DEPENDENCE BETWEEN STOCK MARKET AND FOREIGN EXCHANGE MARKET IN SOUTH ASIA: A COPULA-GARCH APPROACH.

by

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ABSTRACT

The thesis studies the dependence pattern between stock market and foreign exchange market of three South Asian countries; namely Bangladesh, India and Sri Lanka by using five copula functions, to reveal asymmetric dependence structure. Using daily return series for the period of July 31, 2009 to July 31, 2013, the thesis applied ARMA-GARCH type model to obtain marginal distributions of return series. The results from marginal models indicate that positive news creates more volatility than negatives; meanwhile such volatility dies immediately after a crisis. The results from copula models indicate existence of asymmetric dependence, with upper tail dependence for all pairs. Both Bangladeshi and Indian pairs provide some diversification possibility, against no diversification for investing in Srilankan market. Copula based dependence between stock market and foreign exchange market provides important implication in international investment decision making.

Keywords: Copula, GARCH, Stock Market, Foreign Exchange Market.

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DEDICATION

TO

ALMIGHTY ALLAH

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CHAPTER 1

INTRODUCTION

Given the importance of foreign investor's exposure in stock markets of Bangladesh, India and Sri Lanka; the thesis intends to aid investment strategy of multinational corporations, private equity firms, foreign equity investors, focusing South Asia; by analyzing the dependence structure between stock market and foreign exchange market returns using copula functions.

The purpose is to determine the existence of asymmetric [1]dependence structure between asset markets, which deserves closer look for a number of reasons. First, from foreign investor's point of view, understanding dependence is significant for diversification purpose. According to Desislava Dimitrova (2005) the stock market reacts with a less than one percent decline to a one percent depreciation of the exchange rate. Due to positive correlation between markets, risk reduction by diversification strategy becomes ineffective. Second, the thesis is academically appealing, mainly due to relationship between two assets are at the heart of asset pricing in Finance. CAPM (Capital Asset Pricing Model) are based on relationship between expected return and risk (Markowitz, 1951; Sharpe, 1964; Ross, 1976). Third, the dependence structure enables policy makers to explain how one market responds to fluctuations in other market and vice versa and formulate growth oriented policies. The thesis excluded examining data of Pakistan due to political instability it currently facing, whereas Nepal, Maldives, Afghanistan, Bhutan were considered as minor players in these regions in terms of macroeconomics indicators.

South Asian countries have become major growing region, though this region was distinguished by political instability and poverty in 80s. Geared by development of financial systems in 90s, FDIs (Foreign Direct Investment) have not only aided industrialization; but also accelerated wheel of growth of the region. Because of industrial production performance and increasing capital inflows, South Asia is expecting to see an increase in real GDP growth, with 6 percent in 2014, comparing 7% growth by East Asian countries (source: World Bank).

[1]Asymmetry is the absence of, or a violation of, symmetry (the property of an object being invariant to a transformation, such as reflection).

From the south Asian countries context, profitability of listed MNCs and unrestricted dividend repatriation, exit opportunity for private equity funds upon listings, volatile equity markets have made national stock exchanges as the most attractive business opportunities (compared to fixed bank deposits and government treasuries).Highlighting concentration on primary sectors, financial sectors are developing and stock market capitalization as a perchantage of GDP increasing, offering diversification benefit of investing in stock exchanges.

Markets crash together than boom together, can be traced by tail dependence behavior (Hu, 2006). If there is asymmetric dependence, two returns exhibit greater correlation during market downturns than market upturns, evidenced in Longin and Solnik (2001), and Ang and Chen (2002). The probability of joint extreme events is measured by tail dependence parameters. Though a standard measure of dependence, correlation coefficient is incapable of tracing tail dependence parameter of financial time series. Boyer, Gibson and Loretan (1999) found that correlation is incapable of providing information of asymmetric dependence structure, because the joint[2] distribution of financial time series data is no longer a Gaussian[3] normal distribution. Incapability is further intensified, since distribution of dependence is nonlinear and random variables are non-normal. Linking marginal distributions, conversely copula functions obtain joint distributions of two random variables, resulting in dependence structure with asymmetry and non-linearity. Amid 3 pairs of stock market and foreign currency returns of South Asian regions over the period 2009-2013, the thesis applied copula functions to examine dependence pattern

The thesis is organized as follows. The second chapter presents the literatures. The third chapter presents data source and its features used for the study. The Fourth chapter presents the methods used in this thesis, starting with methods for marginal distributions and the estimation procedure. The Fifth chapter explains the findings. Finally some concluding remarks on the study and summarizes the thesis.

[2] joint probability distribution for random variable X, Y is a probability distribution that gives the probability that each of X, Y falls in any particular range or discrete set of values specified for that variable.

[3] Normal (or Gaussian) distribution is a continuous probability distribution that tells the probability that any real observation will fall between any two real limits or real numbers, as the curve approaches zero on either side.

CHAPTER 2

LITERATURE REVIEW

The current section is devoted to studies on examining mainly co-movement of stock market and foreign exchange market in South Asia, using both copula approaches and other methods. While measuring relationships and integration, prior studies applied Co-integration, Correlation, Vector auto Regression (VAR), Granger Causality test for revealing long term existence of dependence, specifically during pre-crisis and crisis period, post financial liberalization period and foreign currency regime change periods.

2.1 THEORIES ON RELATIONSHIP BETWEEN STOCK MARKET AND FOREX MARKET

There are two main theories regarding nature of interactions between foreign exchange and stock prices: (1) one is "flow oriented models" with a focus on trade balance between countries, proposed by Dornbusch and Fisher (1980). Exchange rate fluctuations effect export performance of firms, hence an appreciation of exporter's currency will diminish exporting firms profit and competitiveness and vice versa. If firms are more competitive, this has a positive effect on firm's stock price, as it reflects future streams of cash flows. In line with firms ability to generate cash flows are linked with exporting goods to foreign countries, which in turn dependant on foreign exchange rate of exporter country. Meanwhile (2) other theoretical base is "stock oriented models" proposed by Frankel (1983) and Branson (1977),which argues flows based models for not considering international capital inflows. According to stock based models, exchange rate equates demand and supply of both domestic and foreign financial assets (stock and bonds). An increase in domestic assets will result in increase in the demand of domestic currency, which results in appreciation of domestic currency. Though this theories are well established, empirical findings on interactions vary.

2.2 EMPIRICAL STUDIES ON RELATIONSHIP BETWEEN STOCK AND FOREX MARKET

Attari et al found flow based relationship from stock price to exchange rate for Pakistani data ranging 1995-2012, using cointegration, VECM and Granger cause test. In revealing directional causation, Zia and Rahman (2011) applied Granger Causality test for Pakistani stock market and foreign exchange market from 1995 to 2010, failed to support any causal relationships which indicates mainly existence of political instability. Meanwhile, Jamil and Ullah

(2013) found exchange rate effects stock prices in short run in Pakistan. Sulku (2011) found bi-directional causality between emerging countries' stock markets and RER (real exchange rate). Rajavat (2013) found that foreign exchange effect Sensex. Daily returns of 2007-2009 depict non normality and unidirectional causality between nifty returns and Indian rupee-USD exchanges (Agarwal et al, 2010). Meanwhile , according to Mishra and Paul , Sensex and Nifty based return are positively related with foreign exchange rate with weak form of market efficiency. Nath and Samanta ((2003) ,using daily data from March 1993 to December 2002, found no causal link ,though they think there is strong causal influence from stock market return to forex market return in India.

Benefitting from diversification strategy largely depends on dependence between markets in pre-crisis and post-crisis periods. Dealing with stock market indices and monetary aggregates (exchange rate and M2), Zubair (2013) found no long run relationships before and during financial crisis of 2008 by using Johansen test, while Granger Casualty resulted in unidirectional casualty in pre-crisis period and lack of casualty during crisis. Though not revealing effects of financial crisis, the study performed by Uddin and Rahman (2009) failed to support any relationship between stock market and exchange rate markets of Bangladesh, India and Pakistan, applying both co-integration technique and Granger-Causality test.

Volatilities of assets markets transmitted to each other, affecting related policies. For Malaysian perspective, multivariate VAR documented that industrial and finance sector are mostly affected due to volatility in both exchange rate market and equity markets (Yusuf and Hamisah, 2012). Unaffected by foreign currency regime change, Karoui found positive transmission between volatilities in equity and foreign exchange rates markets, though significantly affected by ownership restrictions and international capital market controls. Apte applied E-Garch in Indian market returns and found volatility moves from foreign exchange market to stock market.

2.3 DEFICIENCY OF LINEAR MEASURMENTS IN MODELLING DEPENDENIES

However, in modeling dependencies, new issues coming into scenarios, for example, Poon et al (2003) found support for asymptotically independent models for dependence structure of tails of stock returns, which makes existing modeling approaches overstating risk of extreme events. In addition, non-normality in dependence structure cannot be traced by linear measurements of dependence. Longin and Solnik (2001) provided evidence of multivariate non-normality in negative tails. Due to non-stationarity property, time series has no tendency to return to constant value or linear trend, leading to assumption that asset prices are generated by nonstationary process and follow stochastic trends. Most of the extreme dependence are due to heteroskedasticity in the stock return process, Poon et al (2003) further added. Besides, according to Andersen et al (2007), volatilities and correlations are time varying. According to Boyer et al (1999), correlations computed separately for ordinary and stressful market conditions differ considerably, a pattern widely termed 'correlation breakdown', implies that correlation fails in measuring extreme dependence. They also found that during major market events, correlations change dramatically. Ang and Bekaert (2002), using a regime-switching process, found that correlations and volatilities increase in international bear markets. With excess kurtosis ('leptokurtic') and fat tails in distribution of asset returns, the possibility of extreme events increases. In computing possibility of severe losses to happen together, tail dependence is located, implies the propensity of dependence concentrating in the tails (Kousky and Cooke) .In most cases, financial time series suffer from tail dependence (Embretchs et al,2001). Correlation cannot explain tail dependence as assumes symmetry in both right and left tails.

2.4 COPULA –AN ALTERNATIVE APPROACH

Due to limitations of linear measurements of dependence, Copula proposed by Sklar (1969) performs better in measuring forms of dependence between financial time series, because copula does not require normality neither in marginal distributions nor in joint distributions, relaxing 'Gaussian assumption' contrast to correlation. Costinot et al (2000) showed that correlation does not provide precise information on dependence, instead they used copulas to study a) international equity markets b)analysis of the East Asian crisis .By filtering the return series through GARCH model (Bollerslev, 1986 and 1987), the standardized residuals are used in capturing dependence via copula functions, thus non-constant volatility is addressed. Through Clayton and Gumbel Copula, it is possible to measure lower and upper tail dependence respectively.

2.5 STUDIES BASED ON COPULAS

Many papers used copulas to study co-movement between equity markets, for example, Chakrobarti and Roll (2002), Longin and Solnik (2001), Ciprian Necula, Silvo Dajcman (2013), Jussi Karlqvist and Paula et al established asymmetric co-movement between equity markets. Meanwhile, Wang et al (2011), Boubaker and Sghaier (2014) used time varying copula models for measuring dependence between equity markets. Patton (2006) studied asymmetry in dependence between exchange rates by using conditional copula models.

However, studying dependence pattern using copula functions between two asset markets is limited; for example, Ning (2006) studied between foreign exchange market and equity markets using copulas. Using SJC (symmetrized Joe Clayton) copula, Ning (2006) revealed significant upper and lower tail dependence between equity and foreign exchange market. In another study, Michelis and Ning found asymmetric tail dependence in the joint distribution of Canadian stock prices and USD/Canada exchange rate, which is partly explained by the interest rate differential between Canada and the US. Meanwhile, Righi et al studied Brazilian stock market and exchange rate market using copulas, found negative relations in all time scales. Sewe et al found significant symmetric dependence, along with tail dependence in Kenyan stock market and foreign exchange market. In his master's thesis,

2.6 ESTIMATION PROCEDURE OF COPULA PARAMETER

Distinguished from existing studies, the thesis addresses asymmetric dependence patterns between stock market and foreign exchange market in South Asian countries using copulas. Among estimation procedures for copula, Canonical Maximum likelihood Method (CML) as suggested by Bouye (2000), first data series are transformed into uniform margins, the copula function is estimated without any assumptions on the form of the marginal distributions, is followed in this thesis due to simple execution. Other methods, Exact Maximum Likelihood (EML) estimates margins and copula parameters simultaneously (Cherubini, Luciano and Vecchiato, 2004), while Inference Functions to Margins employs Multistage Maximum Likelihood process (Joe and Xu ,1997) .

CHAPTER 3

DATA

3.1 SOURCES OF DATA

This thesis used data sets consisting of daily closing prices of three stock markets and three foreign exchange markets for the period ranging from July 30, 2009 to July 31, 2013, generating total of 702 observations. The data are from the stock market and foreign exchange market of three South Asian countries: India, Bangladesh, and Sri Lanka. Exchange rate data are collected from www.oanada.com and stock indices data from www.yahoofinance.com.

The data represents only trading days, hence all official non-weekly holidays have been eliminated. Meanwhile, trading days between stock market and foreign exchange market have been matched; as a result weekly holidays are eliminated. Due to differences in trading days, weekends, and public holidays, if not matched, would result in inaccurate parameters. To comply with this, trading days common to all three countries are taken into consideration. As a result Monday to Thursday fall into common trading days. About 702 trading days fall into sample, within 1440 days approx. (which is 50% of the total observations period considered).

The returns are calculated as 100 times the logarithm differences of the indices or the exchange rates between the day t and the day t -1.

$$\mathbf{r_t = \log(pt - p_{t-1}) * 100} \qquad \textbf{Equation 1}$$

3.2 ATTRIBUTES OF VARIABLES

Stock markets (Dhaka Stock Exchange of Bangladesh, Bombay Stock Exchange of India and Colombo Stock Exchange of Sri lanka) observed boom during this period .There is also US Dollar appreciation against Bangladeshi Taka (BDT), Indian Rupee (INR), and Sri Lankan Rupee (LKR) during this period.

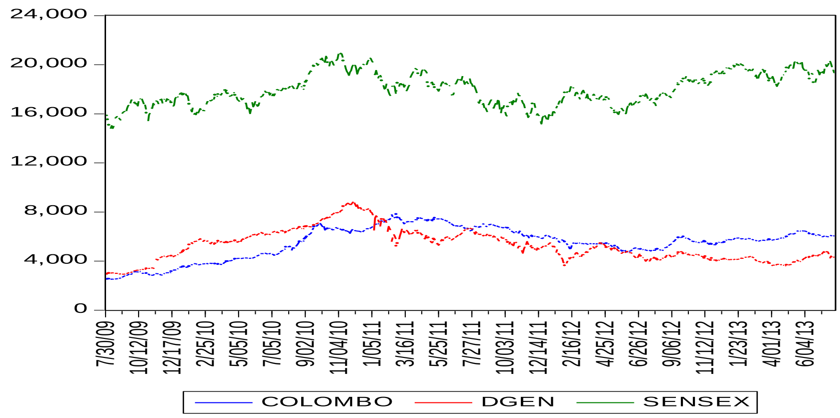

Figure 1 Stock indices of sample countries

The above figure shows stock market indices of three countries Bangladesh, Sri Lanka and India from the period of 30/7/2009 to 31/7/2013. Blue line represents Colombo all share price index, the red one represents DGEN i.e. Dhaka Stock exchange general price index of Bangladesh and the Green one Sensex of India. All indices observed a rise during 2009 and 2010 and decline in 2011 and 2012.Since end of 2012 onward, an upward trend is observed. According to the chart, volatility is visible and one can take advantage of such rise and fall, by trading i.e. buying at low selling at high in a cycle.

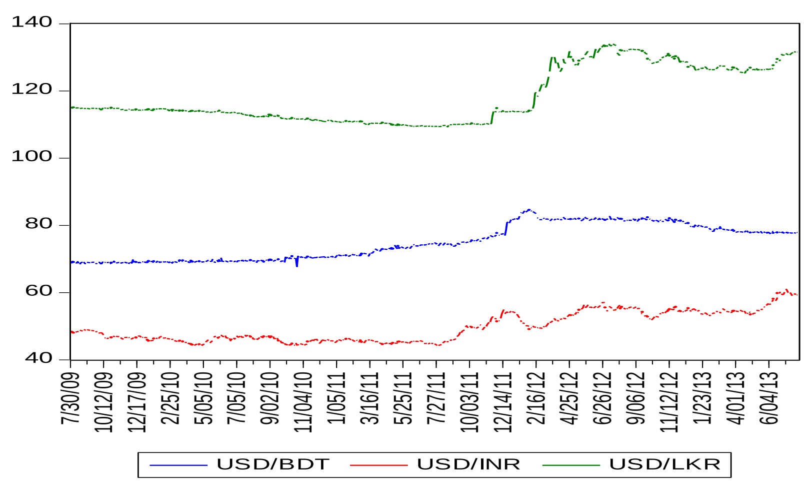

Figure 2 Exchange rates of sample countries

The above figure describes exchange rate of three currencies i.e. Bangladeshi Taka, Indian Rupee, Sri Lankan Rupee from the period of 30/7/2009 to 31/7/2013. Until beginning of 2012, the exchange rate sees little fluctuations. Since 2012 and onwards, there is depreciation in the value of sample currencies against USD. All three currencies depreciated against USD significantly, this fluctuation smoothed during the period of 2013.

CHAPTER 4

METHODLOGY

The pearson's linear correlation, along with kendalls tau and spearmans rho measures linear dependence between variables, say x and y. However, according to Embrechts et al. (1999) ,it is slightly better to use Kendalls tau and Spearmans rho measures than the pearson correlation coefficient. These standard measures do not provide any information on tail dependence between variables. With respect to fat tail behavior of financial time series, nonzero tail dependence increases the probability of joint extreme events. In this connection, Copula (sklar, 1959) (" link" in latin) not only measures non linear dependence but also tail dependence between variables.

This section explains the estimation procedures of copula parameters. First, the models for the marginal distributions are estimated to get filtered standardized residual return series. After that, copula function between marginal distributions is applied to determine copula parameters.

4.1 STATIONARITY AND NORMALITY OF RETURN SERIES

A data series needed to be stationary, before using in econometric analysis. A stationary process has the property that the mean, variance and autocorrelation structure do not change over time. If the data series are nonstationary, the shocks are perceived to be infinite, whereas shocks die away for a stationary series. In addition, high R^2 results in a regression analysis, though variables are not related at all, a phenomenon known as spurious regression. The thesis used ADF (Augmented Dicky Fuller) test for both original data series and returns series, to investigate whether there is unit root (implying the data is nonstationary).

$$\boldsymbol{\Delta yt = \alpha + \beta t + \gamma y_{t-1} + \delta y_{t-1} + \cdots . + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t} \qquad \textbf{Equation 2}$$

H0 : θ = 0 (i.e. the data needs to be differenced to make it stationary)

H1: θ < 0 (i.e. the data is stationary and doesn't need to be differenced)

Meanwhile, the thesis applied both Jarque-Bera and Skewness Kurtosis (SK) test for measuring univariate normality of the return series .Meanwhile, Doornik-Hansen test applied to examine bivariate normality of return series (considering stock market and foreign exchange market of a country as a pair). Jarque-Bera is defined as:

$$\mathbf{Jarque - Bera\ Stata} = \frac{\mathbf{n}}{\mathbf{6}}\left(\mathbf{s}^{2} + \frac{\mathbf{1}}{\mathbf{4}}(\mathbf{k} - \mathbf{3})^{2}\right) \qquad \textbf{Equation 3}$$

Where n is the number of observations (or degrees of freedom in general); S is the sample skewness, and K is the sample kurtosis:

4.2 MODELING THE MARGINAL DISTRIBUTIONS

This section will present the models to be employed for the marginal distributions. Asset returns exhibit fat tails, long memory and conditional heteroskedasticity. As a result, the marginal distributions are assumed to be characterized by an ARMA(1,1)-GARCH(1,1) model to capture all the stylized facts of return series of stock markets and foreign exchange markets. The model to be employed in this thesis was introduced by Bollerslev (1987) and used in copula context by Patton (2001 and 2006).

The first log difference for stock indices and foreign exchange rates will be assumed to follow the process[4]:

$$\mathbf{xit} = \boldsymbol{\mu}\mathbf{i} + \sum_{\mathbf{j=1}}^{\mathbf{p}} \boldsymbol{\varphi}\mathbf{ij}\ \mathbf{Xi, t - j} + \sum_{\mathbf{k=1}}^{\mathbf{q}} \boldsymbol{\theta}\ \mathbf{i, k}\ \boldsymbol{\varepsilon}\mathbf{i, t - k} + \boldsymbol{\varepsilon}\mathbf{i, t} \qquad \textbf{Equation 4}$$

$$\epsilon_{it} = \sigma i, \eta_{i\ ,t}$$

$$\boldsymbol{\sigma}^{2}\mathbf{it} = \boldsymbol{\alpha}\mathbf{i, 0} + \sum_{\mathbf{j=1}}^{\mathbf{m}} \boldsymbol{\alpha}\mathbf{i.j}\ \boldsymbol{\varepsilon}^{2}\ \mathbf{i, t - j} + \sum_{\mathbf{k=1}}^{\mathbf{s}} \boldsymbol{\beta}\mathbf{i}\boldsymbol{\sigma}^{2}\mathbf{it - k} \qquad \textbf{Equation 5}$$

$$\alpha i, 0 > 0, \alpha i, j \geq 0 \text{ and} \sum_{j=1}^{\max\,(m+S)} (\alpha i, j + \beta i, j) < 1$$

Here μi unconditional mean of the series, φij are autocorrelation coefficients for lag 1 to p. in variance equation where , αo , αi , βi and are parameters needed to be estimated.

The parameters of the ARMA-GARCH models are estimated using the conditional likelihood approach, where the log-likelihood function is given by:

[4] The ARMA (1,1)-GARCH(1,1) model estimated in EViews 6. All other models are estimated in Matlab.

$$\mathbf{l(\theta) = -\frac{n}{2}\log(2\pi) - \frac{1}{2}\sum_{t-1}^{n}\log(\sigma^2\, it) - \frac{1}{2}\sum_{t-1}^{n}\frac{\varepsilon^2 i}{\sigma^2}} \qquad \textbf{Equation 6}$$

Then the maximum likelihood estimator maximizes the log likelihood and is given by: $\widehat{\theta_i} = \text{argmax}\, l(\widehat{\theta i},)$.

4.3 COPULA FUNCTION

The word copula is a Latin noun which means ‘a link, tie or bond’, and the word copula was first used in a mathematical sense in the theorem a sklar (1959).The idea of copula combines univariate distributions of two random variables in order to obtain a joint distribution with a particular dependence structure. The asymmetry and the non-linearity in the dependence structure between two vectors can be captured by the copula approach.

Definition 4.3.1 (see Schweizer and Wolf, 1981): A copula is a function C : [0, 1] → [0, 1] which satisfies:

- For every u, v in [0, 1], C(u, 0) = 0 = C(0, v), and C(u, 1) = u and C(1, v) = v;
- for every u1, u2, v1, v2 in [0, 1] such that u1 ≤u2 and v1 ≤v2, C(u2, v2) − C(u2, v1) − C(u1, v2) + C(u1, v1) ≥ 0.

The fundamental theory of copula is due following theorem

Theorem 4.3.2 (Sklar theorem, 1959): Let X and Y be random variables with joint distribution function H and marginal distribution functions F and G, respectively. Then there exists a copula C such that

H(x, y) = C(F(x),G(y))

.If F and G are continuous, then C is unique..Conversely, if C is a copula and F and G are distribution functions, then the function H defined by above equation is a joint distribution function with margins F and G.

Meanwhile, an appealing issue regarding copula is that it can measure tail dependence. Tail dependence measures the dependence between random variables, say x and y, in the upper-right and lower-left quadrant of the joint distribution function (Cherubini, Luciano and Vecchiato, 2004). According to Nelson (2006), the parameter of asymptotic lower tail dependence, is the conditional probability in the limit that one variable takes a very low value, given that the other also takes a very low value. Similarly, the parameter of the asymptotic upper tail dependence, is the conditional probability in the limit that one variable takes a very high value, given that the other also takes a very high value. The asymptotic tail dependence parameters for copula function are given by Nelson (2006):

$$\boldsymbol{\lambda L} = \mathbf{lim}_{\mathbf{t \to 0+}} \frac{\mathbf{C\,(\,t,t)}}{\mathbf{t}}. \qquad \textbf{Equation 7}$$

$$\boldsymbol{\lambda U} = \mathbf{lim}_{\mathbf{t \to 1-}} \frac{\mathbf{1 - C\,(\,t,t)}}{\mathbf{1-t}}. \qquad \textbf{Equation 8}$$

In this thesis, Gumbel and Clayton copula are used to capture the tail dependence .Both Frank and Gaussian copula are symmetrical; hence do not exhibit any tail dependence. Let θ is the parameter of clayton and gumbel copula, then tail dependence of clayton copula (lower tail dependence) is given by λL=$2^{\frac{-1}{\theta}}$ and for gumbel copula (upper tail dependence) is given by $\lambda U = 2 - 2^{\frac{1}{\theta}}$.

Let u and v is the cumulative density functions of the standardized residuals from the marginal models and with a condition $0 \leq u$ and $v \leq 1$, in addition , linear correlation coefficient ρ with boundary condition $0 \leq \rho \leq 1$.

Gaussian copula is given by: $\mathbf{C(u,v,p,)} = \mathbf{\Phi_{\rho}(\Phi^{-1}(u)(\Phi^{-1}(v)}$ **Equation 9**

Where, $\Phi_{\rho}$is the buvariate normal distribution, Φ^{-1} is inverse function of the univariate normal distribution.

Student t copula is given by: $\mathbf{C(u,v,p,)} = \mathbf{t_{v}(t^{-1}(u)(t^{-1}(v))}$ **Equation 10**

Where, t_v is the bivariate student t distribution with degree of freedom$v$. t^{-1} is the inverse function of univariate student t distribution.

Frank copula is given by: $\frac{\mathbf{1}}{\boldsymbol{\theta}}(\mathbf{1} + \frac{\mathbf{exp(-\theta)-1)(exp(\theta-1)}}{\mathbf{exp(-\theta)-1}}$ **Equation 11**

Gumbel copula is given by : $\mathbf{exp(}-((-\mathbf{log(u)}\,.^{\boldsymbol{\theta}} + (-\mathbf{log(v)}.^{\mathbf{1/\theta}}$ **Equation 12**

Clayton copula is given by : $(\mathbf{max\{u^{-\theta} + v^{-\theta} - 1;\}}.^{\mathbf{-1/\theta}}$ **Equation 13**

There is no widely acceptable statistic criterion that selects the copula that provides the best fit to the data. Dias and Embrechts (2004) and Palaro and Hotta (2006) used the AIC[5] criterion to select the copula that provides the best fit. However, various simulation studies shows that the Schwarz Information Criterion (SIC or BIC) performs better in large samples whereas the AIC tends to be superior in small samples (Shumway and Stoffer, 2011 ; Steffen Nneberg et al).

$$\mathbf{AIC = -2 * \log likelihood + 2K}$$ **Equation 14**

$$\mathbf{SIC = -2 * \ (\log liklihood + \ln \ (n) * K}$$ **Equation 15**

Where, k is the number of parameters of the copula model and n is the number of observations.

4.4 GOODNESS-OF-FIT TESTS FOR MARGINAL MODELS

As noted earlier, the joint copula model requires the correct specification of the marginal distributions. If the marginal distributions are not correct, their probability integral transforms using kernel density smoothing, will not be i.i.d. uniform (0, 1), and hence the copula model will be mis-specified. Patton (2006a) employs then Kolmogorov– Simirnov (K–S) tests to test if they are uniform (0, 1).The thesis used K-S tests for goodness-of-fit measurement of marginal distributions.

[5] The Akaike information criterion (AIC) is a measure of the relative quality of a statistical model, for a given set of data.

CHAPTER 5

FINDINGS

5.1 UNIT ROOT TESTS

By performing Augmented Dicky Fuller (ADF) test, whether there is unit root in original data series are examined .It is found that raw data are nonstationary. However, unit root test on return series implies return series are stationary.

Table 1Unit root test result (Augmented Dicky Fuller test) of return series

Particulars	P-value of Augment Dicky Fuller test
DGEN	0.00
COLOMBOASPI	0.00
BSESENSEX	0.00
BDT	0.00
INR	0.00
SLR	0.00

Note: p-values indicate rejection of null hypotheses at 5% significance level. Null hypothesis implies there is unit root in the univariate return series.

5.2 DESCRIPTIVE STATISTICS

Table 2 Descriptive statistics of return series

	Minimum	Maximum	Mean		Std. Dev	Variance	Skewness	Kurtosis
			Stat.	Std. Error				
DGEN	-17.41	20.39	.056	.093	2.46	6.07	-.20 (.02)	14.98 (0.00)
COLOMBOASPI	-5.49	4.96	.125	.044	1.18	1.41	.18 (.04)	2.54 (0.00)
BSESENSEX	-4.88	5.65	.040	.051	1.36	1.86	.00 (.92)	1.32 (0.00)

BDT	-3.67	4.43	.017	.017	.46	.21	1.21 (0.00)	20.37 (0.00)
INR	-2.97	2.56	.031	.024	.66	.43	-.17 (.06)	2.93 (0.00)
SLR	-1.68	2.73	.019	.012	.32	.10	1.74 (0.00)	17.06 (0.00)

Note: number of observation 701. P-values reported in brackets.

Table 2 presents selected summary statistics of daily returns for three stock market and foreign exchange markets. Among the stock markets, Dhaka stock exchange provided highest daily returns, followed by Bombay stock exchange and Colombo stock exchange. For foreign exchange markets, exchange rates of BDT also provided highest daily returns. Except Dhaka stock exchange returns, all other daily returns of both markets fall in closer range. The daily standard deviation follows standard risk-return criteria, as highest return follows highest risk and vice versa. DGEN of Dhaka stock exchange exhibits highest amount of risk, complying with highest amount of daily returns.

Along with volatilities, skewness and kurtosis are considered as important measures of risk,. The significance level of these coefficients individually measures possibility of extreme events, jointly checks normality criteria of uni-variate return series. The skewness of returns is different from zero with most returns slightly skewing to the left i.e positively skewed. All returns show excess Kurtosis ranging from 2.54 to 20.37. And the kurtosis is higher, implying a fatter tail of returns.

5.3 NORMALITY TESTS

Jarque-Bera and SKtest strongly rejects the normality of the uni-variate return series. Meanwhile Doornik-Hansen rejects bi-variate normality of stock-currency pairs.

Table 3 Univariate normality test

	COLOMBOASPI	DGEN	BSESENSEX	BDT	INR	SLR
Jarque-Bera	188.56*	6461.24*	35.49*	12113.4*	249.3*	8731.75*
SK test	0.00	0.00	0.00	0.00	0.00	0.00

Note: * indicates 1% level significance. SK test measures uni-variate normality by joint probability of both skewness and kurtosis

Table 4 Bivariate normality

	Doornik-Hansen
DGEN-BDT	2353 *
SENSEX-INR	169.67*
COLOMBOASPI-SLR	614.32*

Note: * indicates 1% level significance. D-H test indicates bi-variate normality.

5.4 CORRELATION COEFFICIENTS

Table 5 Correlation coefficients

	India pair	Bangladesh pair	Sri Lanka pair
Linear Correlation	-.148*	-0.051	-.051
Coefficient	(0.00)	(.178)	(.179)
Spearman's Rho	-.107*	-.018	-.029
	(.004)	(.636)	(.438)
Kendalls Tau	-0.073*	-0.012	-0.020
	(.004)	(.641)	(.426)

Note: Total observations equal 701 that range 2009-2013.Perason correlation is used for normally distributed data. Meanwhile kendall's tau and spearman's rho fit for non-normal data. Numbers in bracket indicate P-values. * indicates statistical significance at 5% significance level.

In Table 5 the linear correlations, the Kendall's tau and Spearman's rho rank correlations between the stock and the foreign exchange rate return pairs are presented. It is observed that the pair wise correlations are all negative, indicating that the increase (decrease) of the local stock market is associated with the depreciation (appreciation) of the local currency. The Kendall's Taus for are all negative for all pairs ; showing the probability of concordance is lower than the probability of discordance. The Spearman's Rhos for the pairs in each country are also negative, indicating weak rank correlations. The values of Taus and Rhos are consistent with each other and the linear correlation.

5.5 RESULTS OF MARGINAL MODEL

Before estimating the copula model, the marginal distribution model estimated separately. The results from marginal models are used to get the probability integral transforms, which are u and v. First the marginal models estimated, where ARMA (1, 1) -GARCH (p, q) type models are applied for each return series. Experimentation is made based on GARCH, with lag up to p = 2 and q= 2.

EGARCH (1,1) is found to be best fit for Bangladesh and Sri Lankan pair[6]. Bur for Indian pair CARCH is best fit. The estimates of the marginal models are presented in Table 7. Following table shows AIC comparison between two best model EGARCH and GARCH (1,1). Since EGARCH (1,1) model has minimum AIC , EGARCH chosen as fit to the return series of Bangladeshi and sri Lankan pair . For Indian pair, CARCH fitted.

Table 6 AIC criteria of marginal distributions

	EGARCH (AIC) Lag (1,1) Student t	GARCH(1,1) (AIC) Student t
COLOMBOASPI	2.93	2.94
SLR	-.74	-.76
DGEN	4.01	4.03
BDT	.75	.76
SENSEX	3.3604	3.3676
INR	(GED with Fixed Parameter 1.5) 1.86	Student t 1.87

Note: This table compares selected model EGARCH with close contestant GARCH model in terms of minimum AIC. Student t distribution produced best fit. Indian rupee is exception.

Except Indian pair, EGARCH (1,1) is generally able to capture the conditional heteroskedasticity for both stocks and exchange rates. For Indian pair, CARCH is fit. It is seen that β is not large; as a result volatility dies immediately after a crisis. as $\gamma > 0$ positive shocks (good news) generate more volatility than negative shocks(bad news).

[6] A pair means data series of stock market return and exchange rate return of a country.

Table 7 ARMA-GARCH Filtration

	ARMA Model (1,1)			EGARCH				CARCH				
	μ	AR(1)	MA(1)	ω	α	β	γ	ω	ρ	θ	α	δ
COLOMBOASPI	-.004	.81	-.67	-.21	.33	-.04	.91					
	(.94)	(0.0)	(0.0)	(0.0)	(0.0)	(0.27)	(0.0)					
DGEN	.16	.90	-.85	-.12	.26	-.17	.93					
	(.06)	(0.0)	(0.00)	(.001)	(0.0)	(0.0)	(0.00)					
SENSEX	.05	.01	.02					1.53	.97	.03	-.09	.01
	(.20)	(.97)	(.95)					(.00)	(0.00)	(0.0)	(0.00)	(.97)
INR	.009	.003						.37	.97	.04	-.06	.34
	(.68)	(.36)						(0.0)	(0.0)	(0.0)	(.01)	(.46)
BDT	.0020	.20	-.53	-.89	.50	-.03	.66					
	(.75)	(0.02)	(0.0)	(0.00)	(0.00)	(0.00)	(0.00)					
SLR	-.00	.016		-.55	1.2	.25	.88					
	(.96)	(.62)		(0.0)	(0.08)	(.15)	(0.0)					

Note: Total observation 701. The coefficients μ and ω are the intercept of mean and variance equations respectively. Meanwhile the parameters αi and βi refer to the ARCH and GARCH effects respectively. P values are in brackets. Here, 5% significance level has been considered.

Follows is arch effect test applied to return series. It is seen that before fitting a GARCH model, null hypothesis is rejected, and there is arch effect. When GARCH model is fitted, ARCH effect test accepts null hypothesis that there is no ARCH effect left in the return series.

Table 8 ARCH effect test of univariate return series

	ARCH effect test before(after)
COLOMBOASPI	.00 (0.35)
SLR	.00(.99)
DGEN	.00(.99)
BDT	0.00(.97)
SENSEX	.003(.49)
INR	.00(.15)

Note: ARCH effect test has been applied before using ARCH-GARCH type model on uni-variate return series, which is indicated by P – values outside brackets. Again same test is conducted after a using ARCH-GARCH type model to see whether any arch effect left, indicated by P-values within brackets. 5% significance level has been considered.

5.6 GOODNESS-OF-FIT TESTS FOR MARGINAL MODELS

Kolmogorov– Simirnov (K–S) test examines the null hypothesis that the data in vector comes from a standard normal distribution, against the alternative that it does not come from such a distribution. The test statistics shows that null hypotheses is rejected at 1% level of significance.

Table 9 Kolmogorv – Simirnov one sample test

	DGEN	BDT	Colombo	INR	SLR	Sensex
	Std.Res.	Std.Res.	Std. Res.	Std. Res.	Std. Res.	Std. Res.
Kolmogorov-Smirnov Z	14.90*	14.48*	10.17*	13.29*	15.61*	8.53*

Note: * indicates 1% level significance.

5.7 RESULTS OF THE JOINT COPULA MODELS

Table 10 reports parameter estimates for the Gaussian, Student-t, Gumbel , Frank and Clayton copulas. For India and Bangladesh pairs, the dependence parameters, i.e., the correlation coefficient ρ in both Gaussian and t-copulas are negative and close to linear correlation coefficient, whereas the degree of freedom (DoF i.e. ϑ are about 8 in both Indian and Bangladeshi pair. This is not a surprise since both Gaussian and t-copulas belong to elliptical copula family, and the coefficient ρ in these two copulas is just the usual linear correlation coefficient given the elliptical margins (t distributions in this case). Meanwhile, in case of Sri Lankan pair the, unlike the linear correlation coefficient, ρ for Srilankan case is a bit positive, and DoF is 36. Among others, Gumbel copula parameter is about 1 for all three pair. Whereas Frank copula parameter ranges from .02 to .69, and Clayton copula for Indian and Bangladeshi pair is 0 and for sri Lankan pair .019

The DoFs (Degree of Freedom) of the t-copula are 8.04 and 8.91 for Indian and Bangladeshi pair respectively. Meanwhile, DOF is 36 for Sri Lankan pair. It indicates substantial extreme co-movements and tail dependence in all three pairs. Gaussian copula which does not allow for tail dependence is not sufficient in modeling the dependence of the stock-currency pairs.

Tail dependence parameters for the Clayton copula (lower tail dependence) is nil for all pairs. In case of Gumbel copulas, upper tail dependence parameters are positive for Indian and Srilankan pairs. When a country’s stock market is booming, investors believe that it is a good place for investment; therefore they will purchase that country’s currency to buy stocks there. Hence the demand of the currency increases, which leads to the appreciation of the currency. Since there is upper tail dependence, opposed to no lower tail dependence, implying that dependence between markets increases during bull market state (rise in price of financial instruments) in South Asian countries.

Table 10 Copula parameters

		Indian pair	Bangladesh pair	Sri Lanka pair
Gaussian Copula	P	-0.137	-0.0422	0.0168
AIC		-13.42	-1.23	-.1945

Student t Copula	P	-0.1229	-0.0307*	0.0142
	ϑ	8.04	8.91	36.52
	ϑci	(-1.52) -17.6	1.22 - 16.59	(36.52 -89.93i) - (36.52+89.93i)
Frank	Θ	0.6945	-0.145	0.0213
	Θci	(-1.14)-(-.24)	(-0.59) - .30	(-.43)- .47
Gumbel	Θ	1	1 .04*	1.012
	Θci	.95 -1.04	.95- 1.04	.97-1.05
	λ_u	1.63	0	.0168
	Θ	0	0	.019
	Θci	(-.07)- .07	(-.07) - .07	(-.0673) - .1062
Clayton	λ_l	0	0	0

Note: This table presents the copula estimates by using Gaussian copula ,Student t copula , Frank copula , Clayton copula and Gumbel copula. ρ denotes linear correlation coefficient estimates of Gaussian and Student t copula .ϑ represents degree of freedom for Student t copula.λL and λU measures lower and upper tail dependence of Clayton and Gumbel copula respectively. Θ denotes parameter of Frank, Gumbel and Clayton copula. ϑci and Θci measures confidence interval for the respective parameters.

Following are copulafit diagram of Indian, Bangladesh and Srilankan pair.

In x axis, sensex and in y axis exchange rate of Indian rupee is shown.

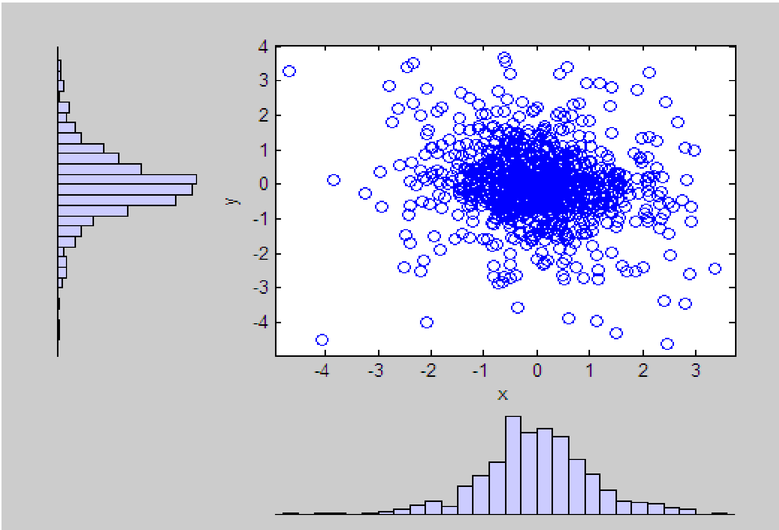

Figure 3 Bombay stock exchange index (Sensex) -Indian rupee

In x axis, DGEN and in y axis exchange rate of Bangladeshi taka is shown.

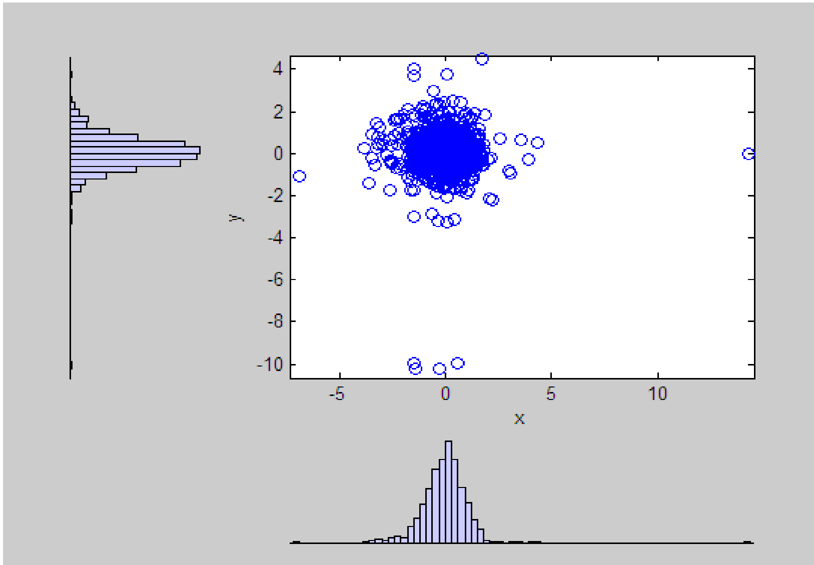

Figure 4 DSE General index -Bangladeshi taka

In x axis, Colombo all share price index and in y axis exchange rate of srilankan rupee is shown.

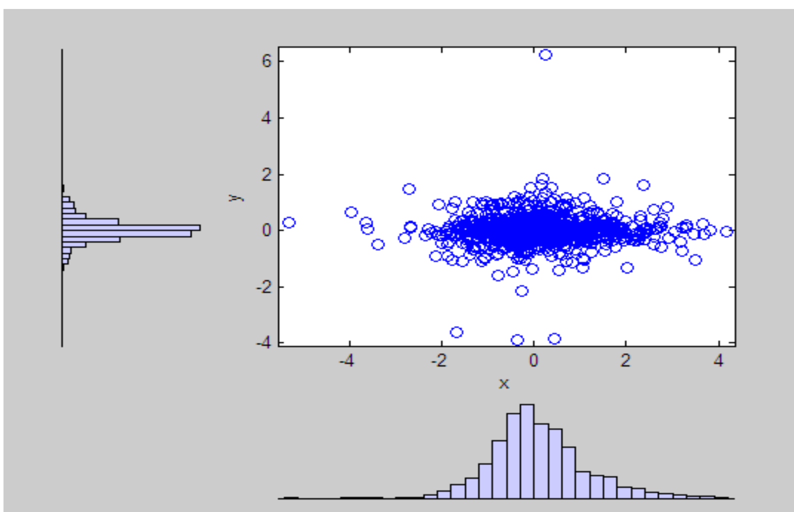

Figure 5 Colombo all share price index- Sri Lankan rupee

CONCLUSION

In this thesis, the degree of dependence of the bivariate distribution of stock market and foreign exchange market returns in 3 south asian countries using copula models over the period 2009-2013 investigated .The thesis considered five dependence structure : (1) Gaussian copula ,similar to Pearson correlation , does not allow tail dependence , (2) Student t copula allows symmetric tail dependence , (3) Frank copula do not exhibit any tail dependence, (4) Gumbel copula reveals asymmetric (upper tail) dependence , (5) Clayton exhibits asymmetric (lower tail) dependence. Results of the thesis show asymmetric dependence with upper tail dependence, opposed to no lower tail dependence. This implies that dependence between markets increases during bull market state (rise in price of financial instruments) in south asian countries. Meanwhile, marginal models exhibit existence of volatility, which is mainly due to positive news rather than negatives. Volatility vanishes immediately after a crisis, indicating rise in investors' confidence and stability after a period of fluctuations. In order to enjoy diversification benefit in selected south asian countries, foreign investors should focus negative relationship between markets for risk management purpose.

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EVIEWS OUTPUT

COLOMBO ALL SHARE PRICE INDEX

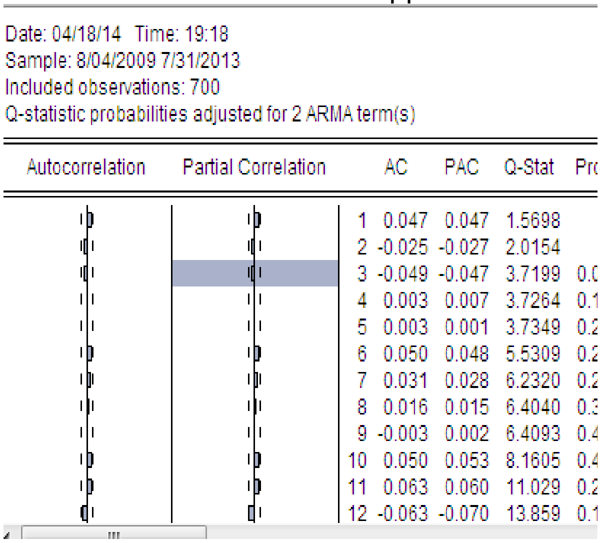
Table 11 EGARCH output of colombo all share price index

LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.004042	0.063207	-0.063943	0.9490
AR(1)	0.818178	0.061407	13.32389	0.0000
MA(1)	-0.672527	0.081648	-8.236860	0.0000
	Variance Equation			
C(4)	-0.214843	0.048210	-4.456428	0.0000
C(5)	0.330003	0.074884	4.406846	0.0000
C(6)	-0.048276	0.044476	-1.085435	0.2777
C(7)	0.917085	0.032012	28.64828	0.0000
T-DIST. DOF	4.340367	0.852163	5.093352	0.0000

R-squared	0.040487	Mean dependent var	0.125258
Adjusted R-squared	0.030781	S.D. dependent var	1.189411
S.E. of regression	1.170963	Akaike info criterion	2.932548
Sum squared resid	948.8382	Schwarz criterion	2.984561
Log likelihood	-1018.392	Hannan-Quinn criter.	2.952654
F-statistic	4.171327	Durbin-Watson stat	1.944740
Prob(F-statistic)	0.000164		
Inverted AR Roots	.82		
Inverted MA Roots	.67		

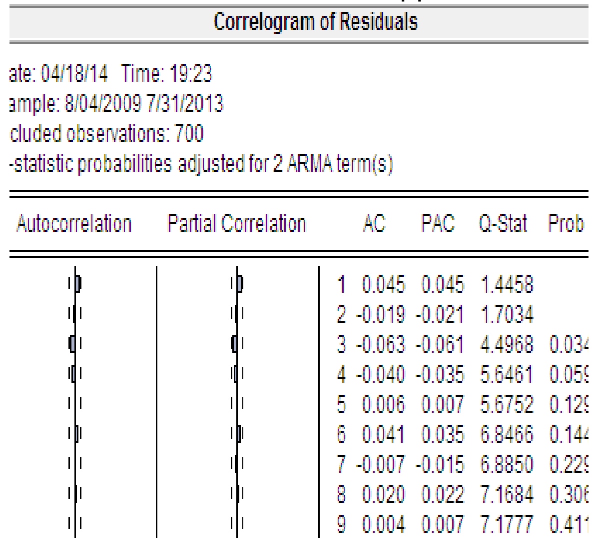
After GARCH model applied



Date: 04/18/14 Time: 19:18
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Pro
		1	0.047	0.047	1.5698	
		2	-0.025	-0.027	2.0154	
		3	-0.049	-0.047	3.7199	0.0
		4	0.003	0.007	3.7264	0.1
		5	0.003	0.001	3.7349	0.2
		6	0.050	0.048	5.5309	0.2
		7	0.031	0.028	6.2320	0.2
		8	0.016	0.015	6.4040	0.3
		9	-0.003	0.002	6.4093	0.4
		10	0.050	0.053	8.1605	0.4
		11	0.063	0.060	11.029	0.2
		12	-0.063	-0.070	13.859	0.1

Before GARCH model applied



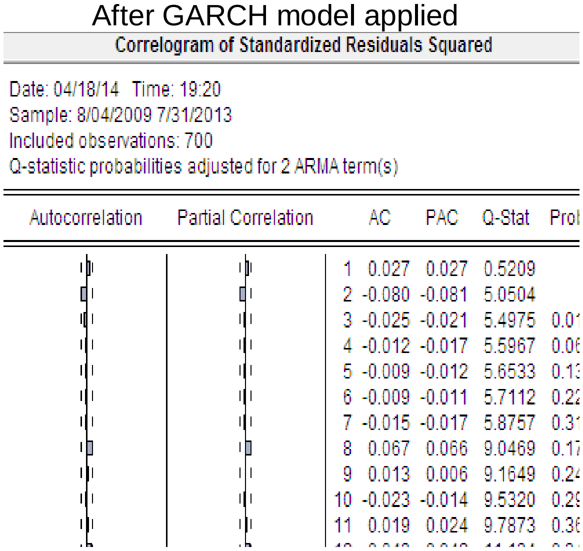
Correlogram of Residuals

ate: 04/18/14 Time: 19:23
ample: 8/04/2009 7/31/2013
cluded observations: 700
-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.045	0.045	1.4458	
		2	-0.019	-0.021	1.7034	
		3	-0.063	-0.061	4.4968	0.034
		4	-0.040	-0.035	5.6461	0.059
		5	0.006	0.007	5.6752	0.129
		6	0.041	0.035	6.8466	0.144
		7	-0.007	-0.015	6.8850	0.229
		8	0.020	0.022	7.1684	0.306
		9	0.004	0.007	7.1777	0.411

Figure 6 Correlogram of residuals colombo all share price index

After GARCH model applied

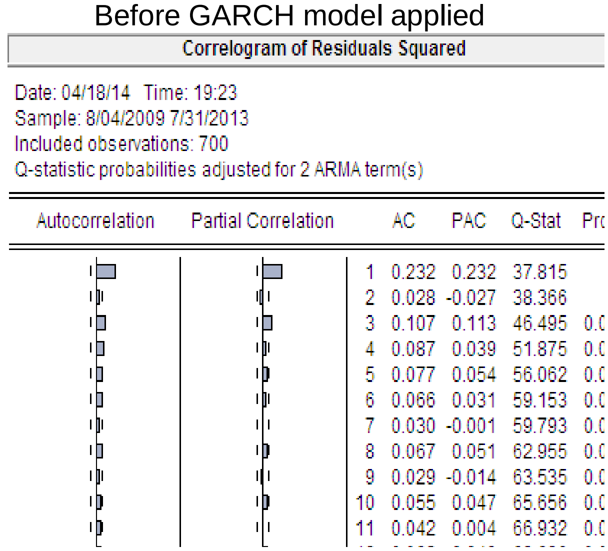


Correlogram of Standardized Residuals Squared

Date: 04/18/14 Time: 19:20
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prol
		1	0.027	0.027	0.5209	
		2	-0.080	-0.081	5.0504	
		3	-0.025	-0.021	5.4975	0.01
		4	-0.012	-0.017	5.5967	0.06
		5	-0.009	-0.012	5.6533	0.13
		6	-0.009	-0.011	5.7112	0.22
		7	-0.015	-0.017	5.8757	0.31
		8	0.067	0.066	9.0469	0.17
		9	0.013	0.006	9.1649	0.24
		10	-0.023	-0.014	9.5320	0.29
		11	0.019	0.024	9.7873	0.36

Before GARCH model applied



Correlogram of Residuals Squared

Date: 04/18/14 Time: 19:23
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Pro
		1	0.232	0.232	37.815	
		2	0.028	-0.027	38.366	
		3	0.107	0.113	46.495	0.0
		4	0.087	0.039	51.875	0.0
		5	0.077	0.054	56.062	0.0
		6	0.066	0.031	59.153	0.0
		7	0.030	-0.001	59.793	0.0
		8	0.067	0.051	62.955	0.0
		9	0.029	-0.014	63.535	0.0
		10	0.055	0.047	65.656	0.0
		11	0.042	0.004	66.932	0.0

Figure 7 Correlogram of standardized residuals squared colombo all share price index

Table 12 ARCH effect test (after GARCH model applied) colombo all share price index

Heteroskedasticity Test: ARCH

F-statistic	1.103876	Prob. F(5,689)	0.3569
Obs*R-squared	5.523200	Prob. Chi-Square(5)	0.3554

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.052966	0.114725	9.178165	0.0000
WGT_RESID^2(-1)	0.026089	0.038079	0.685133	0.4935
WGT_RESID^2(-2)	-0.081329	0.038064	-2.136658	0.0330zz
WGT_RESID^2(-3)	-0.020376	0.038183	-0.533652	0.5938
WGT_RESID^2(-4)	-0.016341	0.038060	-0.429347	0.6678
WGT_RESID^2(-5)	-0.011936	0.038053	-0.313674	0.7539

R-squared	0.007947	Mean dependent var	0.952978
Adjusted R-squared	0.000748	S.D. dependent var	2.036402
S.E. of regression	2.035641	Akaike info criterion	4.268094
Sum squared resid	2855.101	Schwarz criterion	4.307322
Log likelihood	-1477.163	Hannan-Quinn criter.	4.283263
F-statistic	1.103876	Durbin-Watson stat	1.999071
Prob(F-statistic)	0.356923		

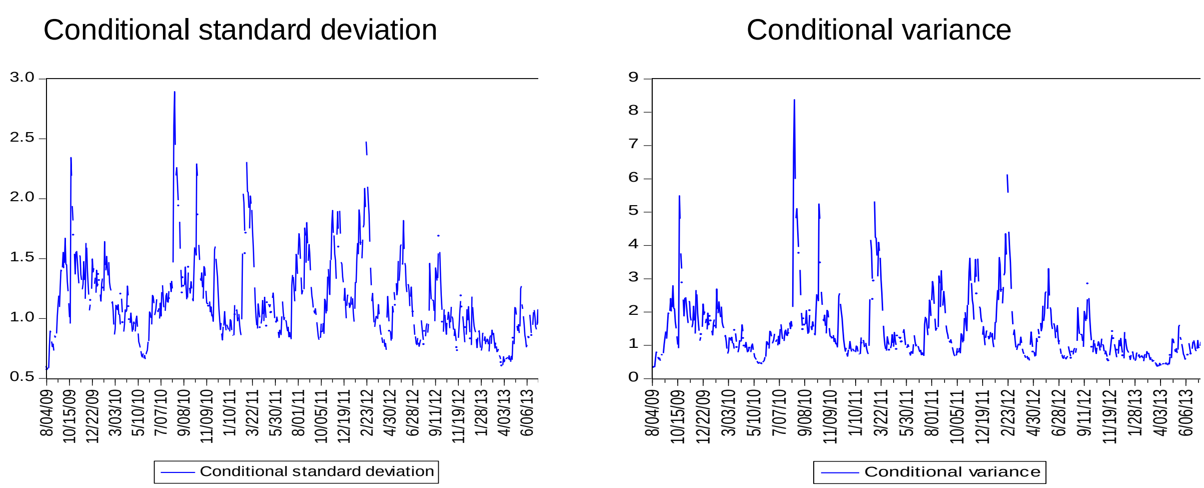


Figure 8 Conditional standard deviation and conditional variance colombo all share price index

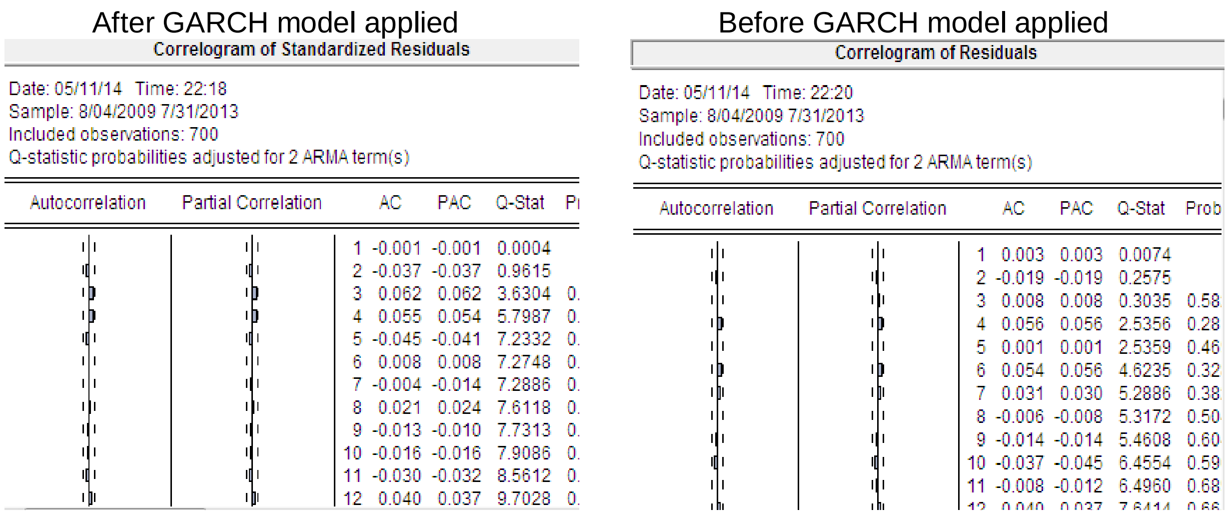
DHAKA STOCK EXCHANGE GENERAL INDEX

Table 13 EGARCH output all Dhaka stock exchange general price index

LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)
*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.160	0.0855	1.87	0.06
AR(1)	0.905	0.062	14.4	0.00
MA(1)	0.857	0.075	-11.28	0.00
	Variance Equation			
C(4)	-0.120	0.038	-3.132	0.0017
C(5)	0.2687	0.055	4.84	0.00
C(6)	-0.170	0.036	-4.71	0.00
C(7)	0.9377	0.017	52.88	0.00
T-DIST. DOF	4.670	0.562538	8.30	0.00

R-squared	-0.009	Mean dependent var	0.056
Adjusted R-squared	-0.019	S.D. dependent var	2.46
S.E. of regression	2.489	Akaike info criterion	4.01
Sum squared resid	4289.29	Schwarz criterion	4.062
Log likelihood	-1395.54	Hannan-Quinn criter.	4.030
Durbin-Watson stat	2.167965		
Inverted AR Roots	.91		
Inverted MA Roots	.86		



After GARCH model applied

Correlogram of Standardized Residuals

Date: 05/11/14 Time: 22:18
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

	AC	PAC	Q-Stat	Pr
1	-0.001	-0.001	0.0004	
2	-0.037	-0.037	0.9615	
3	0.062	0.062	3.6304	0.
4	0.055	0.054	5.7987	0.
5	-0.045	-0.041	7.2332	0.
6	0.008	0.008	7.2748	0.
7	-0.004	-0.014	7.2886	0.
8	0.021	0.024	7.6118	0.
9	-0.013	-0.010	7.7313	0.
10	-0.016	-0.016	7.9086	0.
11	-0.030	-0.032	8.5612	0.
12	0.040	0.037	9.7028	0.

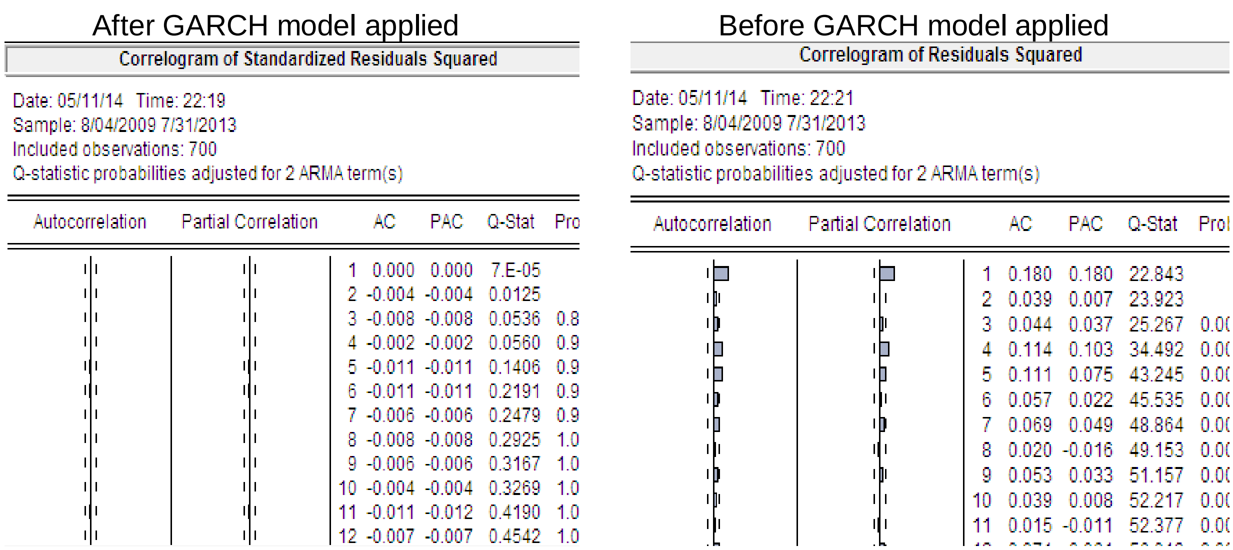
Before GARCH model applied

Correlogram of Residuals

Date: 05/11/14 Time: 22:20
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

	AC	PAC	Q-Stat	Prob
1	0.003	0.003	0.0074	
2	-0.019	-0.019	0.2575	
3	0.008	0.008	0.3035	0.58
4	0.056	0.056	2.5356	0.28
5	0.001	0.001	2.5359	0.46
6	0.054	0.056	4.6235	0.32
7	0.031	0.030	5.2886	0.38
8	-0.006	-0.008	5.3172	0.50
9	-0.014	-0.014	5.4608	0.60
10	-0.037	-0.045	6.4554	0.59
11	-0.008	-0.012	6.4960	0.68

Figure 9 Correlogram of residuals Dhaka stock exchange general price index



After GARCH model applied

Correlogram of Standardized Residuals Squared

Date: 05/11/14 Time: 22:19
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

	AC	PAC	Q-Stat	Pro
1	0.000	0.000	7.E-05	
2	-0.004	-0.004	0.0125	
3	-0.008	-0.008	0.0536	0.8
4	-0.002	-0.002	0.0560	0.9
5	-0.011	-0.011	0.1406	0.9
6	-0.011	-0.011	0.2191	0.9
7	-0.006	-0.006	0.2479	0.9
8	-0.008	-0.008	0.2925	1.0
9	-0.006	-0.006	0.3167	1.0
10	-0.004	-0.004	0.3269	1.0
11	-0.011	-0.012	0.4190	1.0
12	-0.007	-0.007	0.4542	1.0

Before GARCH model applied

Correlogram of Residuals Squared

Date: 05/11/14 Time: 22:21
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 2 ARMA term(s)

	AC	PAC	Q-Stat	Prol
1	0.180	0.180	22.843	
2	0.039	0.007	23.923	
3	0.044	0.037	25.267	0.0
4	0.114	0.103	34.492	0.0
5	0.111	0.075	43.245	0.0
6	0.057	0.022	45.535	0.0
7	0.069	0.049	48.864	0.0
8	0.020	-0.016	49.153	0.0
9	0.053	0.033	51.157	0.0
10	0.039	0.008	52.217	0.0
11	0.015	-0.011	52.377	0.0

Figure 10 Correlogram of residuals squared Dhaka stock exchange general price index

Table 14 ARCH test (after GARCH model applied) Dhaka stock exchange general price index

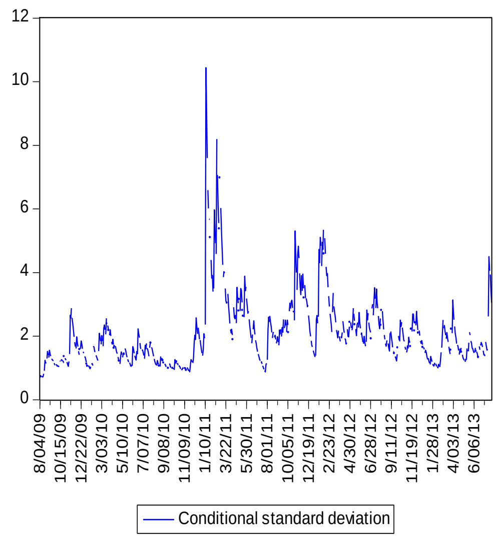
Heteroskedasticity Test: ARCH

F-statistic	0.027705	Prob. F(5,689)	0.9996
Obs*R-squared	0.139704	Prob. Chi-Square(5)	0.9996

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 05/26/14 Time: 21:59
Sample (adjusted): 8/19/2009 7/31/2013
Included observations: 695 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.261219	0.318236	3.963152	0.0001
WGT_RESID^2(-1)	0.000267	0.038095	0.007008	0.9944
WGT_RESID^2(-2)	-0.004287	0.038095	-0.112532	0.9104
WGT_RESID^2(-3)	-0.007711	0.038095	-0.202406	0.8397
WGT_RESID^2(-4)	-0.001881	0.038096	-0.049368	0.9606
WGT_RESID^2(-5)	-0.011001	0.038095	-0.288784	0.7728

R-squared	0.000201	Mean dependent var	1.230841
Adjusted R-squared	-0.007054	S.D. dependent var	7.885479
S.E. of regression	7.913244	Akaike info criterion	6.983548
Sum squared resid	43144.79	Schwarz criterion	7.022776
Log likelihood	-2420.783	Hannan-Quinn criter.	6.998717
F-statistic	0.027705	Durbin-Watson stat	2.000204
Prob(F-statistic)	0.999637		



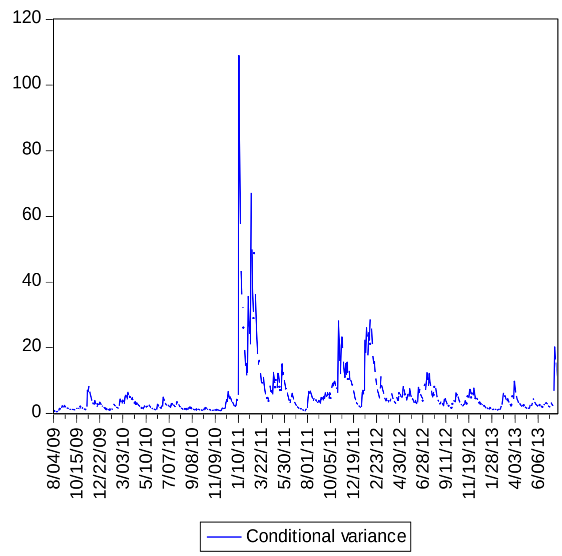


Figure 11 conditional standard deviation and conditional variance Dhaka stock exchange general price index

BOMBAY STOCK EXCHANGE INDEX (SENSEX)

Table 15 CGARCH output of Bombay stock exchange sensex

Q = C(4) + C(5)*(Q(-1) - C(4)) + C(6)*(RESID(-1)^2 - GARCH(-1))
GARCH = Q + C(7) * (RESID(-1)^2 - Q(-1)) + C(8)*(GARCH(-1) - Q(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.058039	0.045662	1.271071	0.2037
AR(1)	0.018592	0.493990	0.037637	0.9700
MA(1)	0.027136	0.494586	0.054865	0.9562
	Variance Equation			
C(4)	1.535153	0.385502	3.982216	0.0001
C(5)	0.979456	0.012636	77.51441	0.0000
C(6)	0.039579	0.014924	2.652066	0.0080
C(7)	-0.090627	0.013059	-6.939812	0.0000
C(8)	0.014291	0.491997	0.029047	0.9768
T-DIST. DOF	5.940153	1.518177	3.912688	0.0001

R-squared	0.002921	Mean dependent var	0.027804
Adjusted R-squared	-0.008622	S.D. dependent var	1.345554
S.E. of regression	1.351343	Akaike info criterion	3.360469
Sum squared resid	1261.854	Schwarz criterion	3.418983
Log likelihood	-1167.164	Hannan-Quinn criter.	3.383088
F-statistic	0.253064	Durbin-Watson stat	1.967964
Prob(F-statistic)	0.980068		
Inverted AR Roots	.02		
Inverted MA Roots	-.03		

After GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.005	0.005	0.0168	
		2	-0.005	-0.005	0.0339	
		3	-0.012	-0.012	0.1388	0.71
		4	-0.032	-0.032	0.8681	0.64
		5	-0.003	-0.003	0.8767	0.83
		6	-0.019	-0.019	1.1206	0.89
		7	0.029	0.028	1.7023	0.88
		8	-0.061	-0.063	4.3258	0.63
		9	-0.012	-0.012	4.4324	0.72
		10	0.069	0.068	7.7829	0.45
		11	-0.014	-0.015	7.9319	0.54
		12	-0.015	-0.019	8.0991	0.61

Before GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Pr
		1	-0.001	-0.001	0.0015	
		2	-0.012	-0.012	0.0961	
		3	-0.025	-0.025	0.5441	0.4
		4	-0.043	-0.043	1.8602	0.3
		5	0.002	0.001	1.8628	0.6
		6	-0.014	-0.016	2.0030	0.7
		7	0.025	0.022	2.4312	0.7
		8	-0.061	-0.063	5.0418	0.5
		9	-0.024	-0.024	5.4356	0.6
		10	0.066	0.065	8.5820	0.3
		11	-0.018	-0.019	8.8086	0.4
		12	-0.011	-0.016	8.8892	0.5

Figure 12 Correlogram of standard residual Bombay stock exchange sensex

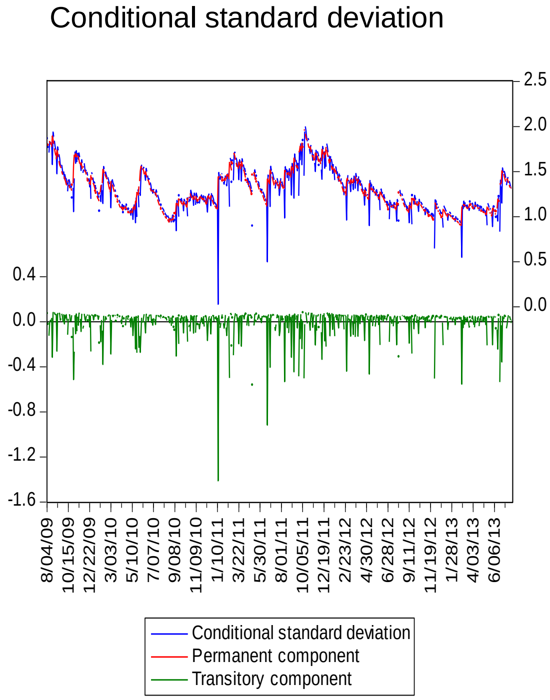
After GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Pr
		1	0.019	0.019	0.2528	
		2	-0.010	-0.010	0.3232	
		3	0.006	0.007	0.3511	0.
		4	0.067	0.067	3.5461	0.
		5	-0.035	-0.037	4.3900	0.
		6	-0.018	-0.015	4.6164	0.
		7	0.021	0.021	4.9428	0.
		8	-0.020	-0.026	5.2307	0.
		9	-0.038	-0.032	6.2735	0.
		10	-0.010	-0.008	6.3422	0.
		11	-0.015	-0.019	6.4963	0.
		12	-0.024	-0.019	6.8948	0.

Before GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.012	-0.012	0.1063	
		2	0.035	0.035	0.9912	
		3	0.049	0.050	2.6891	0.10
		4	0.143	0.144	17.141	0.00
		5	0.021	0.023	17.452	0.00
		6	0.051	0.040	19.258	0.00
		7	0.078	0.066	23.527	0.00
		8	0.072	0.052	27.180	0.00
		9	0.009	-0.001	27.242	0.00
		10	0.038	0.017	28.292	0.00
		11	0.005	-0.022	28.308	0.00
		12	0.048	0.025	29.986	0.00

Figure 13 Correlogram of standardized residuals squared Bombay stock exchange sense



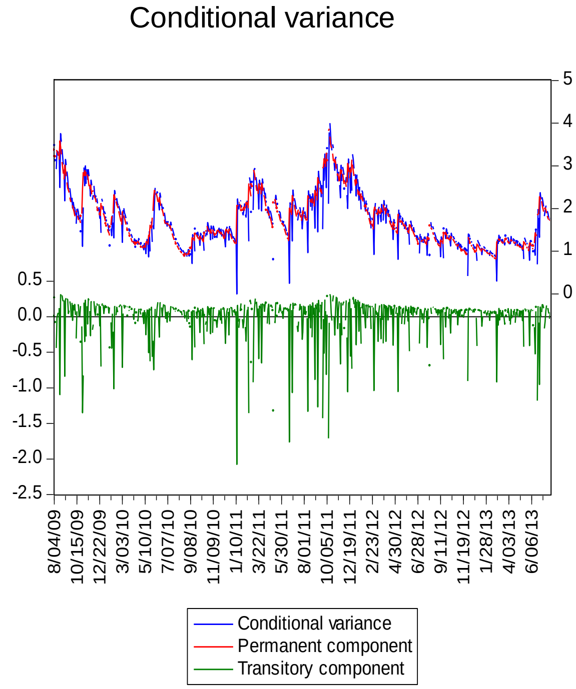


Figure 14 Conditional standard deviation and conditional variance Bombay stock exchange sensex

Table 16 ARCH afect test after CGARCH applied Bombay stock exchange sensex

Heteroskedasticity Test: ARCH				
F-statistic	0.881151	Prob. F(5,689)		0.4932
Obs*R-squared	4.415884	Prob. Chi-Square(5)		0.4912
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.999639	0.113505	8.807033	0.0000
WGT_RESID^2(-1)	0.021166	0.038079	0.555859	0.5785
WGT_RESID^2(-2)	-0.00898	0.038000	-0.236410	0.8132
WGT_RESID^2(-3)	0.005067	0.037985	0.133386	0.8939
WGT_RESID^2(-4)	0.067650	0.037984	1.781026	0.0753
WGT_RESID^2(-5)	-0.037160	0.038057	-0.976427	0.3292
R-squared	0.006354	Mean dependent var		1.049964

Adjusted R-squared	-0.000857	S.D. dependent var	1.912282
S.E. of regression	1.913102	Akaike info criterion	4.143924
Sum squared resid	2521.711	Schwarz criterion	4.183152
Log likelihood	-1434.014	Hannan-Quinn criter.	4.159093
F-statistic	0.881151	Durbin-Watson stat	2.000687
Prob(F-statistic)	0.493200		

SRILANKAN RUPEE

Table 17 EGARCH output of Srilankan rupee

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)
*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000160	0.003588	-0.044494	0.9645
AR(1)	0.016976	0.034600	0.490633	0.6237
	Variance Equation			
C(3)	-0.551030	0.129188	-4.265328	0.0000
C(4)	1.208975	0.700885	1.724926	0.0845
C(5)	0.251344	0.176212	1.426374	0.1538
C(6)	0.889008	0.021408	41.52778	0.0000
T-DIST. DOF	2.106474	0.128863	16.34667	0.0000

R-squared	0.004359	Mean dependent var	0.019396
Adjusted R-squared	-0.004261	S.D. dependent var	0.327402
S.E. of regression	0.328099	Akaike info criterion	-0.743366
Sum squared resid	74.60069	Schwarz criterion	-0.697855
Log likelihood	267.1781	Hannan-Quinn criter.	-0.725773
F-statistic	0.505689	Durbin-Watson stat	1.549059
Prob(F-statistic)	0.804285		
Inverted AR Roots	.02		

After GARCH applied

Correlogram of Standardized Residuals

Date: 05/12/14 Time: 11:25
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 1 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.049	0.049	1.7059	
		2	0.025	0.022	2.1359	0.14
		3	0.043	0.041	3.4271	0.18
		4	-0.011	-0.016	3.5153	0.31
		5	0.004	0.003	3.5249	0.47
		6	-0.007	-0.009	3.5621	0.61
		7	0.019	0.021	3.8163	0.70
		8	-0.010	-0.012	3.8815	0.79
		9	-0.013	-0.012	4.0015	0.85
		10	-0.034	-0.035	4.8401	0.84
		11	-0.027	-0.022	5.3609	0.86
		12	-0.035	-0.031	6.2604	0.85

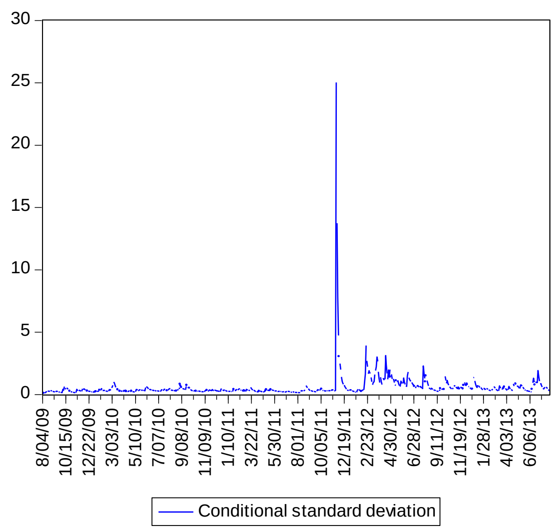
Before GARCH applied

Correlogram of Standardized Residuals Squared

Date: 05/12/14 Time: 11:29
Sample: 8/04/2009 7/31/2013
Included observations: 700
Q-statistic probabilities adjusted for 1 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.012	-0.012	0.1084	
		2	-0.012	-0.012	0.2078	0.64
		3	-0.012	-0.012	0.3071	0.85
		4	-0.002	-0.002	0.3094	0.95
		5	-0.014	-0.015	0.4518	0.97
		6	-0.002	-0.002	0.4540	0.99
		7	-0.011	-0.012	0.5454	0.99
		8	-0.007	-0.008	0.5834	0.99
		9	-0.011	-0.012	0.6684	1.00
		10	-0.010	-0.011	0.7403	1.00
		11	-0.006	-0.007	0.7630	1.00
		12	-0.008	-0.010	0.8139	1.00

Figure 15 Correlogram of standardized residuals and residuals squared Srilankan rupee



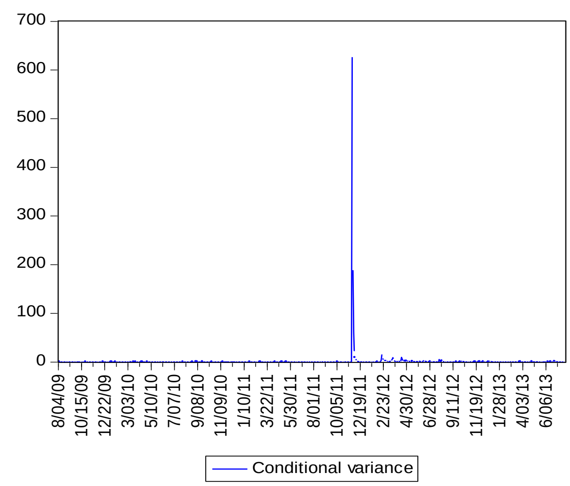


Figure 16 Conditional standard deviation and conditional variance Srilankan rupee

Table 18 ARCH effect test (after GARCH applied) Srilankan rupee

Heteroskedasticity Test: ARCH				
F-statistic	0.091721	Prob. F(5,690)		0.9935
Obs*R-squared	0.462285	Prob. Chi-Square(5)		0.9934
Variable	Coefficient	Std. Error	t-Statistic	Prob.

C	0.302634	0.068094	4.444353	0.0000
WGT_RESID^2(-1)	-0.012765	0.038066	-0.335325	0.7375
WGT_RESID^2(-2)	-0.012414	0.038070	-0.326073	0.7445
WGT_RESID^2(-3)	-0.012380	0.038070	-0.325198	0.7451
WGT_RESID^2(-4)	-0.002458	0.038071	-0.064555	0.9485
WGT_RESID^2(-5)	-0.014558	0.038068	-0.382427	0.7023

R-squared	0.000664	Mean dependent var	0.286931
Adjusted R-squared	-0.006577	S.D. dependent var	1.664931
S.E. of regression	1.670397	Akaike info criterion	3.872583
Sum squared resid	1925.256	Schwarz criterion	3.911767
Log likelihood	-1341.659	Hannan-Quinn criter.	3.887734
F-statistic	0.091721	Durbin-Watson stat	2.000012
Prob(F-statistic)	0.993533		

BANGLADESHI TAKA

Table 19EGARCH output of Bangladeshi taka

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)
*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.202554	0.089715	2.257752	0.0240
MA(1)	-0.537381	0.070920	-7.577302	0.0000
	Variance Equation			
C(3)	-0.895773	0.231559	-3.868443	0.0001
C(4)	0.502474	0.116729	4.304603	0.0000
C(5)	-0.034006	0.070907	-0.479581	0.6315
C(6)	0.669250	0.106165	6.303880	0.0000
T-DIST. DOF	3.058521	0.430722	7.100920	0.0000

R-squared	0.098137	Mean dependent var	0.017384
Adjusted R-squared	0.090329	S.D. dependent var	0.463309
S.E. of regression	0.441889	Akaike info criterion	0.750648
Sum squared resid	135.3191	Schwarz criterion	0.796158
Log likelihood	-255.7266	Hannan-Quinn criter.	0.768240
Durbin-Watson	1.992979		

stat	
Inverted AR Roots	.20
Inverted MA Roots	.54

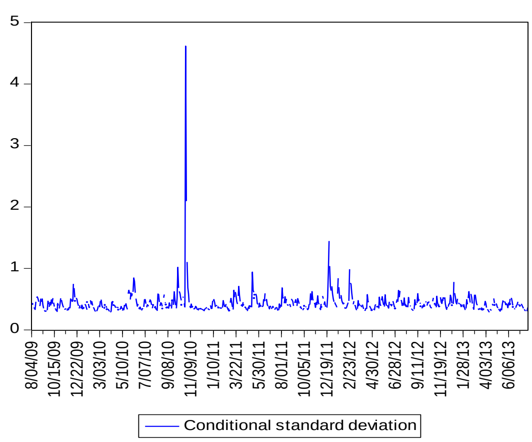
After GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	F
		1	-0.013	-0.013	0.1225	
		2	-0.022	-0.022	0.4636	
		3	-0.013	-0.013	0.5803	(
		4	-0.014	-0.015	0.7235	(
		5	0.058	0.057	3.0639	(
		6	0.022	0.022	3.3929	(
		7	-0.003	-0.001	3.4010	(
		8	0.085	0.087	8.4800	(
		9	0.009	0.014	8.5387	(
		10	0.029	0.031	9.1545	(
		11	0.021	0.023	9.4827	(
		12	0.069	0.074	12.869	(

Before GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Pr
		1	-0.003	-0.003	0.0057	
		2	-0.018	-0.018	0.2360	
		3	0.004	0.004	0.2456	0.
		4	0.012	0.011	0.3415	0.
		5	0.066	0.066	3.4206	0.
		6	0.038	0.039	4.4257	0.
		7	-0.019	-0.016	4.6805	0.
		8	0.078	0.080	9.0544	0.
		9	0.009	0.007	9.1108	0.
		10	0.044	0.042	10.482	0.
		11	0.028	0.024	11.029	0.
		12	0.126	0.129	22.294	0.

Figure 17 Correlogram of standardized residuals Bangladeshi taka



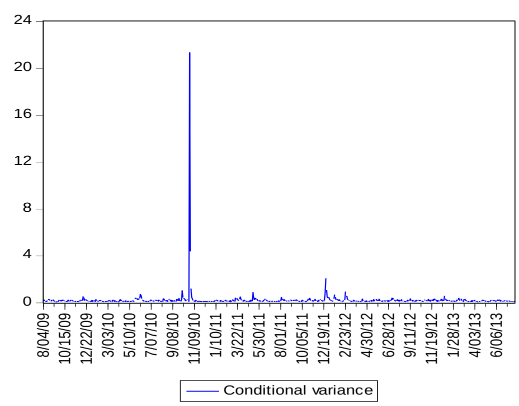


Figure 18 Conditional standard deviation and conditional variance Bangladeshi taka

Table 20 ARCH effect test result (after GARCH applied) Bangladeshi taka

Heteroskedasticity Test: ARCH

F-statistic	0.164622	Prob. F(5,689)	0.9755
Obs*R-squared	0.829287	Prob. Chi-Square(5)	0.9751

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.921005	0.172408	5.342001	0.0000
WGT_RESID^2(-1)	0.004265	0.038096	0.111958	0.9109
WGT_RESID^2(-2)	-0.012132	0.038082	-0.318577	0.7501
WGT_RESID^2(-3)	-0.017294	0.038079	-0.454145	0.6499
WGT_RESID^2(-4)	0.026077	0.038083	0.684741	0.4937
WGT_RESID^2(-5)	-0.007387	0.038097	-0.193894	0.8463

R-squared	0.001193	Mean dependent var	0.915091
Adjusted R-squared	-0.006055	S.D. dependent var	4.036538
S.E. of regression	4.048740	Akaike info criterion	5.643284
Sum squared resid	11294.29	Schwarz criterion	5.682512
Log likelihood	-1955.041	Hannan-Quinn criter.	5.658453
F-statistic	0.164622	Durbin-Watson stat	1.999412
Prob(F-statistic)	0.975450		

INDIAN RUPEE

Table 21 CGARCH output of Indian rupee

Q = C(3) + C(4)*(Q(-1) - C(3)) + C(5)*(RESID(-1)^2 - GARCH(-1))
GARCH = Q + C(6) * (RESID(-1)^2 - Q(-1)) + C(7)*(GARCH(-1) - Q(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.009304	0.023031	0.403979	0.6862
AR(1)	0.031953	0.035245	0.906593	0.3646
	Variance Equation			
C(3)	0.376796	0.060452	6.233021	0.0000

C(4)	0.979604	0.010330	94.82961	0.0000
C(5)	0.044954	0.013105	3.430365	0.0006
C(6)	-0.063052	0.024625	-2.560461	0.0105
C(7)	0.345751	0.476823	0.725114	0.4684

R-squared	0.000883	Mean dependent var	0.030875
Adjusted R-squared	-0.007767	S.D. dependent var	0.661544
S.E. of regression	0.664108	Akaike info criterion	1.869978
Sum squared resid	305.6401	Schwarz criterion	1.915489
Log likelihood	-647.4923	Hannan-Quinn criter.	1.887571
F-statistic	0.102129	Durbin-Watson stat	1.957553
Prob(F-statistic)	0.996158		
Inverted AR Roots	.03		

After GARCH applied

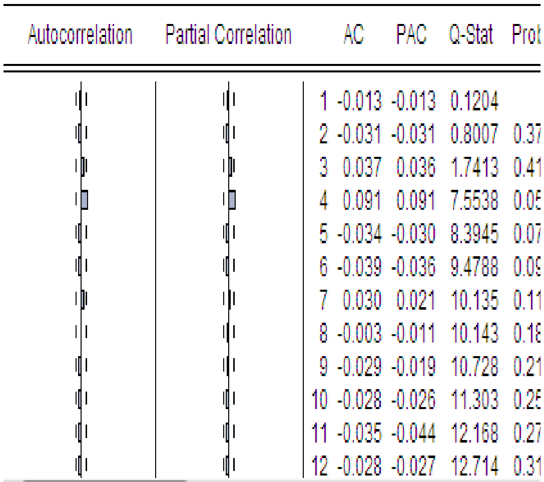
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.028	0.028	0.5359	
		2	-0.004	-0.005	0.5459	0.46
		3	-0.025	-0.024	0.9693	0.61
		4	0.067	0.068	4.1328	0.24
		5	0.037	0.033	5.1073	0.27
		6	-0.004	-0.007	5.1209	0.40
		7	0.105	0.110	12.933	0.04
		8	0.043	0.035	14.227	0.04
		9	0.024	0.018	14.645	0.06
		10	0.002	0.008	14.649	0.10
		11	-0.037	-0.050	15.648	0.11
		12	0.010	0.001	15.725	0.15

Before GARCH applied

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.002	0.002	0.0026	
		2	-0.005	-0.005	0.0173	0.89
		3	-0.041	-0.041	1.2189	0.54
		4	0.072	0.072	4.8844	0.18
		5	0.027	0.027	5.4142	0.24
		6	-0.026	-0.027	5.8846	0.31
		7	0.123	0.130	16.552	0.01
		8	0.037	0.034	17.546	0.01
		9	0.015	0.010	17.713	0.02
		10	-0.001	0.015	17.713	0.03
		11	-0.025	-0.040	18.158	0.05
		12	-0.009	-0.021	18.214	0.07

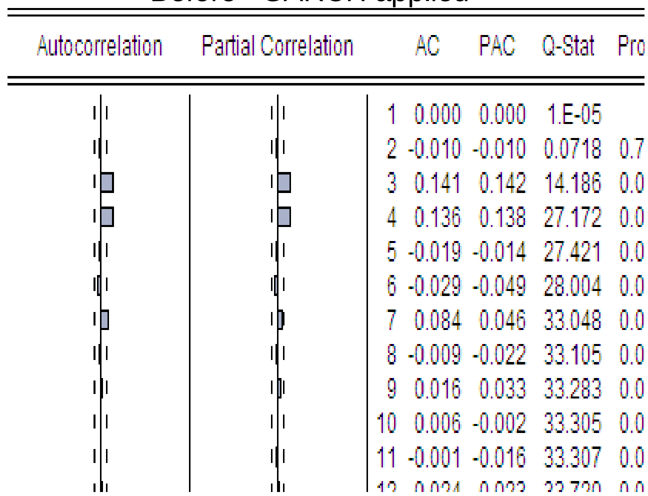
Figure 19 Correlogram of standardised residuals of Indian rupee

After GARCH applied



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.013	-0.013	0.1204	
		2	-0.031	-0.031	0.8007	0.37
		3	0.037	0.036	1.7413	0.41
		4	0.091	0.091	7.5538	0.05
		5	-0.034	-0.030	8.3945	0.07
		6	-0.039	-0.036	9.4788	0.09
		7	0.030	0.021	10.135	0.11
		8	-0.003	-0.011	10.143	0.18
		9	-0.029	-0.019	10.728	0.21
		10	-0.028	-0.026	11.303	0.25
		11	-0.035	-0.044	12.168	0.27
		12	-0.028	-0.027	12.714	0.31

Before GARCH applied



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.000	0.000	1.E-05	
		2	-0.010	-0.010	0.0718	0.7
		3	0.141	0.142	14.186	0.0
		4	0.136	0.138	27.172	0.0
		5	-0.019	-0.014	27.421	0.0
		6	-0.029	-0.049	28.004	0.0
		7	0.084	0.046	33.048	0.0
		8	-0.009	-0.022	33.105	0.0
		9	0.016	0.033	33.283	0.0
		10	0.006	-0.002	33.305	0.0
		11	-0.001	-0.016	33.307	0.0

Figure 20 Correlogram of standardised residuals squared of Indian rupee

Table 22 ARCH effect test after CGARCH applied Indian rupee

Heteroskedasticity Test: ARCH

F-statistic	1.619322	Prob. F(5,690)	0.1526
Obs*R-squared	8.072295	Prob. Chi-Square(5)	0.1523

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.016860	0.125812	8.082387	0.0000
WGT_RESID^2(-1)	-0.012975	0.038140	-0.340180	0.7338
WGT_RESID^2(-2)	-0.026776	0.037979	-0.705025	0.4810
WGT_RESID^2(-3)	0.036145	0.037967	0.952005	0.3414
WGT_RESID^2(-4)	0.090901	0.037980	2.393367	0.0170
WGT_RESID^2(-5)	-0.030027	0.038144	-0.787197	0.4314

R-squared	0.011598	Mean dependent var	1.078447
Adjusted R-squared	0.004436	S.D. dependent var	2.301571
S.E. of regression	2.296461	Akaike info criterion	4.509199
Sum squared resid	3638.875	Schwarz criterion	4.548383
Log likelihood	-1563.201	Hannan-Quinn criter.	4.524350
F-statistic	1.619322	Durbin-Watson stat	1.997193
Prob(F-statistic)	0.152585		

MATLAB CODE FOR COPULAFIT (COPULA PARAMETER ESTIMATION)

INDIAN PAIR (SENSEX AND INDIAN RUPEE)

```
scatterhist (sensex,usd_inr)

u = ksdensity(sensex,sensex,'function','cdf');

v = ksdensity(usd_inr,usd_inr,'function','cdf');

scatterhist(u,v)

xlabel('u')

ylabel('v')

[Rho,nu] = copulafit('t',[u v],'Method','ApproximateML')

[Rho] = copulafit('gaussian',[u v]);

r = copularnd('t',Rho,nu,1000);r = copularnd('t',Rho,nu,1000);

u1 = r(:,1);

v1 = r(:,2);

scatterhist(u1,v1)

xlabel('u')

ylabel('v')

x1 = ksdensity(sensex,u1,'function','icdf');
```

```
y1 = ksdensity(usd_inr,v1,'function','icdf');

scatterhist(x1,y1)

[[paramhat,paramci] = copulafit('clayton',[u v]);

[paramhat,paramci] = copulafit('frank',[u v]);

[paramhat,paramci] = copulafit('gumbel',[u v]);
```

TAIL DEPENDENCE FOR INDIAN PAIR

```
tauLU(2,:) = [2^(-1/paramhat),0];% Clayton copula has zero upper tail dependence

tauLU = [0,2-2^(1/paramhat)];    % Gumbel copula has zero lower tail dependence
```

SRILANKAN PAIR (COLOMBO ALL SHARE PRICE INDEX AND SRILANKAN RUPEE)

```
scatterhist (colombo,usd_lkr)

u = ksdensity(colombo,colombo,'function','cdf');

v = ksdensity(usd_lkr,usd_lkr,'function','cdf');

scatterhist(u,v)

xlabel('u')

ylabel('v')

[Rho,nu] = copulafit('t',[u v],'Method','ApproximateML')

% fit a t copula

[Rho] = copulafit('gaussian',[u v])
```

```
r = copularnd('t',Rho,nu,1000);r = copularnd('t',Rho,nu,1000);

u1 = r(:,1);

v1 = r(:,2);

scatterhist(u1,v1)

xlabel('u')

ylabel('v')

x1 = ksdensity(colombo,u1,'function','icdf');

y1 = ksdensity(usd_lkr,v1,'function','icdf');

scatterhist(x1,y1)

[paramhat,paramci] = copulafit('clayton',[u v]);

[paramhat,paramci] = copulafit('frank',[u v]);

[paramhat,paramci] = copulafit('gumbel',[u v]);
```

TAIL DEPENDENCE FOR SRI LANKAN PAIR

```
tauLU(2,:) = [2^(-1/paramhat),0];% Clayton copula has zero upper tail dependence

tauLU = [0,2-2^(1/paramhat)];    % Gumbel copula has zero lower tail dependence
```

BANGLADESH PAIR (DHAKA STOCK EXCHANGE ALL SHARE PRICE INDEX AND TAKA)

```
scatterhist (Dgen,usd_bdt)

u = ksdensity(Dgen,Dgen,'function','cdf');
```

```
v = ksdensity(usd_bdt,usd_bdt,'function','cdf');

scatterhist(u,v)

xlabel('u')

ylabel('v')

[Rho,nu] = copulafit('t',[u v],'Method','ApproximateML')

% fit a t copula

[Rho] = copulafit('gaussian',[u v])

r = copularnd('t',Rho,nu,1000);r = copularnd('t',Rho,nu,1000);

u1 = r(:,1);

v1 = r(:,2);

scatterhist(u1,v1)

xlabel('u')

ylabel('v')

x1 = ksdensity(Dgen,u1,'function','icdf');

y1 = ksdensity(usd_bdt,v1,'function','icdf');

scatterhist(x1,y1)

[paramhat,paramci] = copulafit('clayton',[u v]);

[paramhat,paramci] = copulafit('frank',[u v]);
```

```
[paramhat,paramci] = copulafit('gumbel',[u v]);
```

TAIL DEPENDENCE FOR BANGLADESHI PAIR

```
tauLU(2,:) = [2^(-1/paramhat),0];% Clayton copula has zero upper tail dependence

tauLU = [0,2-2^(1/paramhat)];    % Gumbel copula has zero lower tail dependence
```

GAUSSIAN COPULA LOGLIKLIHOOD FUNCTION

```
x2 = norminv(u);

y2 = norminv(v);

CL = -1*(2*(1-rho^2))^(-1)*(x2.^2+y2.^2-2*rho*x2.*y2);

CL = CL + 0.5*(x2.^2+y2.^2);

CL = sum(CL) - size(x2,1)/2*log(1-rho^2);

CL = -CL;
```

AIC

```
T = length(u)

params = (1);  % number of parameters in each model

AIC = 2*CL + 2/T*params;
```

The End