C: Diagnostics on Standardized and Squared Standardized Residuals									
Jarque-Bera statistic	725.0	180.9	632.4	126.7	550.9	78.8	53.4	461.4	16460.7
LB(6)	6.2091	14.2920	9.3241	9.1736	7.8576	12.1215	8.3227	7.5840	6.0126
	[0.4000]	[0.0270]	[0.1560]	[0.1640]	[0.2490]	[0.0590]	[0.2150]	[0.2700]	[0.4220]
LB(12)	13.8916	18.6630	18.2663	17.1463	16.4519	19.5879	15.1638	22.0721	15.3297
	[0.3080]	[0.0970]	[0.1080]	[0.1440]	[0.1710]	[0.0750]	[0.2330]	[0.0370]	[0.2240]
$LB^2(6)$	8.2867	5.1431	1.9895	2.6644	1.9672	2.7444	2.7100	7.2896	0.8446
	[0.2180]	[0.5260]	[0.9210]	[0.8500]	[0.9230]	[0.8400]	[0.8440]	[0.2950]	[0.9910]
$LB^2(12)$	10.7286	6.4961	4.5923	4.6227	3.9156	38.3501	9.5785	9.6050	2.2708
	[0.5520]	[0.8890]	[0.9700]	[0.9690]	[0.9850]	[0.0000]	[0.5910]	[0.6510]	[0.9990]

Note: α_1 and α_2 are the coefficients on the first order and second order autoregressive process specified for the mean equations. a_1 is the measure of the autoregressive conditional heteroskedasticity (ARCH) effect. b_1 is the measure of volatility persistence. θ is the measure of asymmetric effect. The null hypothesis for Wald test is $a_1=b_1=\theta=c_1=c_2$. Jarque-Bera statistic tests the normality of the standardized residual series. LB(k) and $LB^2(k)$ are the Ljung-Box *q*-statistics for the standardized residuals and squared standardized residuals distributed as χ^2 with k degrees of freedom. The standard errors and *p*-values are provided in parentheses ( ) and [ ] respectively. The *** denotes statistical significance at the 1 per cent level, the ** denotes at the 5 per cent level, and the * denotes at the 10 per cent level.