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Performance of GARCH Models in Forecasting the Exchange Rate Volatility of SAARC Countries

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Abstract

Volatility plays a key role in asset and portfolio management, derivatives pricing as well as exchange rate forecasting. In this paper we find out the performance of the Linear GARCH and Non-linear GARCH model for forecasting the exchange rate volatility of SAARC countries. Using the data from seven SAARC countries we have found that non-linear GARCH model gives better results and good forecasting performance for Maldives, Nepal, Pakistan and Sri Lanka whereas linear GARCH model gives better result and good forecasting performance for Bangladesh, Bhutan, and India.

Key words: ARCH-model, GARCH model, Ljung-Box Stat, Jarque-Berra Test.

Introduction

Exchange rates are the quintessential international financial variable, a factor in virtually every international financial market decision. For most countries the exchange rate is the single most important price in the economy. Without determining the appropriate exchange rate system no nation can achieve their economic goal, although country can be rich in wealth but bad exchange rate management can destroy the whole economy.

Before the Asian financial crisis most of the Asian countries used the fixed exchange rate system, after that they are changing their exchange rate arrangement. Now nation understand stand that exchange rate is not only dichotomy, fixed and freely floating, more beneficial need to in-between position. So, now exchange rate arrangement changing their trend and adjust the flexible exchange rate especially for developing countries and least developed countries (LDCs). In our study, we consider only SAARC (South Asian Association for Regional Co-Operation) countries. In 1985 the seven South Asian countries Bangladesh, India, Pakistan, Nepal, Bhutan, Maldives and Sri Lanka built up SAARC. In the 13th SAARC summit Afghanistan was declared as the 8th members of SAARC countries but it will be effective in the next 2006, so we put aside Afghanistan from our analysis. Among these seven countries Bangladesh, Nepal, Bhutan and Maldives are considered as LDCs and India, Pakistan and Sri Lanka are considered as developing countries.

Volatility plays a key role in asset and portfolio management, derivatives pricing as well as exchange rate forecasting. Accurate measures and good forecasts of volatility are crucial for the implementation and evaluation of asset and derivative pricing models in addition to trading and hedging strategies in foreign exchange market. Volatility also impact greatly on investing and financing decision-making, consumer behavior and so on.

Gokcan (2000) suggested that volatility is related to the stage of market development. Risk or the uncertainty of returns in emerging markets is typically higher than those in

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developed markets. As such, volatility in emerging markets is generally larger and more persistent than in developed markets. Volatility clustering or non-constant variance gives rise to thick tails or leptokurtosis. The presence of excess kurtosis or thick tails in asset returns implies that estimations based on the assumption of identical and independently distributed (i.i.d.) errors are inappropriate for asset returns. Further, there is strong evidence in the finance literature linking volatility in asset returns with higher order serial correlation. Against this background, the empirical distribution of asset return shows typically higher non-normality. Harvey and Huang (1992) find that foreign exchange volatility is higher when there is news of heavy central bank trading or there is a release of macroeconomic news. Longmore and Robinson (2004) compared the performance of linear GARCH models in forecasting the volatility of returns in the Jamaican foreign exchange market with that of asymmetric models, and also examined the relevance of volatility spill-overs using multivariate GARCH. McMillan and Speight (2004) conducted a study on reassessing the performance of GARCH Models. Zhang (2003) described his paper about Fixed versus Flexible Exchange Rate in China and told Getting exchange rate right is essential for economic stability and growth in the developing countries. Tabak, Chang and Andrade (2002) examined the relationship between dollar-real exchange rate volatility implied in option prices and subsequent realized volatility. Esquivel and Larrain (2002) described G-3 exchange rate volatility and evaluate its impact on developing countries. Walker (2002) focused only on a limited set of microstructure variables in a linear GARCH model.

Our aim in this paper is to fit both non-linear and linear GARCH models for modeling the volatility of exchange rates of SAARC countries to recommend a model for each country that enables us to capture more volatility.

Linear versus Non-linear GARCH Models

Recently many researches have been done about the volatility of foreign exchange market, most researchers agreed that volatility is forecastable in many foreign exchange markets, but there are differences in the way to use the model. Among these models different versions of the GARCH (Generalized Auto Regressive Conditional Heteroscedasticity) models are the most successful. One of the reasons that the GARCH models are very popular is that it can effectively remove the excess kurtosis in return series. Besides having excess kurtosis market returns may display seriously skewed distributions. The linear GARCH models cannot cope with such skewness, and therefore we can expect forecast of linear GARCH model to be biased for skewed time series. To deal with this problemy non-linear GARCH models are introduced, which take into account skewed distributions; for example, Quadratic GARCH model (QGARCH) introduced by Engle and Ng (1993) and Santana (1995), the model introduced by Glosten, Jogannathan, and Runkle (1992) is the GJR model, and that introduced by Nelson (1991) the Exponential GARCH model (EGARCH). One should raise the question about the usefulness of linear or non-linear GARCH models to explain the past volatility and forecast the future volatility for emerging markets.

These markets have very different risk and return characteristics from developed markets. The risk of investing in emerging markets has been greater than that of investing in developed markets. In other words, emerging foreign exchange market volatility has been larger than that of developed foreign exchange markets.

According to asset pricing theories expected returns are related to volatility. Therefore, for portfolio management it becomes critical to model and examine the volatility. In this research we compare the EGARCH model only with the linear GARCH model.

Data and Descriptive Statistics

The data we analyze here is the weekly exchange rate returns for SAARC countries, from January, 1998 to June, 2005. We choose the data from the year of 1998 because Asian crisis occurred in 1997. After that crisis in financial sector as well as in exchange rate market some developing countries followed the managed floating or freely floating exchange rate system. Before 1998 those countries followed the fixed exchange rate system, but GARCH or EGARCH model cannot work in fixed exchange rate, because in normally there is no volatility in fixed exchange rate system. Weekly return indexes of emerging markets are obtained from the website (URLhttp://pacific. commerce. ubc.ca/xr/) or (http://fx.sauder.ubc.ca/). Weekly returns are calculated by using the following formula:

$$r_{it} = \log(I_t) - \log(I_{t-1})$$

where I_t is the return index for country i at time t.

Some of the descriptive statistics for weekly returns are displayed in Table1. Sample size is the number of the weeks for the sample. In total the sample size (from January 1998 to June 2005) is 390. Table1 premises the mean returns of the emerging markets range from -0.121(Afghanistan (Afghani/USD)) to 0.1229% (Sri Lanka (Rupee/USD)). Volatility (measured as a standard deviation) ranges from 0.23371% (Afghanistan (Afghani/USD)) to 2.17% (Maldives (Rufiyaa/USD)). All the emerging foreign exchange market returns are leptokurtic in the sense that kurtosis exceeds positive three (kurtosis for normal distribution should be positive three). Table1 also portrait that all the countries' return series bear significant skewness, and three out of the eight countries are negatively skewed (skewness for normal distribution should be zero). Negative skewness shows that the lower tail of the distribution is thicker than the upper tail, that is, market declines occur more often than market increases. So the results show that all countries bear significant skewness, excess kurtosis and deviation from normality.

We also report the Ljung-Box Q-statistics for squared residual. At lag 4, we reject the hypothesis of no autocorrelation at the 5% level of significance. Autocorrelated squared residuals are indications of GARCH type of heteroscedasticity. Also the Jarque-Berra statistics displayed in Table1 reject the normality for all the return series. Figure1 depicts the trend of exchange rate return for the SAARC countries.

Models

ARCH - Autoregressive Conditional Heteroskedasticity model

The ARCH-model was first presented by Engle (1982) and has since then received a lot of attention. First consider an ordinary AR (p) model of the stochastic process y_t.

$$y_t = c + \alpha_1 y_{t-1} + ... + \alpha_p y_{t-p} + u_t \quad (1)$$

Where u_t is white noise, the basic AR (p)-model is now extended so that the conditional variance of u_t could change over time. One extension could be that u_t^2 itself follows an AR(m)-process.

$$u_t^2 = \theta_0 + \theta_1 u_{t-1}^2 + ... + \theta_m u_{t-m}^2 + w_t \quad (2)$$

Where w_t is a new white noise process and u_t is the error in forecasting y_t. This is the general ARCH(m) - process (Engle,1982). For easier calculations and for estimation, a stronger assumption about the process is added.

$$u_t = h_t^{\frac{1}{2}} v_t \quad (3)$$

Where v_t is an i.i.d. Gaussian process with zero mean and variance equal to one, that is, $v_t \sim N(0,1)$. The whole model for the variance is then obtained as

$$\varepsilon_t \big|_{\psi_{t-1}} \sim N(0,1).$$

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \quad (4)$$

Where $\alpha_0 > 0$, $\alpha_i > 0; i = 1,2....q$ and Ψ_{t-1} is the information available at time t - 1. Now, when the process for the variance is defined, we add an additional equation for modeling y_t. The return price is modeled with a constant.

$$y_t = c + \varepsilon_t \quad (5)$$

This means that is an innovation from a linear regression.

Generalized ARCH (GARCH) model

Generalization of the ordinary ARCH-model is more prevalent today. Bollerslev (1986) introduced the structure of such GARCH model. The generalization is quite similar to the extension of an AR (p) to an ARMA (p, q). Formally the process can be written as

$$\varepsilon_t \big|_{\psi_{t-1}} \sim N(0, h_t)$$
$$h_t = \alpha_0 + \sum_{i-1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} \quad (6)$$

Where p and q are integers with, $\alpha_0 > 0$, $\alpha_i \geq 0$;i = 1,2....q and â j ≥0, j = 1,2,....p. Thus the additional feature is that the process now also includes lagged h_{t-1} values. For $p = 0$ the process is an ARCH (q). For $p = q = 0$ (an extension allowing $q = 0$ if $p = 0$), ε_t is white noise (Bollerslev 1986).

GARCH (1, 1) model

In equation (6) if we put $p = q = 1$ then the model becomes a GARCH(1, 1) process and we may write this process as

$$\varepsilon_t \big|_{\psi_{t-1}} \sim N(0, h_t) \quad (7)$$
$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$$

Where $\alpha_0 > 0, \alpha_1 \geq 0, \beta_1 \geq 0, \text{and}\ \alpha_1 + \beta_1 < 1$

Non-linear GARCH Model

A number of the researchers have found asymmetry in foreign exchange market return series and have observed that the negative return shocks seem to increase volatility more than positive return shocks of the same size (see Bollerslev, Chou and Kroner, (1992); Engle and Ng, (1993); Pagan and Schwert, (1990)). Despite the success of the linear GARCH model, it cannot capture the asymmetry and skewness of the foreign exchange market return series. Among the number of non-linear GARCH models the Exponential GARCH (EGARCH) model is the most commonly used. Nelson (1991) presents a model which is known as Exponential-GARCH or EGARCH. The idea is to loosen the positively constraints from the standard GARCH but still keep the non-negativity constraint on the volatility for the conditional variance. Nelson (1991) presents a model which is known as Exponential-GARCH or EGARCH. A suitable way of doing this is by establishing the following equation

$$\ln(\sigma_t^2) = \alpha_t + \sum_{i=1}^{\infty} \beta_i g(z_{t-i}) \;\; \beta \equiv 1 \quad (8)$$

Where the function can be formulated in different ways. According to Nelson (1991) this function can be formed as

$$g(z_t) = \theta . z_t + \gamma(|z_t| - E(z_t)) \quad (9)$$

To handle both the sign and the magnitude of, a slightly different model of the EGARCH is implemented by Laurent & Peters (2002)

$$\ln(\sigma_t^2) = \omega + (1 - \beta(L))^{-1}(1 + \alpha(L)) g(z_{t-i}) \quad (10)$$

Our interest centers on EGARCH model which can be written as:

$$\log(h_t) = \alpha_0 + \sum_{i=1}^{q} \alpha_i \left[\frac{|\varepsilon_{t-i}|}{\sqrt{h_{t-1}}} - \sqrt{2/\pi} \right] + \gamma \frac{\varepsilon_{t-i}}{\sqrt{h_{t-1}}} + \sum_{j=1}^{p} \beta_j \log(h_{t-j}) \quad (11)$$

In equation (11) the α_0, α_i, γ and â $_j$ are the parameters. Unlike the linear GARCH model there are no restrictions on the parameters to ensure non-negativity of the conditional variances. The EGARCH model allows good news (positive return shocks) and bad news (negative return shocks) to have a different impact on volatility, where the linear GARCH model does not (Engle and Ng, 1993). The parameter γ would cause the asymmetry. If γ = 0 then a positive return shock has the same effect on volatility as the negative return shock of the same amount. If γ less than zero, a positive return shock actually reduces volatility, if γ greater than zero, a positive return shock increases volatility.

In- sample Estimation

The parameter estimates, the value of the Akaike Information Criterion (AIC) and Log likelihood for both the GARCH (1, 1) and EGARCH (1, 1) model have been incorporated in Table2. We use AIC and log likelihood values to compare between models in equations (7) and (11). From Table2 it is also clear that for most of the countries the â parameter is usually significant at the 5%

level, expect for Bangladesh (Taka/USD) and Nepal (Rupee/USD) in case of EGARCH(1, 1) model. For all the countries á and â parameters are positive and also their sums are less than unity for GARCH(1,1). Again the estimation results for the EGARCH(1,1) model depicts that for all the countries both á and â parameters are positive and their sums are almost unity that authenticates the model as well fitted. The ã parameter is significant and is positive for all SAARC countries, which means a positive return shock increases volatility. Comparing the results of the EGARCH (1,1) model with the GARCH(1,1) model we obtain that for Maldives[d], Nepal[e], Pakistan[f] and Sri Lanka[g] non-linear GARCH(1,1)(i.e. EGARCH) model produces lower AIC and higher log likelihood values than the GARCH(1,1). On the other hand AIC and log likelihood values expedite that GARCH(1,1) model gives better results than EGARCH(1,1) model for Bangladesh[a], Bhutan[b] and India[c].

Forecasting

In order to evaluate the forecasting power of the different GARCH models we must have a true measure of the volatility (Day and Lewis, (1992); Pagan and Schwert, (1990); Franses and Van Dijk, (1996)). To measure the volatility for the foreign exchange market we have used the formula of Chong et al (1999), that is, we use the following formula to find the true so-called unconditional volatility:

$$\sigma_t^2 = (r_t - \bar{r})^2 \qquad (12)$$

Where σ_t^2 is the unconditional volatility, r_t is the actual weekly return for week t, and $\bar{r}$ is expected return for week. The expected return over 21 weeks is measured by calculating the arithmetic average of weekly returns from week 1 to week 20. The expected return for the first week of February, 2005 is measured by calculating the arithmetic average of weekly returns from first week of January, 1998 to last week of January, 2005. The expected return in second week of February, 2005 is measured by calculating the arithmetic average of weekly returns from second week of January, 1998 to first week of February, 2005. This is repeated for the 21 weeks from the first week of February, 2005 to last week of June, 2005. Squaring of the difference between actual returns and moving average returns would give us the implied volatility as in equation (12). We find one-period-ahead forecasting errors for different GARCH models as follows:

$$u_{t+1} = \sigma_{t+1}^2 - \hat{h}_{t+1} \qquad (13)$$

Where u_{t+1} is the forecasting error of the GARCH models, and $\hat{h}_{t+1}$ is the forecasted variance which is generated by using equations (7) and (11). In order to find the one-week-ahead forecast of the variance for first week of February, 2005, we use equations (7) and (11) to run the regressions by using the data from first week of January 1998 to last week of January, 2005 and obtain the constant parameters. Then these parameters are entered into equations (7) and (11) to find forecasted variances. In Table3 we report the mean squared errors obtained from GARCH(1,1) and EGARCH(1,1) models. The results indicate that for the countries Maldives[d], Nepal[e], Pakistan[f] and Sri Lanka[g] non-linear GARCH(1,1)(i.e. EGARCH) model produces smaller forecasting errors than the GARCH(1,1) model. We see that the AIC values with log likelihood and the mean squares error terms show the same result, that is, EGARCH outperform than GARCH model in the case of exchange rates for Maldives[d], Nepal[e], Pakistan[f] and Sri Lanka[g], however GARCH(1,1) model gives better result in case of Bangladesh[a], Bhutan[b] and India[c].

Conclusions

Linear and non-linear GARCH models are applied for forecasting the volatility of exchange rate to the SAARC countries. The return series are significantly skewed and leptokurtic, which is an indication of finding non-linear GARCH models as very helpful in explaining the volatility of the time series. Our comparative study reveals the superiority of non-linear GARCH model over linear GARCH model for explaining the exchange rates volatility in Maldives, Nepal, Pakistan, and Sri Lanka, but the linear GARCH model is superior to non-linear GARCH model for

Bangladesh, Bhutan and India. Therefore, we may confine that exchange rate volatilities are predicted well when the non-linear GARCH model is applied for Maldives, Nepal, Pakistan and Sri Lanka whereas linear GARCH model for Bangladesh, Bhutan and India.

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Table 1: Descriptive Statistics of SAARC Countries Weekly Exchange Rate Return

Country (Currency(symbol)/ USD) [Code]	Sample Size	Mean (%)	Standard Deviation (%)	Skewness	Kurtosis	Ljung-Box Stat Q (4)	Jarque-Berra Test
Bangladesh (Taka(Tk)/USD) [a]	390	0.0862	0.5474	4.2009	40.7549	82.264	24247.61
Bhutan (Ngultrum(Nu)/USD) [b]	390	0.0363	1.8510	2.8580	78.1300	283.45	92018.27
India (Rupee(Rs)/USD) [c]	390	0.0256	0.4001	-0.6758	14.7721	81.619	2276.09
Maldives (Rufiyaa(Rf)/USD) [d]	390	0.0226	2.1700	-0.0150	77.1271	389.51	89062.08
Nepal (Rupee(NRs)/USD) [e]	390	0.0623	0.9068	2.8930	34.5095	102.94	16635.19
Pakistan (Rupee(Rs)/USD) [f]	390	0.0786	0.8800	3.8294	42.4150	86.257	26131.51
Sri Lanka (Rupee(SLRs)/USD) [g]	390	0.1229	0.6601	1.0239	33.3470	101.07	14995.18

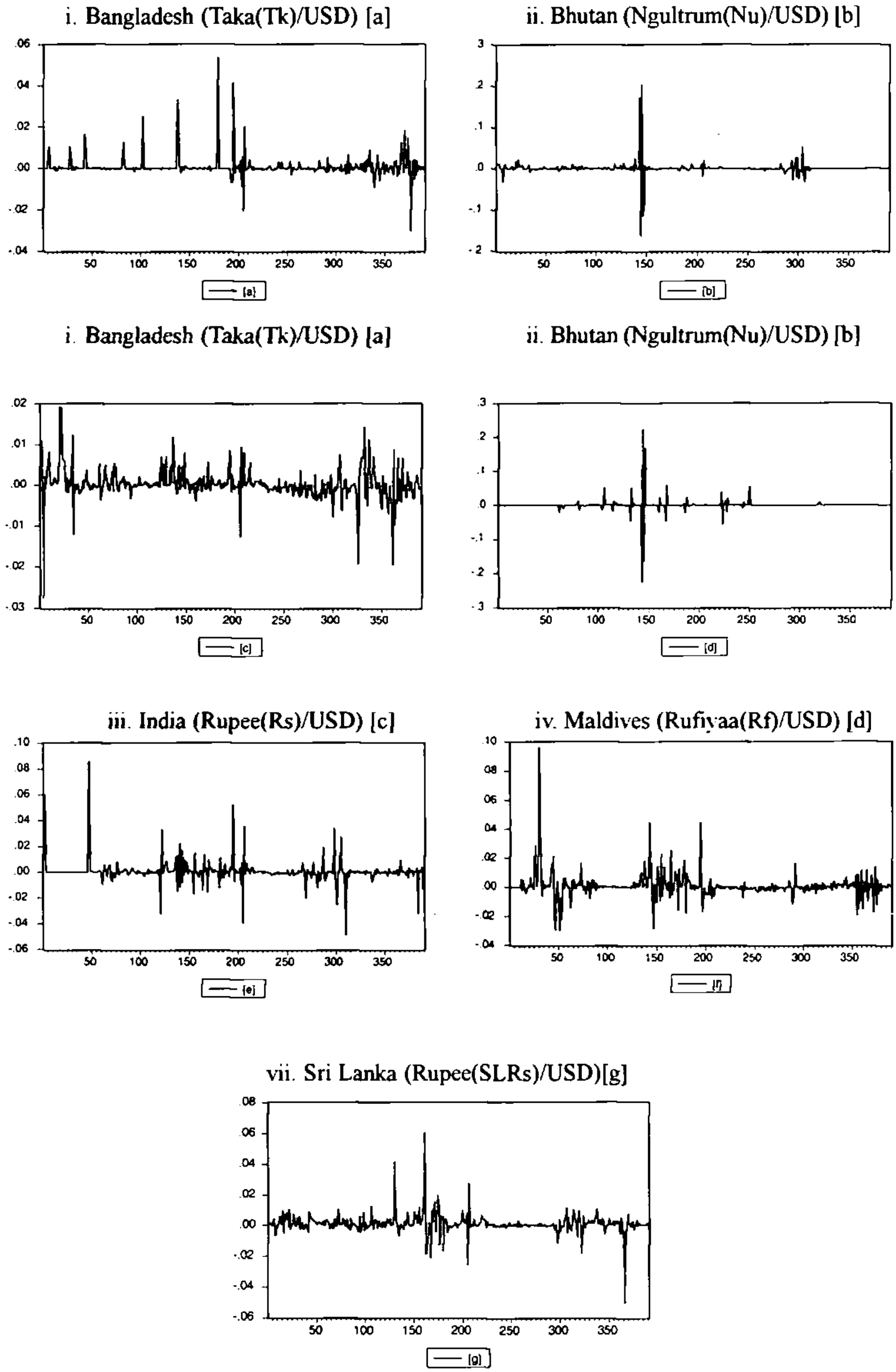
Table 2: Parameters Estimates and AIC Values

[Code]	Parameters Estimates							AIC values (Log Likelihood)	
	GARCH (1,1)			EGARCH (1,1)				GARCH (1,1)	EGARCH (1,1)
	á$_0$	á$_1$	â	á$_0$	á$_1$	â	δ		
[a]	6.01E-06	0.7620	0.7620	-5.7060	0.3377	0.0509	0.5478	-8.509	-8.3990
	(36.1553)	(21.1922)	(21.1922)	(-19.397)	(17.7060)	(0.8914)	(18.673)	(1659.03)	(1638.77)
[b]	-2.40E-11	0.4650	0.4650	-1.2505	0.4658	0.5904	0.8969	-8.938	-6.9556
	(-1.33E-110)	(21.367)	(21.367)	(-120.807)	(33.916)	(74.844)	(48.285)	(1742.626)	(1357.882)
[c]	5.10E-07	0.1256	0.1256	-5.1050	0.7423	0.1206	0.6022	-8.595	-8.538
	(9.3092)	(9.3314)	(9.3314)	(-20.4560)	(13.4101)	(2.1725)	(29.158)	(1675.806)	(1665.72)
[d]	0.000402	0.3811	0.3811	-0.5035	0.4432	0.1530	0.9553	-5.4431	-7.3975
	(28.994)	(2.0653)	(2.0653)	(-36.2506)	(28.836)	(9.460)	(87.227)	(1062.69)	(1443.81)
[e]	9.23E-05	0.3262	0.3262	-7.3503	0.6249	0.0567	0.25876	-6.713	-6.716
	(35.9166)	(8.5840)	(8.5840)	(-20.2861)	(10.8683	(1.1512)	(15.3706)	(1309.83)	(1311.09)
[f]	3.41E-07	0.3541	0.3541	-0.5810	0.2856	0.2302	0.9611	-7.383	-7.458
	(8.656)	(19.339)	(19.339)	(-12.780)	(20.2471)	(15.2853)	(184.391)	(1440.10)	(1455.62)
[g]	9.56E-07	0.4360	0.4360	-2.3290	0.2510	0.0769	0.8587	-7.969	-7.972
	(5.6204)	(18.042)	(18.042)	(-14.059)	(36.208)	(2.4840)	(57.405)	(1554.12)	(1555.58)

Table 3: Mean Square Error Terms:

Country(Currency/USD) [Code]		Error × 10^6	
		GARCH(1,1)	EGARCH(1,1)
Bangladesh (Taka(Tk)/USD)	[a]	0.00530	0.00548
Bhutan (Ngultrum(Nu)/USD)	[b]	0.01849	0.01950
India (Rupee(Rs)/USD)	[c]	0.00399	0.00400
Maldives (Rufiyaa(Rf)/USD)	[d]	0.02178	0.02137
Nepal (Rupee(NRs)/USD)	[e]	0.009061	0.009058
Pakistan (Rupee(Rs)/USD)	[f]	0.0089	0.0088
Sri Lanka (Rupee(SLRs)/USD)	[g]	0.00665	0.00664

Figure1: Trend of Exchange Rate Return for SAARC Countries, from January, 1998 to June, 2005.



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4.2.5 Figures and Tables: Figures and Tables should be submitted on separate sheet, with their location notes in the text. Table and figure references should be in a consistent style. Caption for illustration should be listed on a separate sheet.

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ArticlesBender, K.A. & Sloane, P.J. (1998) 'Job satisfaction, trade unions, and exit-voice revisited', *Industrial and Labour Relations Review,* 51: 2, 222-239.

Chapters in Edited Books

Okubayashi, Koji. (1998) 'The Japanese style of management of Japanese affiliates in Germany and the UK', in Richard Thorpe and Stephen Little (eds.), *Global chang; the impact of Asia in the 21st century* at the Manchester Metropolitan University, (London: Palgrave), 146 – 168.

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