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Efficiency of the foreign exchange markets in South Asian Countries

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Abstract:

This paper examines the weak form efficiency of the foreign exchange markets in seven SAARC countries using monthly return series for each of these markets over a period of 21 years (1985 – 2005). We applied a battery of unit root tests and variance ratio tests (individual and multiple) to see whether the return series (and also, the raw data) follow random walk process. Our results suggest that the increments of the return series are not serially correlated. Therefore, we conclude that foreign exchange markets in SAARC countries are weak form efficient.

JEL Classification: F31

Keywords: Exchange rates; Market efficiency; Variance ratio test; Random walk; SAARC

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1. Introduction

Market efficiency, as explained by Fama (1970), is the characteristic of a market such that the market prices (e.g., the exchange rate which is the price of one currency in terms of another currency) fully and instantaneously reflect all relevant information. In a perfectly efficient market, market prices change in an unpredictable pattern and market participants cannot earn any excess profit based on any available information, or past prices. Fama (1991) categorized market efficiency into three degrees – weak, semi-strong, and strong form of market efficiency. In its weak form, market prices reflect all information derived from market trading data such as past prices, trading volume etc. Solely based on historical prices or other trading data, investors cannot predict future price and earn abnormal return, although investors may gain excess profit by exploiting other public or private information. In this paper, we focus only on the weak form efficiency of foreign exchange markets in seven SAARC countries. SAARC (The South Asian Association for Regional Cooperation) is an economic and political organization of eight countries namely India, Pakistan, Bangladesh, Sri Lanka, Nepal, Bhutan, Maldives, and Afghanistan, the latest member since April 2007. We studied the market efficiency of the first seven countries in this regional bloc. In a weak form efficient foreign exchange market, time series of spot rate show the properties of nonstationarity and follows random walk process. Each spot rate at any moment depends upon its own random shock that governs the direction of the rate's next movement. These random shocks or error term, like spot rate, also constitute a time series in which they are not serially correlated.

The remaining paper is organized as follows. Section 2 reviews relevant empirical literature while data and descriptive statistics are discussed in section 3. Methodological issues are highlighted in section 4 and results and findings are recorded in section 5. A final section concludes the paper.

2. Literature Review

To test the weak form efficiency of time series, a good number of methods have been developed. A common and popular method to test the nonstationarity is ADF (augmented Dicky-Fuller) test. This conventional test examines the unit root null of the autoregressive time series. Although ADF test can decide whether the time-series is difference stationary or trend stationary, a necessary property for random walk process, it is not able to detect the serial correlation of error terms. A time series with serially uncorrelated error terms does not have any predictable pattern whereas a series with unit root, although nonstationary, can still show predictability (Rahman and Saadi, 2007). Apart from low power of the ADF test, using too-short time intervals and low-frequency series that consider outliers or transitory movement as permanent trend breaks causes a spurious rejection of the unit root null hypothesis. Still, several researchers (e.g. Messe and Singleton (1982), Corbae and Ouliaris (1986) and Coleman (1990)) use ADF tests, find unit roots in major foreign exchange rates, and claim the presence of random walk behavior in those foreign exchange markets. Wu and Chen (1998) examine the hypothesis of foreign exchange market efficiency in nine OECD countries. They analyze the unit-root property of forward premia by employing the panel unit-root test and examine the stationarity of interest differentials. They find that the null hypothesis of unit root in the forward premium can be rejected and interest differentials are stationary that support the hypothesis of foreign exchange market efficiency.

Lo and Mackinlay (1988) develop a better method, variance ratio test, to identify whether a financial time series truly follows random walk process or not. According to variance ratio test, if the return series of foreign exchange rate is random, the variance of k-period return is k times the variance of a single-period return. Rejecting the null hypothesis of variance ratio of unity would imply serial correlations in returns, mean reversion in time series, and return predictability. The variance ratio tests whether the variance of the increments in a random walk is linear in the sampling lag. Lo and Mackinlay develop a standardized test statistic that has an asymptotic standard normal distribution. Besides, there are separate versions of statistics for both homoscedastic increments and heteroscedastic increments. Many researchers (e.g. Ayadi and Pyun (1994), Huang

(1995), Chang and Ting (2000), Darrat and Zhong (2000), Lee, Chen, and Rui (2001), Urrutia (1995), Grieb and Reyes (1999)) used Lo–Mackinlay VR tests to examine the random walk hypothesis mostly in emerging stock markets. Huang (1995) find that stock markets in Korea, Malaysia, Hong Kong, Singapore, and Thailand are not efficient in its weak form. Darrat and Zhong (2000) find that two Chinese stock markets (Shanghai and Shenzhen) do not follow random walk process although they are more in favor of model-comparison approach due to its more decisive result. Liu and He (1991) and Ajayi and Karemera (1996) use a variance ratio test and reject the random walk hypothesis in major and Asian foreign exchange rates. Using VR test, Smoluk *et al.* (1998) find random walk behavior in U.K. pound/U.S. dollar real exchange rate. Although the pound–dollar real exchange rates has mean reverting tendencies due to the purchase power parity (PPP), frequent and strong shocks to the nominal exchange rate assume that the series follows a random walk since these shocks directly influence real exchange rate. The random walk hypothesis is also not rejected for the pound–dollar monthly nominal exchange rates and it suggests that a random walk in nominal exchange rates should lead to a random walk in real exchange rates. Lee, Pan, and Liu (2001) employ a joint variance ratio test and technical trading rules to investigate the random walk behavior for nine Asian foreign exchange rates for the period 1988-1995. They first investigate the serial correlation version of random walk hypothesis by using the variance ratio test of Lo and Mackinlay (1988). They apply a joint variance ratio test to see if all variance ratios over a particular lag length simultaneously equal unity. The joint variance ratio test results show little evidence of serial correlations for all the exchange rates, except the Kor (Hoque *et al*., 2007). Kawakatsu and Morey (1999), Ryoo and Smith (2002), Abraham, Seyyed, and Alsakran (2002), Smith *et al*. (2002), Smith and Ryoo (2003), Lima and Tabak (2004), Buguk and Brorsen (2003) apply the Chow–Denning and multiple VR tests to examine RWH. Kawakatsu and Morey (1999) study the effect of financial liberalization on the efficiency of emerging equity markets and find that markets have been already efficient prior to the actual liberalization. Ryoo and Smith (2002) find that price limit system prevents Korean stock market to follow random walk process since market approaches to a random walk when price limits are relaxed. Smith *et al.* (2002) reject random walk hypothesis for seven medium and small size African stock markets due to the presence of serial correlation in return series. Smith and Ryoo (2003) find serial correlation of returns in four European emerging stock markets (Greece, Hungary, Poland, and Portugal). Lima and Tabak (2004) suggest that liquidity and market capitalization may affect the market efficiency based on their findings in different classes of shares in Chinese, Hong Kong, and Singapore stock markets.

In addition to Lo-Mackinlay and Chow-Denning tests, Hoque, Kim, & Pyun (2007) use two new variance ratio tests (Wright's (2000) rank and sign tests and Whang-Kim (2003) sub-sampling tests) to re-examine the random walk hypothesis for eight emerging equity markets in Asia and find that stock markets in Indonesia, Malaysia, Philippines, Singapore, and Thailand show significant mean-reverting and predictable behavior in their weekly return series, while Taiwanese and Korean stock markets exhibit some mean-reverting, but largely unpredictable patterns in the same series.

There are other relatively less adopted methods to examine random walk process in time series. Oh, Kim, and Eom (2007) investigate the degree of randomness in the time series of various foreign exchange markets by using the approximate entropy (ApEn) method. They find that the market with a larger liquidity such as European and North American foreign exchange markets have higher market efficiency than those with a smaller liquidity such as the African and Asian markets except Japan. Aron and Ayogu. (1997) apply cointegration methodology to test foreign exchange market efficiency in Sub-Saharan African countries. They use monthly parallel market and official exchange rates for South Africa to test weak form efficiency by a variant of the martingale model and find that exchange rate returns are predictable by past values of the exchange rate and the market is inefficient.

Although there have been many studies that investigated foreign exchange market efficiency in many countries around the globe, there is dearth of investigations that involves South Asian markets. Recently, Ahmed, *et al.* (2005) report their findings that the returns series in South Asian foreign exchange markets are stationary during the period from 1999 to 2004. They reject random walk hypothesis for those markets by using the Runs test. The current paper involves longer period of data which is required to detect the tendency of mean reversion in a time series. In addition, it employs more advanced techniques to test for efficiency in the foreign exchange market.

3. Data and Descriptive Studies

The current paper looks into the weak form efficiency of the foreign exchange markets in a set of South Asian countries which are members of SAARC. The data for this paper are of monthly frequency and span over 21 years from 1985 through 2005. This means that for each country, we have over 250 observations. The data for this paper are collected from the International Monetary Fund's (IMF) *International Financial Statistics*.

We obtain the return series in the foreign exchange market as follows. Let S_t be the nominal exchange rate defined as the price of a foreign currency in units of local currency. Then the simple net return, R_t, on this asset between period t–1 and t is given by

$$R_t = \frac{S_t}{S_{t-1}} - 1 \tag{1}$$

The simple gross return can be defined as (1+ R_t). The continuously compounded return, r_t, is then just the log of the gross return, i.e.

$$r_t = \log(1 + R_t) = s_t - s_{t-1} \tag{2}$$

where, the lower cases denote the logarithm of each variable.

Table 1: Summary Statistics of monthly SAARC foreign exchange returns

	Bangladeshi (Taka)	Bhutan (Ngultrum)	Indian (Rupee)	Maldives (Rufiyaa)	Nepalese (Rupee)	Pakistani (Rupee)	Sri Lanka (Rupee)
Mean (μ)	0.0037	0.0051	0.0051	0.0024	0.0056	0.0053	0.0054
t (μ = 0)	7.920*	4.019*	4.039*	1.571	4.744*	6.508*	6.580*
S.D.	0.0074	0.0201	0.0200	0.0242	0.0187	0.0129	0.0130
Skewness	2.4626	5.7939	5.8040	9.5915	3.7468	2.8212	1.8887
Ex Kurtosis	8.2889	50.809	50.929	124.15	24.275	10.555	16.308
Q (6)	28.36*	10.92**	10.95**	6.98	19.10*	39.28*	6.43
Q(12)	35.24*	11.80	11.68	9.20	22.35*	46.50*	8.29
JB	972.24*	28403.07*	28535.65*	165045.2*	6750.12*	1498.10*	2930.63*

*Notes: t, testing mean equal to zero; The critical value Jarque-Bera JB statistic for normality is 5.99 for the 5% level of significance. Q(q) is the Ljung–Box Q statistic for testing q–order joint serial correlation, which distributes as a chi–square with q degrees of freedom. * (**) Indicates significance at 5% (10%) level.*

Table 1 provides summary statistics of the data. In all cases, the means are statistically significant indicating presence of nonzero return on holding foreign exchange. The Jarque-Bera (JB) test of normality shows that the return distributions do not conform to the theoretical normal distribution. Moreover, the excess kurtosis (equals zero in case of normal distribution) on all foreign exchange returns indicates that their distributions have thick tails. The Ljung–Box (1978) *Q* statistic is calculated for testing the joint null hypothesis that all autocorrelations up to a certain lag are zero. We choose to see the test statistic at 6 and 12 lags, as the frequency of the data is monthly. The results are mixed. Five test statistics out of seven return series reject the joint null of no autocorrelations at lag 6. However, at lag 12, the number of series that suffers multiple serial correlation decreases to 3.

4. Methodology

4.1. The Lo– MacKinlay Variance ratio Test

An important property of the random walk hypothesis is that the variances of random walk increments must be a linear function of the time interval (Campbell *et. al.* 1997). For log prices, where continuously compounded returns, r_t, (as given as in equation 2 above) are independently and identically distributed, the variance of the $(r_t + r_{t-1})$ must be twice the variance of r_t, or $Var\ (r_t + r_{t-1}) = 2\ Var\ (r_t)$. The ratio of these 2 variances, $VR(2)$ is given by, $VR\ (2) = Var\ (r_t + r_{t-1})\ /\ 2\ Var\ (r_t)$. It is straightforward to show that $VR(2) = 1 + \rho(1)$, where $\rho(1)$ is the first-order autocorrelation coefficient of returns (r_t). For any stationary time-series, the population value of the variance ratio statistic $VR(2)$ is simply $1 + \rho(1)$. However, if the market is efficient and the return series follows random walk, all $\rho(k)$ are zero and, therefore, $VR(2) = 1$. However, in the presence of nonzero autocorrelations, variance ratio will be different from unity, below or above.

The two-period variance ratio constructed above can be extended for the general q-period variance ratio statistic. The general q-period variance ratio statistic $VR(q)$ satisfies the following relation

$$VR(q) = [Var(r_q) / qVar(r_t)] = 1 + 2\sum_{k=1}^{q-1}(1-\frac{k}{q})\,\hat{\rho}(k) \tag{3}$$

where, $r_q \equiv r_t + r_{t-1} + \ldots\ldots\ldots\ldots + r_{t-k+1}$ and $\hat{\rho}(k)$ is the k^{th} order autocorrelation coefficient of r_t. The above equation shows that *VR(q)* is a particular linear combination of the first k–1 autocorrelation coefficients of r_t, with linearly declining weights. Again, if the market is efficient and return series follows random walk, then for all q, $VR(q) = 1$, since $\rho(k) = 0$ for all $k \geq 1$.

If we define the variance ratio as in the equation 3 above and T is the number of observations in a time series, Lo and MacKinlay (1988) define another measure $|Z(q)|$

$$\left|Z(q)\right| = \frac{\sqrt{T}\,(VR(q)-1)}{\sqrt{[2(2q-1)(q-1)]/3q}} \sim \mathrm{N}(0,\,1) \tag{4}$$

which follows standardised normal distribution and is robust to both heteroscedasticity and non-normality. This statistic is typically used for the variance ratio test of random walk hypothesis.

4.2. The Chow–Denning (CD) Test

A problem with the Lo–Mackinlay variance ratio test is that it focuses on the comparison between the variance of a single period return and that of the return of a particular lag at a time. However, conducting separate individual tests for a number of lags may over-reject the null hypothesis. To avoid this problem, Chow and Denning (1993) develop a multiple VR test with the null hypothesis that $VR(q_i) = 1$, for $i = 1\ldots l$. *The Chow–Denning* (1993) test statistic is

$$CD = \max_{1 \leq i \leq l} \left|Z(r_t; q_i)\right| \tag{5}$$

The test utilises the idea that the above null hypothesis can be either rejected or accepted on the basis of the maximum absolute value of individual variance ratio statistics. The CD test statistic follows the studentised maximum modulus distribution with l and T degrees of freedom. The critical values of this test are tabulated in Stoline and Ury (1979).

5. Results and Findings

This section presents results and findings of our estimation. First, we test for unit root in original exchange rates series of our sample. Table 2 reports three different unit root test results, namely, the Augmented Dickey–Fuller, or the ADF test (Dickey and Fuller, 1981), the ADF–GLS test (proposed by Elliott *et al.*, 1996) and the KPSS test (Kwiatkowski *et. al.* 1992). The last two tests are employed recognizing the poor power problem of the ADF test. Unlike the ADF and the ADF–GLS tests, the KPSS tests assume the null of stationarity against the unit root alternative. The test statistics in all cases show that the nominal exchange rates of these countries contain unit root.

Table 2: Unit Root Tests of SAARC Exchange Rates

Country	ADF	ADF–GLS	KPSS
1. Bangladesh	–2.526 (8)	–1.944 (1)	0.258 (5)
2. Bhutan	–0.573 (3)	–0.321 (0)	0.875 (5)
3. India	–0.573 (3)	–0.320 (0)	0.875 (5)
4. Maldives	–2.595(13)	–1.752 (0)	0.738 (5)
5. Nepal	–0.684 (2)	–0.411 (1)	0.908 (5)
6. Pakistan	–0.936 (3)	–1.343 (1)	0.445 (5)
7. Sri Lanka	–2.093 (6)	–1.882 (1)	0.187 (5)

Notes: Test equations for all cases include a constant and time trend. The critical values for the ADF–GLS test are –2.92 (5%) and –2.62 (10%) and for the KPSS test 0.146 (5%) and 0.119 (10%) The Lag lengths for the ADF and ADF–GLS tests are selected Swartz Bayesian Information Criterion. The Lag truncation parameter for the KPSS test is selected using formula $4(T/100)^{1/4}$.

Table 3 presents results of the same three unit root tests on the return series obtained by taking the first difference of the original exchange rates series. The ADF and ADF–GLS test results clearly reject the unit root null at all levels of significance. However, the null of stationarity under the KPSS test is also rejected in little more than 40% cases, while rest of the cases cannot reject the null. In other words, all of the return series do not appear to be stationary as under the case ADF test. The unit root tests applied on the returns data, on the whole, produce mixed results and we are far from passing conclusive verdict that the time series being considered are all stationary. In addition, for a time series to be a random walk, its increments have to be serially uncorrelated in addition to be nonstationary. Therefore, we go ahead to test for random walk hypothesis with the variance ratio tests which are more accurate in this regard.

Table 3: Unit Root Tests of SAARC Exchange Returns

Country	ADF	ADF–GLS	KPSS
1. Bangladesh	–6.718 (5)	–11.260 (0)	0.077
2. Bhutan	–7.556 (2)	–12.572 (0)	0.128**
3. India	–7.556 (2)	–12.565 (0)	0.128**
4. Maldives	–5.785 (12)	–15.104 (0)	0.021
5. Nepal	–8.990 (1)	–12.925 (0)	0.061
6. Pakistan	–4.345 (12)	–9.883 (0)	0.158*
7. Sri Lanka	–15.946 (1)	–15.933 (0)	0.087

See notes for Table 2

Table 4 reports the Lo–MacKinlay variance ratio test results. We calculate the variance ratios at lags 3, 6, 9 and 12. The values within parentheses under variance ratio statistics are $|Z(r_t, q_i)|$ that follows standard normal distribution. All test statistics fail to reject the null hypothesis that $VR\ (r_t,\ q_i) = 1$. In other words, all foreign exchange returns in our sample are random walk process. The foreign exchange markets in these countries therefore can be considered (weak form) efficient.

Table 4: Results of variance Ratio Tests

Country	*q* = 3	*q* = 6	*q* = 9	*q* = 12
Bangladesh (Taka)	1.464	1.750	1.809	1.870
	(1.643)	(0.567)	(0.259)	(0.153)
Bhutan (Ngultrum)	1.231	1.478	1.574	1.624
	(0.817)	(0.361)	(0.184)	(0.110)
India (Rupee)	1.231	1.479	1.576	1.627
	(0.819)	(0.362)	(0.184)	(0.110)
Maldives (Rufiyaa)	0.987	0.886	0.782	0.716
	(0.045)	(0.086)	(0.070)	(0.050)
Nepal (Rupee)	1.359	1.620	1.655	1.674
	(1.270)	(0.468)	(0.210)	(0.119)
Pakistan (Rupee)	1.536	1.745	1.792	1.829
	(1.536)	(0.563)	(0.253)	(0.146)
Sri Lanka (Rupee)	0.979	1.007	1.048	1.047
	(0.979)	(0.005)	(0.015)	(0.008)

Notes: Values within parentheses are $|Z(r_t, q_i)|$ *which is asymptotically distributed as standardized normal.*

Table 5 reports the results of the Chow–Denning test. The null hypothesis is that the variance ratio equals unity across all lags simultaneously. In our case, the joint test statistics in all instances fail to reject the joint null of random walk hypothesis. In other words, the foreign exchange markets in South Asian country seem to pass the tests of the Weak Form Efficient Market Hypothesis (WFEMH).

Table 5: Joint Test Results

Country	*CD*
Bangladesh (Taka)	1.643
Bhutan (Ngultrum)	0.817
India (Rupee)	0.819
Maldives (Rufiyaa)	0.086
Nepal (Rupee)	1.270
Pakistan (Rupee)	1.536
Sri Lanka (Rupee)	0.979

Notes: The 5% and 10% critical values for the CD test are 3.361 and 3.157, respectively.

6. Conclusion

In this paper, we investigated the weak-form efficiency for foreign exchange markets in seven SAARC countries during the period from 1985 to 2005. In our study, we emphasized more on Lo-Mackinlay variance ratio test and Chow-Denning joint variance ratio test rather than on conventional unit root tests. By running the ADF and KPSS unit root tests, we observed the unit root in both the return series and series of raw data. Again, both the variance ratio tests fail to reject the null of unit variance that implies no serial correlation and predictability in return series. Our results show that all these foreign exchange markets in South Asian region follow random walk process and, therefore, are weak-form efficient.

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