DO THE STOCK MARKETS OF SOUTH ASIA FOLLOW A RANDOM WALK?

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Abstract: This paper examines stock market behaviour in India, Sri Lanka, Pakistan, and Bangladesh employing unit root tests, autocorrelation tests and spectral analysis. Evidence suggests that all markets exhibit a random walk. The multivariate cointegration tests based upon the Johansen Juselius (1988, 1990) methodology indicate three long run stochastic trends. The results of the multivariate cointegration tests are corroborated by the Likelihood Ratio block causality tests which indicate a high degree of interdependence between the markets. The generalized impulse response analysis used to examine the effects of a India stock market price shock on the stock price indices of Sri Lanka, Pakistan and Bangladesh show that Pakistan and Sri Lanka are more responsive to price shocks in India than Bangladesh.

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1 Introduction

This study examines the behaviour of stock indices in India, Sri Lanka, Pakistan and Bangladesh employing post-deregulation data. The South Asian economies introduced a series of reforms starting in the 1980s and 1990s - Sri Lanka in 1977. The purpose of this study therefore is to see if the removal of restrictions on foreign investment in South Asia has led to weak form efficiency of the stock markets in this region. If stock markets are weak form efficient, stock prices are said to follow a random walk. The random-walk hypothesis states that price changes in stock prices are unpredictable. The information contained in past prices is fully and instantaneously reflected in current prices in an efficient market. Hence, the opportunity for any abnormal gain on the basis of the information contained in historical prices is eliminated.

Studies of stock price behaviour in the developing economies can be found in Magnusson and Wydick (2002), Chiang, Yang and Wang (2000) and Alam Hasan and Kadapakkam (1999). The results have been mixed. Magnusson and Wydick (2000) test the random walk hypothesis for a group of African countries and find that there is a greater degree of support for the African stock markets than for other emerging stock markets. Chian, Yan and Wang (2000) analyzing stock returns in a group of Asian economies find that most markets exhibit an autoregressive process rejecting the random walk hypothesis. Alam, Hasan and Kadapakkam (1999) test the random walk hypothesis for Bangladesh, Hong Kong, Sri Lanka and Taiwan. They find that all the stock indices except the Sri Lankan stock index follow a random walk. This study on the contrary, supports the random walk hypothesis for all four countries studied. The random walk hypothesis is tested using the ADF (1979) and Phillips Perron (1988) unit root tests, autocorrelation tests and spectral analysis. Evidence supports the random walk hypothesis. The bivariate and multivariate cointegration tests indicate a long run relationship between the stock market indices. Likelihood Ratio (LR) block causality tests are employed to examine the degree of linkage between the stock markets. The paper also examines how a standard deviation shock in the India stock price index affects the stock price indices of Sri Lanka, Pakistan and Bangladesh.

The paper is structured as follows. Part 2 describes the data. Part 3 presents the methodology. Part 4 evaluates the results and Part 5 summarizes the conclusions.

2 Data

The data set consists of stock market indices for India, Sri Lanka, Pakistan and Bangladesh. The stock indices used are the FTSE for India and Pakistan, the All Share Index for Sri Lanka and the S&P for Bangladesh. The data used are monthly and covers the period 1996.1 to 2003.10. All data series are obtained from DATASTREAM. In order to obtain a better understanding of the data, Table 1 presents summary statistics for the logarithms of the first differences of the stock prices indices.

Table 1

Statistics of the First Differences of the Stock Price Indices

	India FTSE	**Pakistan FTSE**	**SL All Share**	**Bangladesh S&P**
Maximum	.17205	.29203	.19330	.64531
Minimum	-.21175	-.47011	-.19112	-.35881
Mean	.00472	.00331	.00789	-.0047
Std Deviation	.08684	.12928	.06699	.12136
Skewness	-.4910	-.71437	.10562	1.6091
Kurtosis-3	.02459	1.5168	.29781	8.9116
Coef of Variation	18.403	39.074	8.0946	25.647

The data indicate that the means of the first differences for the India FTSE, Pakistan FTSE, and the Sri Lanka All Share Index are not far apart. For Bangladesh the mean is negative. The standard deviation of all the stock indices appear to move closely together. The first differences of the India FTSE and the Pakistan FTSE appear to be skewed to the left while the Sri Lanka All Share and Bangladesh S&P are skewed to the right. All the series appear to exhibit kurtosis. The coefficient of variation indicates that price changes have been relatively more variable in India, Pakistan and Bangladesh than in Sri Lanka.

Table 2 presents the pairwise co-movements among the changes in stock prices. The correlation coefficients are in the range of -.11 and 0.44.

Table 2

Estimated Correlation Matrix of Variables of Stock Price Changes

	India FTSE	Pakistan FTSE	Bangladesh S&P	All Share
India FTSE	1.0000	.44245	-.11289	.30887
Pakistan FTSE	.44245	1.0000	-.03387	.25320
Bangladesh S&P	-.11289	-.03387	1.0000	-.06294
All Share	.30887	.25320	-.06294	1.0000

Autocorrelation Tests

The Ljung Box statistics are examined in Table 3. Note that the normality of returns does not have to be assumed for the Ljung test. The null hypothesis is that the autocorrelation coefficients are equal to zero and the alternative is that they deviate from zero. If the t statistics for the autocorrelation coefficients fall within ± 1.96 the null hypothesis that ρ=0 is not rejected. The correlation coefficients for 1, 2, 4, 8 and 16 are reported.

Table 3

		Autocorrelation Coefficient	**Standard Error**	**Ljung Box Stastistics**
India FTSE				
	ρ1	-.10103	.10370	0.98028
	ρ2	.12123	.10475	2.4071
	ρ4	-.11432	.10700	4.4405
	ρ8	-.052010	.11001	6.4631
	ρ16	.046608	.12270	21.5050
Pakistan FTSE				
	ρ1	-.029728	.10370	.084868
	ρ2	-.065645	.10379	.50324
	ρ4	.12496	.10424	2.0631
	ρ8	.049862	.10790	4.3842
	ρ16	-.091562	.11263	10.3641
Bangladesh S&P				

ρ1	.30896	.10370	9.1669
ρ2	-0.77000	.11316	9.7425
ρ4	.11719	.11380	11.1819
ρ8	.020919	.12351	20.6825
ρ16	-.038024	.12810	26.5097
Sri Lanka All Share			
ρ1	.16615	.10370	2.6510
ρ2	.098532	.10652	3.5936
ρ4	-.019389	.10898	5.0967
ρ8	.014677	.11102	7.2020
ρ16	.084382	.11422	11.6351

Except the first autocorrelation coefficient for Bangladesh, the rest of the autocorrelation coefficients are not statistically significant. The t ratios for all the autocorrelation coefficients except the first autocorrelation coefficient for Bangladesh are within the critical value of the standard normal distribution at the 5% level. The results therefore can be said to support the random walk hypothesis.

3 Methodology

The random walk hypothesis is tested using unit root tests. Both the augmented Dicky Fuller test and Phillips-Perron (1987, 1988) tests based upon equations (1) and (2) are carried out to examine the univariate time series properties of the data to see if the random walk hypothesis holds. The Augmented Dickey Fuller (ADF) unit root test is based on the estimation of the following equation:

$$\Delta X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 T + \sum_{i=1}^{n} \beta_i \Delta X_{t-i} + \varepsilon_t \quad (1)$$

where X_t = the time series; T = linear time trend; ε_t = the error term with zero mean and constant variance. The null hypothesis of a unit root $\beta_1 = 0$; is tested against the alternative hypothesis, $\beta_1 < 0$. The Z_t statistic put forward by Phillips and Perron (1987, 1988) is a modification of the Dickey-Fuller *t* statistic which allows for autocorrelation and conditional heteroscedasticity in the error term of the Dicky-Fuller regression. This is based on the estimation of the following for $\alpha_2 = 1$:

$$\Delta X_t = \alpha_0 + \alpha_1 T + \alpha_2 X_{t-1} \quad \varpi_t \qquad (2)$$

Cointegration

The Johansen (1988) and Johansen and Juselius (1990) procedure is employed to test for a long-run relationship between the variables. Johansen and Juselius propose a maximum likelihood estimation approach for the estimation and evaluation of multiple cointegrated vectors. Johansen and Juselius (1990) consider the following model:

Let X_t be an nx1 vector of I(1) variables, with a vector autoregressive (VAR) representation of order k,

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \upsilon + e_t \qquad (3)$$

$t = 1, 2, \ldots\ldots T$

where υ is an intercept vector and e_t is a vector of Gaussian error terms.

In first difference form equation (3) takes the following form,

$$\Delta X_t = \Gamma_{k-1} \Delta X_{t-k+1} + \ldots + \Pi X_{t-k} + \upsilon + e_t \qquad (4)$$

where

$\Gamma_i = -(I - \Pi_1 - \ldots \Pi_i)$, $\quad$ *for* $i = 1, \ldots , k-1$

and

$\Pi = -(I - \Pi_1 - \ldots\ldots - \Pi_k)$

Π is an nxn matrix whose rank determines the number of cointegrating vectors among the variables in X. If matrix Π is of zero rank, the variables in X_t are integrated of order one or a higher order, implying the absence of a cointegrating relationship between the variables in X_t. If Π is full rank, that is, r=n, the variables in X_t are stationary; and if Π is of reduced rank, $0 < r < n$, Π can be expressed as $\Pi=\alpha\beta'$ where α and β are nxr matrices, with r the number of cointegrating vectors. Hence, although X_t itself is not stationary, the linear combination given by $\beta'X$ is stationary.

Johansen and Juselius propose two likelihood ratio tests for the determination of the number of cointegrated vectors. One is the maximal eigenvalue test which evaluates the null hypothesis that there are at most r cointegrating vectors against the alternative of r+1 cointegrating vectors. The maximum eigenvalue statistic is given by,

$$\lambda_{max} = -T \ln (1 - \lambda r+1) \qquad (5)$$

where λ r+1,….λn are the n-r smallest squared canonical correlations and T= the number of observations.

The second test is based on the trace statistic which tests the null hypothesis of r cointegrating vectors against the alternative of r or more cointegrating vectors. This statistic is given by

$$\lambda_{trace} = -T \Sigma \ln (1 - \lambda i) \qquad (6)$$

In order to apply the Johansen procedure, a lag length must be selected for the VAR.

Impulse Response and Forecast Error Variance Decomposition Analysis

Given that India is the largest country in this region, the study also examines the generalized impulse responses of Sri Lanka, Pakistan and Bangladesh to a price shock in India. Following Pesaran and Shin (1998), this can be represented by the following. If X_t has a VAR representation of the following form:

$$\Delta X_t = \mu + \sum_{i}^{p} \phi_i X_{t-i} + e_t$$

where μ is a vector of constant terms and is a vector of Gaussian error terms with $E(e_t)$ =0 and $E(e_t e'_t) = \Sigma = (\sigma_{ij})$. The generalized impulse response of X_{t+n} relating to a unit shock in the jth variable at time t is:

$$Z_n \Sigma \varepsilon_j / \sigma_{ij} \qquad n=0, 1, 2\ldots..$$

Where $Z_n = \phi_1 Z_{n-1} + \phi_2 Z_{n-2} + \ldots + \phi_p Z_{n-p}$ $\quad n=1, 2, 3,\ldots$ and Z_n =0 for $n<0$.

The forecast variance of i, n periods hence takes place due to the innovations in the jth variable. This can be calculated as:

$$\sigma_{ij}^{-1} \sum_{k=0}^{n} (\varepsilon'_i Z_k \Sigma \varepsilon_j)^2 / \varepsilon'_i Z_k \Sigma Z'_k \varepsilon_j \qquad i,j=1,..$$

The above equations will hold in a system of cointegrated variables.

Spectral Analysis

Spectral analysis is the study of time series in the frequency domain. The purpose of this analysis is to determine if the stock prices exhibit any systematic cyclical variation. The sample spectrum is the Fourier Cosine transformation of the estimate of the autocovarience function. The Fourier series is a representation of a function as a sum of harmonic terms such that;

$$f(x) = \sum_{\alpha=1}^{\infty} a_\alpha \sin \alpha x + 1/2\, a_0 + \sum_{\alpha=1}^{\infty} b_\alpha \cos \alpha x$$

$$\text{or} \qquad a_0/2 + \sum_{\alpha=1}^{\infty} c_\alpha \sin(\alpha x + \delta),$$

where δ = time lag and α = amplitude of price changes.

If δ is measured in radians per unit of time, sin αx repeats itself with period $2\pi/\alpha$ and therefore the number of cycles per unit or frequency is $\alpha/2\pi$ The period $2\pi/\alpha$ is a dimension of t. Spectral analysis permits the identification of any cyclical components in a data series. The angular frequency measured in radians per unit is represented by $2\pi/\alpha$. If p_t, the price series, contains a periodic element of period k and therefore the frequency, $2\pi/k$, the spectral densities will have a sharp spike at $\alpha = \alpha_{k}$.. If the filtered p_t does not contain any periodicities, the spectral densities will be smooth.

The spectral densities of the logarithms of the prices and their first differences are estimated for 150 lags. The spectral densities are estimated as follows:

$$F(\varpi_j) = 1/2\pi\, [\lambda_0 C_0 + 2 \sum_{K=0}^{\infty} \lambda_k C_k \cos \varpi_j k\,]$$

$\varpi_j = \pi j/m$ = j = 0, 1, 2, ….m, where m = 150 lags.

The estimated autocovariance is given by,

$$C_k = 1/\text{n-k}\, [\sum_{t=1}^{n-k} p_t\, p_{t+k} - 1/\text{n-k} \sum_{t=1+k}^{n} p_t \sum_{t=1}^{n-k} p_t\,]$$

With data, p_t, t=1, …n and the weights, λ_k are dependent upon *m*. Microfit computes the Bartlett, Tukey and Parzen estimates.

4 Empirical Results

Table 4 presents the time series properties of the data.

Unit Root Tests

Table 4

ADF and Phillips Unit Root Tests

	Log	Levels	Log First	Differences
Variable	**ADF**	**PP**	**ADF**	**PP**
India FTSE	-2.03	-2.63*	-9.73***	-13.31***
Pakistan FTSE	-1.55	-2.46	-8.84***	-7.30***
Bangladesh S&P	-1.33	-0.69	-8.24***	-6.91***
All Share	-1.02	-0.54	-6.80***	-8.71***

Note: The lag length for the ADF and Phillip-Perron regressions has been selected to ensure white noise residuals. A sixth order autoregressive model is used for the ADF test on the basis of the AIC and six lags on the Bartlett window are used for the PP test.
Significance levels with trend: 1%, -4.07 : 5%, -3.46 : 10% -3.16; without trend: 1%, -3.51 : 5%, -2.90, 10% -2.58 (Davidson and MacKinnon 1993).
*, **, *** significant at the 10%, 5% and 1% levels respectively.

Table 4 suggests that all stock market indices are I(1) confirming the random walk hypothesis of stock market prices and I(0) in the first differences.

Cointegration Tests

Table 5

Johansen-Juselius Maximum Likelihood Cointegration Test

Null	Alternative	mλ	Trace	95% critical value mλ	95% critical value Trace
		India FTSE-Pakistan FTSE			
r=0	r=1	10.18	13.31	15.87	20.18
r<=1	r=2	3.13	3.13	9.16	9.16
		India FTSE-All Share			
r=0	r=1	19.48	26.28	15.87	20.18
r<=1	r=2	6.79	6.79	9.16	9.16
		India FTSE-S&P			
r=0	r=1	41.70	50.80	15.87	20.18
r<=1	r=2	9.10	9.10	9.16	9.16
		PakistanFTSE-All Share			
r=0	r=1	6.96	8.48	15.87	20.18
r<=1	r=2	1.52	1.52	9.16	9.16
		PakistanFTSE-S&P			
r=0	r=1	41.25	48.90	15.87	20.18
r<=1	r=2	7.64	7.64	9.16	9.16
		All Share-S&P			
r=0	r=1	34.68	37.19	15.87	20.18
r<=1	r=2	2.51	2.51	9.16	9.16
		All			
r=0	r=1	44.64	116.89	28.27	53.48
r<=1	r=2	39.76	72.24	22.04	34.87
r<=2	r=3	26.05	32.47	15.87	20.18
r<=3	r=4	6.42	6.42	9.16	9.16

The cointegration tests presented in Table 5 indicate four cointegrating vectors for the six bivariate models, the India FTSE-All Share, IndiaFTSE-S&P, PakistanFTSE-S&P and All Share-S&P. The multivariate tests indicate three cointegrating vectors implying the existence of three common stochastic trends in the system of four variables.

Likelihood Ratio (LR) Tests of Block Non- Causality

LR tests of block causality are performed to see if lags of changes in stock markets indices cause changes in other stock market indices. The block causality tests involve estimation of the multivariate regressions:

$$\Delta P_{It} = \alpha_1 + \psi_1 \Delta P_{It-1} + \psi_2 \Delta P_{SLt-1} + \psi_3 \Delta P_{Pt-1} + \psi_4 \Delta P_{Bt-1} + v_{1t} \qquad (7)$$

$$\Delta P_{SLt} = \alpha_2 + \gamma_1 \Delta P_{SLt-1} + \gamma_2 \Delta P_{It-1} + \gamma_3 \Delta P_{Pt-1} + \gamma_4 \Delta P_{Bt-1} + v_{2t} \qquad (8)$$

$$\Delta P_{Pt} = \alpha_3 + \phi_1 \Delta P_{Pt-1} + \phi_2 \Delta P_{It-1} + \phi_3 \Delta P_{SLt-1} + \phi_4 \Delta P_{Bt-1} + v_{3t} \qquad (9)$$

$$\Delta P_{Bt} = \alpha_1 + \gamma_1 \Delta P_{Bt-1} + \gamma_2 \Delta P_{It-1} + \gamma_3 \Delta P_{SLt-1} + \gamma_4 \Delta P_{Pt-1} + v_{4t} \qquad (10)$$

Table 6 presents summary statistics for the Likelihood Ratio tests of block causality.

The chi square statistics for the LR causality tests are all below the 5% critical value of 7.81 suggesting bi-directional causality between all the indices. The null hypothesis that changes in the India FTSE does not cause changes in the stock market indices of Sri Lanka, Pakistan and Bangladesh cannot be rejected at the 0.73 level of significance and that the stock price indices of Sri Lanka, Pakistan and Bangladesh do not cause changes in the India FTSE cannot be rejected at the 0.50 level of significance.

Table 6

LR Tests of block non-causality:
ΔP_{It} does not Granger cause $\Delta P_{SLt}\, \Delta P_{Pt}\, \Delta P_{Bt}$; $\chi^2(3) = 1.29(0.73)$

$\Delta P_{SLt}\, \Delta P_{Pt}\, \Delta P_{Bt}$ do not Granger cause ΔP_{It} ; $\chi^2(3) = 2.36(0.50)$
ΔP_{SLt} does not Granger cause $\Delta P_{It}\, \Delta P_{Pt}\, \Delta P_{Bt}$; $\chi^2(3) = 3.12(0.37)$

$\Delta P_{It}\, \Delta P_{Pt}\, \Delta P_{Bt}$ do not Granger cause $\Delta P_{SLt;}$ $\chi^2(3) = 0.36(0.95)$
ΔP_{Pt} does not Granger cause $\Delta P_{It}\, \Delta P_{SLt}\, \Delta P_{Bt}$; $\chi^2(3) = 0.08(0.99)$

$\Delta P_{It}\, \Delta P_{SLt}\, \Delta P_{Bt}$ do not Granger cause $\Delta P_{Pt;}$ $\chi^2(3) = 3.43(0.32)$
ΔP_{Bt} does not Granger cause $\Delta P_{It}\, \Delta\, \Delta P_{SLt}\, P_{Pt}$; $\chi^2(3) = 1.46(0.69)$

$\Delta P_{It}\, \Delta P_{SLt}\, \Delta P_{Pt}$ do not Granger cause $\Delta P_{Bt;}$ $\chi^2(3) = 1.12(0.77)$

Similarly the hypothesis that the changes in the stock price indices of India, Pakistan and Bangladesh do not cause changes in the Sri Lanka All Share Index cannot be rejected at the .95 per cent level of significance while the hypothesis that changes in the Pakistan FTSE does not cause changes in the stock indices of India, Sri Lanka and Bangladesh cannot be rejected at the .99 level of significance. The hypothesis that changes in the Bangladesh S&P do not cause changes in the India FTSE, Sri Lanka All Share Index and Pakistan FTSE cannot be rejected at the 0.69 level of significance and the hypothesis that changes in the India FTSE, Sri Lanka All Share Index and Pakistan FTSE do not cause changes in the Bangladesh S&P cannot be rejected at the 0.77 level of significance. These results appear to be consistent with the multivariate cointegration results.

Impulse Response Analysis

This section examines the generalized impulse responses of Pakistan, Bangladesh and Sri Lanka to a price shock in India. Figures 1-6 show the generalized impulse response functions for each country with respect to a standard deviation price shock in India.

Figure 1 shows the generalized impulse response function of the India FTSE with response to a price shock in India of the India FTSE and the generalized impulse response of the Pakistan FTSE to a standard deviation shock of the India FTSE. Figures 2 and 3 show the impulse response of Bangladesh and Sri Lanka respectively to a standard deviation shock of the India FTSE. A standard deviation shock in the India FTSE has greater and more variable effect on the Sri Lanka and Pakistan stock price indices. In Bangladesh on the other hand, the effect of a standard deviation shock of the India FTSE is smaller and appears to wane with time.

Figure 1

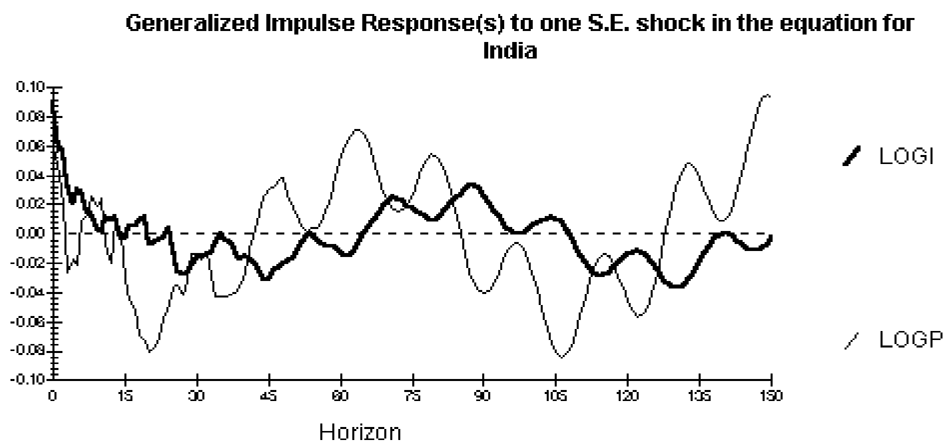


Figure 2

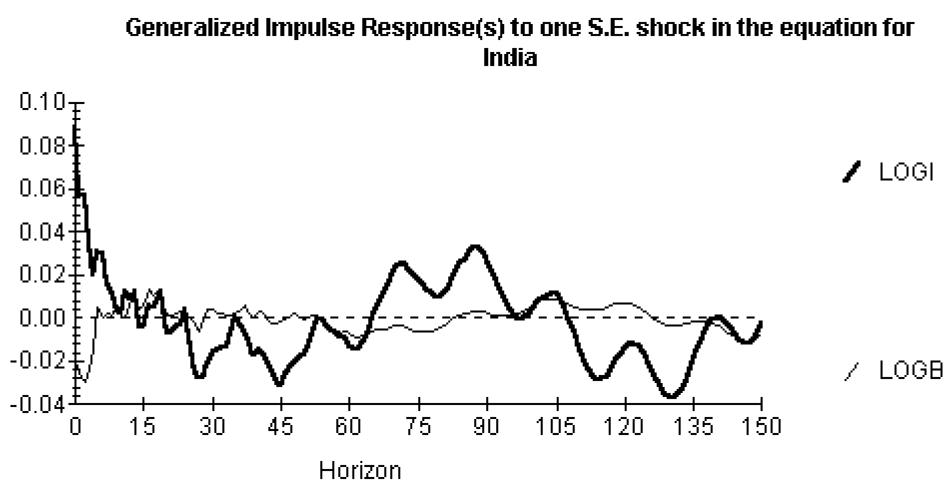
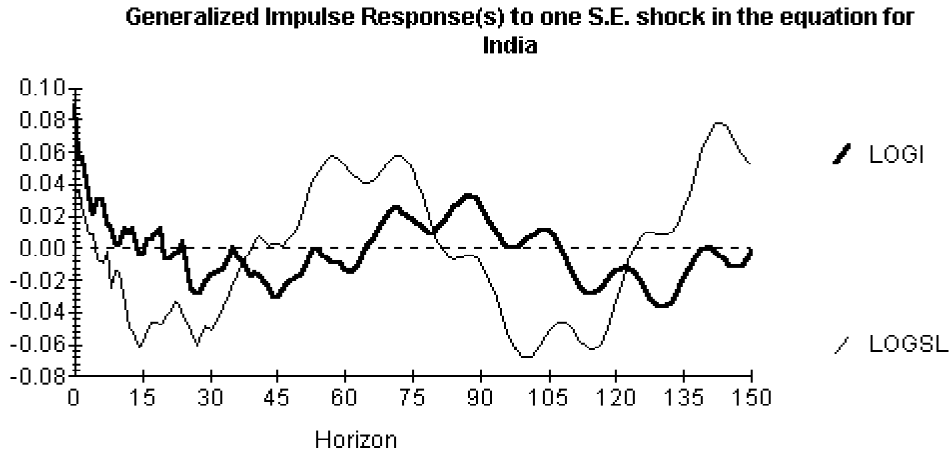


Figure 3



Spectral Analysis

The spectral densities are estimated for the Hodrick Prescott filtered stock price series using the Bartlett, Tukey and Parzen lag windows (see Figures 4-7 and Appendix for the spectral density functions). Figures 4-7indicate the absence of any cyclical movement in the stock prices. The spectrum decreases as the frequency increases. There appears to be a sharp peak in all the indices that corresponds to a frequency of 0.3. However, there are no systematic cyclical variations. The spectral analysis results therefore appear to support the random walk hypothesis.

Figure 4

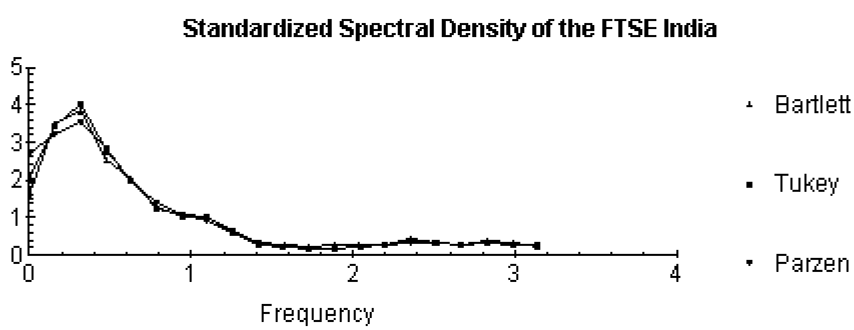


Figure 5

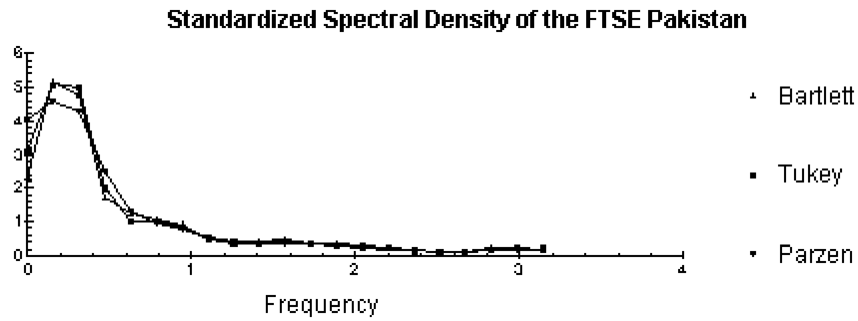


Figure 6

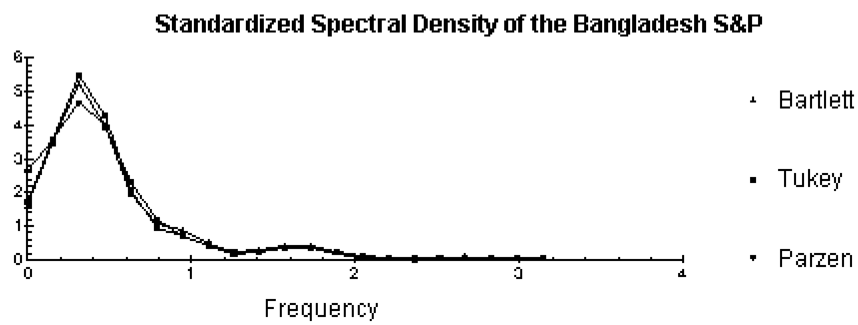
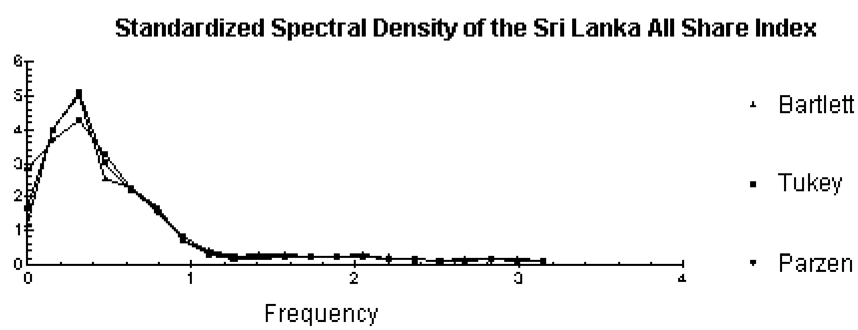


Figure 7



5 Conclusion

This paper examines the efficiency of the stock markets of India, Sri Lanka, Pakistan and Bangladesh. The paper finds that all markets exhibit a random walk indicating weak form efficiency in the stock markets of South Asia. The multivariate cointegration tests indicate that the markets share three long run stochastic trends suggesting that they are highly integrated in the long run. These results are further supported by the block causality tests. The generalized impulse response functions show that stock price shocks in India have greater effects on Pakistan and Sri Lanka than on Bangladesh.

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