Full Length Research Paper

Modeling the exchange rate volatility, using generalized autoregressive conditionally heteroscedastic (GARCH) type models: Evidence from Pakistan

Yasir Kamal\(^1\)*, Hammad-Ul-Haq, Usman Ghani\(^1\) and Muhammad Muhsin Khan\(^1\)

\(^1\)Institute of Management Sciences, IMS, Peshawar, Pakistan.
\(^2\)Shaheed Zulfikar Ali Bhutto Institute of Science and Technology, SZABIST, Islamabad, Pakistan.

Accepted 28 January, 2011

Increasing role of foreign exchange (FOREX) rate in corporate decision making is becoming famous in the developing economies, where FOREX rate volatility occupied a central position all over the world in investment decision. In a scenario, where FOREX rate volatility is equally helpful in many micro as well as macro economic decision-making (remembering historical roots of some of the financial crises were traced in the FOREX rate volatility). In this study, an attempt is made to examine the performance of GARCH family models (including symmetric GARCH-M, asymmetric EGARCH and TARCH models) in forecasting the volatility behavior of Pakistani FOREX market. Daily FOREX rates data, ranging from January, 2001 to December, 2009 was put to statistical manipulation to examine the FOREX volatility behavior in Pakistan. Theoretically, the first order autoregressive behavior of the FOREX rate was evidenced in GARCH-M and E-GARCH models while the GARCH-M model supports that previous day FOREX rate affected the current day exchange rate. The EGARCH-based evaluation of FOREX rates showed asymmetric behavior of volatility, where TARCH model showed insignificance but detailed exploratory analysis of the FOREX rate behavior requires prolonged study by applying advance models.

**Key words:** Exchange rate, GARCH-M, TARCH, EGARCH, volatility, Pakistan.

INTRODUCTION

Traditionally, corporate decision makers use volatility models as a tool in portfolio allocation, risk management and as an input in derivative asset pricing while the policymakers use the same to keep an eye on the economic factors, their impact on exchange rate, and to develop monetary and fiscal policies as well. Export oriented countries with substantial impact of exports on economic growth emphasize more on the exchange rate volatility in their economic policies. Many financial crises stemming from sudden and unexpected oscillation in the financial crises of Latin American, Southeast Asian and Russian economies highlighted the importance of measurement of FOREX rate volatility, its forecasting and its behavior.

FOREX rate system can either be fixed or floating, that is, fixed exchange rates is treated as a permanent one and the floating exchange rate may drift, up and down, according to certain market trends. Floating FOREX rates are expected to be more volatile as they are free to fluctuate. The volatility in FOREX rates result in increase of exchange rate risk and adversely affects the international trade and investment decisions.

According to the findings of Taylor (2005), FOREX volatility inputs are supportive in certain financial decisions related to portfolio optimization, hedging, risk management, pricing of options and other types of derivatives. FOREX rate is one of the key macroeconomic variables, with direct effect on international trade balance. Kemal (2005) observes that, FOREX rate volatility,
adversely, affects the long-term decisions by stirring the volume of global marketing and decisions to allocate resources for investment, sales and procurement policies of governments. In the medium term, FOREX rate can influence the balance of payments and level of the overall economic activity while affecting the local consumers and traders in the short run. Sengupta (2002) find resemblance in the FOREX market and the world’s largest financial market by miles. The FOREX market is an uninterrupted one with no opening or closing hours, and functioning 24 hours a day and 7 days a week. An investor’s confidence to invest in a particular country is inversely related to high volatilities in the exchange rate. This is the basic reason that volatility models are used to explain the enduring and significant instances in the FOREX rate movements. Poon and Granger (2003) asserted that financial volatility has significant influence on the economy while the policy and decision makers depends heavily upon the volatility modeling to anticipate on the vulnerabilities of financial markets and economy.

Most of the research on exchange rate volatility and its forecasting is focused on the developed markets while the current study aims to adjunct the existing literature by examining the exchange rate volatility of Pakistani rupee against the US dollar. The prime concern of the researchers revolves around the application of appropriate model to be applied to analyze the FOREX volatility and the ability of a model to forecast movements in exchange rates based on information, contained in historical trading activities.

In the available literature of modeling time series volatility, the authenticity and the popularity of ARCH family (GARCH, EGARCH and stochastic volatility models) is recognized universally. According to Engle (1982) and Bollerslev (1986), time series’ models are more reliable for capturing the volatility in financial time series as these models are specifically designed for volatility modeling.

According to Dimson and Marsh (1990) and Bollerslev (1986), ARCH and GARCH models are very useful to capture the leptokurtic and volatility clustering and help to model the changing conditional variances in time series. Brooks and Burke (2003) are of the view that the lag order (1,1) model is effective enough to capture all the volatility clustering available in data. To account for asymmetrical and leverage effects, the extension of ARCH models, EGARCH, was introduced by Nelson (1991). Similarly, Akgiray (1989) was also in support of ARCH and GARCH model and praised the model capability while forecasting volatility in New York Stock Exchange.

The purpose of the current study is to model and quantify the volatility of exchange rate of Pakistani Rupee against the US Dollar through different available types of GARCH family models. The symmetric GARCH-M (1,1), asymmetric EGARCH (1,1) and TARCH (1,1) models will be applied to capture the main characteristics of exchange rate, such as, volatility clustering and the leverage effect. According to Engle (1993), all of these three models are capable of predicting returns volatility in the financial market and may create an impact on investors’ portfolio decision. This forecast of the volatility of financial variables is a relevant piece of information and of particular significance for making economic decisions.

Problem statement

FOREX rate volatility is an important factor involved in the decision making of investors and policy makers. The literature provides a number of volatility measures to develop model of volatility behavior of time series. The current study is the first such attempt in Pakistan to capture the Pak Rupee volatility against US Dollar. The capturing of asymmetric and leverage behavior of Pakistan’s exchange rate was really vital and significant from policy makers, individual as well as the group investors’ point of view.

Objective of the study

The objective of the paper is to estimate the time varying variances in Pak-US FOREX rate, from year 2001 to 2008, through GARCH (1, 1), EGARCH and TARCH models, resulting in a larger estimated conditional variance indicating potential but substantial risk.

LITERATURE REVIEW

Modeling and forecasting FOREX rate has many practical applications in economics and finance with wide discussion in the literature. The basic ARCH/GARCH models are frequently applied and quoted to describe the volatility in financial markets, such as, stock exchanges and FOREX markets.

Hsieh (1989) used 10 years (1974 – 1983) of daily closing-bid prices, consisting of 2,510 observations, for five countries in comparison of US dollar to estimate the autoregressive conditionally heteroscedastic (ARCH) and generalized autoregressive conditionally heteroscedastic (GARCH) models along with the other modified/altered types of ARCH and GARCH. The findings of Hsieh (1989) proved that the two understudy models were capable of removing all heteroscedasticity in price changes. It was also concluded that the standardized residuals from all the ARCH and GARCH models using the standard normal density were highly leptokurtic, and the standard GARCH (1,1) and EGACH (1,1) were found to be more efficient for removing conditional heteroscedasticity from daily exchange rate movements. The EGARCH proved to fit the data, better than GARCH.
Mundaca (1991) modeled the NOK/US Dollar exchange rate through ARCH and GARCH models, the results of which supported that three out of four analyzed series fitted better through GARCH than the ARCH model. Johnston and Scott (2000) examined the British Pound, Canadian Dollar, German Mark and Japanese Yen against the US Dollar, for the years 1978 to 1992, by applying the GARCH models. Though, the findings of Johnston and Scott (2000) identified that FOREX rate time variation were not the only reason of overall volatility but the fact that after removing the GARCH effect, the frequency distributions still showed the existence of independence. This puzzled the authors and forced them to GARCH family models with normality assumption that were unable to provide good description of exchange rate dynamics. Kazantzis (2001), who studied the information contents and predictive power of implied volatility models against the volatility estimates, based on six-year prices data from the currency options market for six different currencies. The author deduced that, implied volatility contained more information contents than measures based, where information embedded in past price history.

Application of GARCH model by Chong et al. (2002), to capture FOREX rate volatility in the data of Malaysian Ringgit/Pound Sterling, for the period 1990-1997, resulted in their suggestion to possibly reject the hypothesis of constant variance model, arguing that the GARCH models were better ones than native random walk models. The use of Peso-dollar exchange rate data, with 1730 observations from January 2, 1997 to December 5, 2003, by Mapa (2004) compared, the out of sample forecasting performance of 68 ARCH-type models. In the estimation by Mapa (2004), the model specifications were observed through application of Maximum Likelihood method with Gaussian, student’s t-test, Generalized Error distributions and through Quasi-Maximum likelihood.

The findings helped the author to argue that focusing on the specification of the models is not sufficient but data distribution should also be considered in FOREX rate modeling and their findings demonstrated that accommodating the leveraged effect models, such as, TARCH, PARCH and EGARCH were able to show superior forecasting performance than the models which did not. Longmore and Robinson (2004) applied linear GARCH and asymmetrical volatility models on Jamaican Dollar for the period 1998 to 2003 and found long memory process for the exchange rate with effects of shocks being asymmetric, while in terms of explanatory power, the non-linear GARCH model performed well.

A weekly Baht/US Dollar exchange rate, for the period 1999-2005, was analyzed by Jitthikulchai (2005) to study the application of parametric and non-parametric volatility models in which ARCH and ARCH-M were found more realistic, both theoretical and empirically, because of their low volatility around zero mean whereas, the asymmetric coefficients of EGARCH and TGARCH showed insignificant results. The TGARCH model was declared the best model of modeling the exchange rate volatility in out-of-sample case by the researcher who suggested that non-parametric models could be the best for the conditional volatility prediction, while in the case of high frequency data; it is more preferable than any other volatility model.

Alberg et al. (2006) investigated the forecasting performance of GARCH, EGARCH, GJR and APARCH models and found that the EGARCH model, which used a skewed Student-t distribution, produced significant results than any other model. Sandoval (2006) examined the daily exchange rate data, from year 2000 to 2004, of seven Asian and emerging Latin American countries, by applying the ARMA, GARCH, EGARCH and GJR-GARCH models for modeling the exchange rates and capturing the important characteristics of data. Sandoval (2006) pointed out that, in the developing countries the absence of statistical significance between asymmetric and symmetric models was conditional to the application of in-sample and out-of-sample tests jointly.

Hussein and Jalil (2007) applied the parametric and non-parametric techniques on daily exchange rate of Pak Rupee / US Dollar exchange rate and tried to measure the success of intervention in foreign exchange market in Pakistan, which was done either in shape of alteration in the exchange rate level or smoothing the exchange rate fluctuations. The GARCH results, as reported by Hussein and Jalil (2007) proved that intervention was successfully altered, in both direction of exchange rate and smoothed the fluctuations in exchange rate while the event study confirmed that the intervention was successful for level and volatility of the exchange rate.

Olowe and Ayodeji (2009) used a number of GARCH models to investigate the volatility of Naira/US Dollar exchange rate in which the hypothesis of leverage effect was rejected by all asymmetry models, though all the coefficients of the variance equations were significant, the TS-GARCH and APARCH models proved to be the best models. On the other hand, EGARCH model showed that in Nigerian foreign exchange market, with all variances being non-stationary, the volatility is highly persistence. Khalid (2008) analyzed the capability of existing exchange rate models by using the monthly data of 20 years of Pakistan, India and China and reported that for the developing economies, the model based on macroeconomic fundamentals perform better than the random walk model in both in and out sample.

METHODODOLOGY

Sample of the study

FOREX rate data used in this paper has been expressed in terms of US dollar for which data was obtained from the International Financial Statistics online database, available at www.imfstatistics.org. The data was in the form of daily observations for the period, from January, 2001 to December, 2009 with 2005 observations and monthly data for the same period with
108 observations (Figure 1).

Data

The presence of unit root indicates that price movements are non-stationary, while the absence of unit root will show the stationary of the data, since the non-stationary is undesirable; the time series' data of this study was transformed into daily returns to achieve stationary before the application of the models. The study is focused to model and quantify volatility of exchange rate of Pakistani rupee against the US dollar with different types of GARCH family models. The symmetric GARCH-M (1,1) model along with the other two asymmetric EGARCH (1,1) and TARCH (1,1) have been used to capture the main characteristics of exchange rate time series, such as, volatility clustering and the leverage effect. According to Engle (1993), all of these three models are capable of predicting return volatility in the financial market and may create an impact on investors' portfolios' decisions.

Measuring the daily returns

The daily representative rates data of Pak. Rs. / U.S. Dollar was transformed into the nominal returns by adopting the method of continuously compounded annual rate of return. Daily returns are measured with the help of following method in this study:

$$r_t = \log \left( \frac{s_t}{s_{t-1}} \right)$$

(1)

The dependent variable is the daily nominal return, where \(r_t\) is the return on the day \(t\), \(S_t\) is the exchange rate at time \(t\) and \(S_{t-1}\) represent the exchange rate at time \(t-1\). Natural log is used to calculate the returns of the data.

Augmented Dickey Fuller (ADF) unit root test

The equation used for conducting Augmented Dickey Fuller test has the following structure:

$$X_t = \alpha + \beta_t + \rho X_{t-1} + \sum_{i=1}^{\rho} \delta_i \Delta X_{t-i} + \epsilon_t$$

(2)

To check the ADF unit root, the following hypotheses were developed:

H₀: \(\delta (p - 1) = 0\) or \(p = 1\)

H₁: \(\delta (p - 1) < 0\) or \(p < 1\)

GARCH-M (1,1) Process

$$\sigma_t^2 = \omega + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 + \sum_{j=1}^{q} \alpha_j u_{t-j}^2$$

$$\omega > 0, \alpha_j \geq 0, \beta_j \geq 0 \; \; i=1,\ldots,q \; j=1,\ldots,p$$

$$Y_t = \alpha + \beta X_t + \theta h_t + u_t$$

$$u_t / \sqrt{\Omega_t} \sim iidN(0, h_t)$$

$$h_t = \gamma_0 + \sum_{i=1}^{p} \delta_i h_{t-i} + \sum_{j=1}^{q} \gamma_j u_{t-j}^2$$

Bollerslev (1986) modified the classical Engle (1982) ARCH model with his Generalized ARCH or GARCH process, resulting also to the GARCH (p,q) process. According to Bollerslev (1986), "the conditional variance is a linear function of q lags of the squares of the error terms \((u_t)^2\) or the ARCH terms (also referred to as the "news" from the past) and p lags of the past values of the conditional variances \((\sigma_t)^2\) or the GARCH terms, and a constant \(\omega\)."

However, in the equation the inequality restrictions were imposed to guarantee a positive conditional variance. Hansen and Lunde (2001) demonstrated that, the GARCH (1,1) process is sufficient enough to explain the characteristics of the time series. GARCH-in-Mean (GARCH-M) model was introduced by Engle et al. (1987). The GARCH-in-mean (GARCH-M) model adds a heteroscedasticity term into the mean equation. This model allows the conditional mean to depend on its own conditional variance. It has the specification:

Exponential GARCH (EGARCH) process

The GARCH model is not the best model to explain the "leverage effects", which are often observed in financial time series. Concept of leverage effects, which were first observed by Black (1976), is related to the fluctuation in the stock prices which seemed to be inversely related to the fluctuation in the stock volatility. One can deduce that the effects of a shock on the volatility are asymmetric or in other words, one can say that the effect of good news, a positive lagged residual, may be different from the effects of the bad ones, a negative lagged residual. Development and the presentation of EGARCH model by Nelson (1991) which accounts for an asymmetric response to a shock. A commonly used model is the EGARCH (1, 1) given by:

$$\log(\sigma_t^2) = \alpha_0 + \alpha_1 \frac{u_{t-1}}{\sigma_{t-1}} + \beta_1 \log(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sigma_{t-1}}$$
Figure 2. The time series plot of daily and monthly returns.

Table 1. ADF unit root test on daily exchange rate returns.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKR (-1)</td>
<td>-0.961834</td>
<td>0.0000</td>
</tr>
<tr>
<td>D(PKR (-1))</td>
<td>0.037747</td>
<td>0.0910</td>
</tr>
<tr>
<td>C</td>
<td>0.000170</td>
<td>0.0064</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>2.001067</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

ADF test statistic -31.62495
5% Critical Value -2.8635

*MacKinnon critical values for rejection of hypothesis of a unit root.

The term γ accounts for the presence of the leverage effects, which makes the model asymmetric. When the asymmetric model for volatility is applied, it allows the volatility to respond, more readily, when the prices are falling due to the bad news than with corresponding increases due to the good news.

Threshold ARCH (TARCH) process

Zakoïan (1994) and Glosten et al. (1993) applied the TARCH model with a purpose of independence than for the asymmetric effect of the “news”. The TARCH (p,q) specification is given by:

\[ \sigma_t^2 = \omega + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{k=1}^{r} \gamma_k u_{t-k}^2 I_{t-k}^- \]

where,

\[ I_{t-k}^- = \begin{cases} 1 & \text{if } u_t < 0 \\ 0 & \text{otherwise} \end{cases} \]

In the TARCH model, “good news”, \( u_t > 0 \) and “bad news”, \( u_t < 0 \) have different effects on the conditional variance. When \( \gamma_k \neq 0 \), it can be concluded that the news impact is asymmetric and that there is presence of leverage effects. The difference between the TARCH and EGARCH is that TARCH assumes leverage effect as quadratic and the EGARCH assumes leverage effect as exponential.

ANALYSIS AND DISCUSSION

Display of data

Exchange rate, expressed in terms of US Dollar, consist of daily representative exchange rates of the Pakistani currency against U.S. Dollar. The time horizon of data comprises from January, 2001 to December, 2009, with 2005 observations. The time series plot of the daily and monthly exchange rate data is shown in Figure 1.

The time series plot of daily and monthly returns is given in Figure 2. The return series clearly shows volatility clustering in the data, especially in the start and at the end of sample.

Stationary of data

Prior to GARCH model application, the univariate analysis was necessary to be performed due to time varying variances of time series. In the stationary time series, the shocking effects will be noted temporarily which will be eliminated when the series will come back to the long-run mean values. On the other hand, non-stationary time series will necessarily contain permanent components. Stationary of data is important because if the series is non-stationary then all the CLRM assumptions were violated and one can not apply linear regression (Asteriou and Hall, 2007). To check the stationary of time series the Augmented Dickey-Fuller unit root test was used, Table 1 and 2 which regress each series on its lagged value in different time points. Following the literature, all data series has been transformed into natural logarithms.

Both of above tables show that the values of ADF statistic remained at -31.625 and -3.841, respectively, and are lesser than all the critical values. So, the null
hypothesis was rejected as the series contained the unit root and the alternative hypothesis was accepted that both the time series are stationary and conclude that $P<1$. The results show that daily and monthly returns of representative exchange rates of Pakistani rupee against US dollar are independent of serial correlation.

**Results of GARCH-M (1,1)**

The ARCH model specifications are similar to moving average specification than an autoregressive one; a fact from where Bollerslev (1986) introduced the lagged conditional variance terms, to be included into ARCH model as auto regressive terms, thus starting the GARCH model family.

The risk behavior of exchange rate is estimated by GARCH-M model that allows the conditional mean to depend on its own conditional variance. In this model with two equations, the mean exchange rate equation explains autoregressive process, that is, the previous exchange rates affect current rate and GARCH-M term, which shows the impact of risk of exchange rate upon the mean exchange rate.

The results displayed in Tables 3 and 4 describes that the Pak exchange rate has an order-one autoregressive
process in both the daily and monthly exchange rate returns, which implies that the past day exchange rate affects the current day exchange rate. The variance equation shows that ARCH (1) term is significant at 1% showing that the volatility of risk is affected, significantly, by past square residual terms. The GARCH (1) is also significant at 1% level, which shows that past volatility of exchange rate is significantly, influencing current volatility. The GARCH-M term is not significant at both the daily and monthly exchange rate returns, showing the exchange rate risk (variance) which is not significantly compensated in the exchange rate market. The conditional standard deviation (SQR (GARCH)) coefficient is insignificant, suggesting that if there is an effect of the risk on the mean return, then that could not be better captured by this standard deviation method. There is positive insignificant tradeoff between foreign risk and return.

**Results of EGARCH (1, 1)**

EGARCH parameters, displayed in Table 5 and 6 show the calculated coefficients and the 'p' values of the EGARCH model on daily and monthly exchange rate returns. The results shows that, there is a first order autoregressive behavior in the exchange rate as in the mean equation, the term PKR (-1) is significant at 1% in daily and monthly returns. The constant C is also significant at 1% in daily returns and is significant at 10% in monthly returns. In the variance equation, all the terms are significance at 1% level for the daily exchange rate returns while all the terms of the variance equation, for the monthly exchange rate returns, also remain significant. The EGARCH variance equation indicates that there exists the asymmetric behavior in volatility which means that positive shocks are effecting, differently, than the negative on volatility. The EGARCH model proves to be the best model to explain the behavior of exchange rate on daily and monthly data; most of the coefficients of mean and variance equation are significant.

**Results of TARCH (1, 1)**

TARCH parameters on the daily and monthly returns are displayed in Tables 7 and 8, where output shows calculated coefficients and the 'p' values of the TARCH coefficients. For the daily exchange rate returns, the results show no autoregressive behavior. In the mean equation, the terms C remains significant and PKR (-1) shows insignificant results. For the monthly exchange rate returns, the results shows the first order autoregressive behavior in the exchange rate as in the mean

### Table 5. Results of EGARCH model on daily exchange rate returns.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>6.47E-05</td>
<td>0.0080</td>
</tr>
<tr>
<td>PKR (-1)</td>
<td>0.076445</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

**Variance equation**

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.129287</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>RES</td>
<td>/SQR[GARCH] (1)</td>
</tr>
<tr>
<td>RES/SQR[GARCH] (1)</td>
<td>0.065703</td>
<td>0.0000</td>
</tr>
<tr>
<td>EGARCH (1)</td>
<td>0.990439</td>
<td>0.0000</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.998262</td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable, PKR; Method, ML – ARCH

### Table 6. Results of EGARCH model on monthly exchange rate returns.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.000949</td>
<td>0.0678</td>
</tr>
<tr>
<td>PKRM (-1)</td>
<td>0.329340</td>
<td>0.0075</td>
</tr>
</tbody>
</table>

**Variance equation**

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-1.180407</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>RES</td>
<td>/SQR[GARCH] (1)</td>
</tr>
<tr>
<td>RES/SQR[GARCH] (1)</td>
<td>0.349751</td>
<td>0.0000</td>
</tr>
<tr>
<td>EGARCH (1)</td>
<td>0.903236</td>
<td>0.0000</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.897213</td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable, PKRMN1; Method, ML – ARCH
Table 7. Results of TARCH model on daily exchange rate returns.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.000245</td>
<td>0.0000</td>
</tr>
<tr>
<td>PKR (-1)</td>
<td>0.033206</td>
<td>0.1514</td>
</tr>
</tbody>
</table>

Variance equation

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>6.28E-08</td>
<td>0.0000</td>
</tr>
<tr>
<td>ARCH (1)</td>
<td>0.030487</td>
<td>0.0000</td>
</tr>
<tr>
<td>(RESID&lt;0)*ARCH (1)</td>
<td>-0.027467</td>
<td>0.0000</td>
</tr>
<tr>
<td>GARCH (1)</td>
<td>0.961703</td>
<td>0.0000</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.916090</td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable: PKRN1; Method, ML - ARCH

Table 8. Results of TARCH model on monthly exchange rate returns.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.000658</td>
<td>0.2552</td>
</tr>
<tr>
<td>PKRM (-1)</td>
<td>0.356485</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Variance equation

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>4.10E-06</td>
<td>0.0051</td>
</tr>
<tr>
<td>ARCH (1)</td>
<td>0.411069</td>
<td>0.0432</td>
</tr>
<tr>
<td>(RESID&lt;0)*ARCH (1)</td>
<td>-0.482825</td>
<td>0.0139</td>
</tr>
<tr>
<td>GARCH (1)</td>
<td>0.755390</td>
<td>0.0000</td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.965453</td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable: PKRM; Method: ML – ARCH.

equation, the term PKR (-1) is significant at 1%, while the constant C remains insignificant. In the variance equation, the ARCH (1) and GARCH (1) terms remained significant for both the daily and monthly exchange rate returns. This implies that the previous square error terms significantly affects volatility and that the past volatility of exchange rate is also, significantly, influencing current volatility. The leverage effect term (y) is represented by the (RESID<0)*ARCH (1). This term is significant for both the daily and monthly exchange rate returns, representing that there are asymmetric behavior and presence of leverage effect.

Conclusion

A symmetric GARCH-M (1, 1) with other two asymmetric models EGARCH (1, 1) and TARCH (1, 1) were used to analyze the daily and monthly exchange rates of Pakistan. The data consisted of exchange rates of Pakistani Rupee against the U.S. Dollar for the period January, 2001 to December, 2009.

The GARCH-M (1, 1) model has shown that, the first order autoregressive process, supporting the previous day exchange rate affects the current day exchange rate. In the variance equation, ARCH (1) and GARCH (1) both remained significant at 1% for the daily and monthly exchange rate returns. The EGARCH results have shown first order autoregressive behavior in the exchange rate, while the variance equation indicated that the asymmetric behavior was shown by the time series, that is, positive and negative news has different impact on volatility progression. The TARCH result did not show any autoregressive behavior in the daily exchange rate returns but the monthly exchange rate returns showed the autoregressive behavior. Whereas, the results of TARCH model supported the asymmetric behavior in both the daily and monthly exchange rate returns. The results of GARCH-Type models, applied on the exchange rate of Pak Rupee against the US Dollar can be very much helpful for the investor’s decision and policy making. The results can also be helpful to understand the historical patterns of exchange rate behaviors, and thus being helpful to predict the future movements of exchange rate markets. The overall results proved that the EGARCH model remains the best in explaining the volatility behavior of the data, making all the coefficients of mean and variance equations significant. The TARCH model supports the time series exchange rate, following the asymmetric behavior and depicts the presence of leverage effect in both the daily and monthly returns. The results of this research work also support the fact that
EGARCH is the best model to explain the volatility behavior of exchange rate data, similar to the one analyzed in the works of Hsieh (1989), Longmore and Robinson (2004), Mapa (2004) and Alberg et al. (2006). The research can act as first step to observe the volatility behavior of the Pakistani exchange market. Specified period's data can be tested by the future researchers using new and more enhanced models to capture the effects and predictions of the volatility behavior.

REFERENCES