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Exchange Rate Volatility and Market Efficiency Evidence from Pakistan

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This paper empirically investigates the volatility dynamics of Pak Rupee exchange rates and its effects on market efficiency through using GARCH models. The monthly data on Pak Rupee exchange rates in the terms of major currencies (US Dollar, British Pound, Canadian Dollar and Japanese Yen) are taken from April, 1982 to June, 2012. The results show that Pak Rupee exchange rates depict high persistence and volatility clustering across GARCH models. There are no evidences of asymmetry and risk premium in Pak Rupee exchange rates except PKR-USD. Moreover, results indicate inefficiency of Pakistan exchange market which implies that the past information is not quickly incorporated by the current volatility.

1. Introduction

The exchange rate is one of the important economic indicators which play a crucial role to determine the degree of competitiveness among economies because it has a strong impact on economic developments, foreign direct investment flows, international trade and capital mobility. It also affects firm profitability, price stability, and financial stability of a country (Benita and Lauterbach, 2007)**.** It plays an important role in currency related derivative pricing and international capital budgeting and key input to investment, portfolio design and risk management.

Further, for stable economic conditions there is need of existence of an efficient foreign exchange market. According to Fama (1970), an efficient foreign exchange market is the one if exchange rates reflect all available relevant information. The exchange rates immediately absorb

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new information so that there exist no opportunities for investors to earn excess profits. There is efficient allocation of the resources as decisions are made on the basics of observed exchange rates by economic agents.

Exchange rate volatility in developing countries like Pakistan is very pervasive. In Pakistan, an extensive increase in the exchange rate volatility is seen in the recent years. This results in uncertainty and risk that adversely affect foreign exchange market agents as well as market efficiency in Pakistan. Market efficiency has sufficient condition that exchange rates fluctuate randomly or without any identifiable pattern i-e they follow a random walk. If foreign exchange market is efficient, abnormal profits cannot be earned from trading rules based on past returns. Therefore, exchange rate returns are unpredictable, and any technical analysis or statistical technique to predict future pattern of exchange rate returns based on past returns is impossible. Therefore, exchange rate volatility and market efficiency are important issues in Pakistan.

The conventional market efficiency tests e.g serial correlation test, unit root test, variance ratio test and runs test assume linear structure in the exchange rates returns generation process and are not able to capture non-linear behavior in exchange rate return series. Therefore, GARCH models are used to estimate exchange rates volatility and for testing market efficiency. These models are able to capture characteristics of exchange rate returns that include fat tails, peakedness (leptokurtosis), skewness and volatility clustering.

This paper empirically investigates the volatility dynamics of Pak Rupee exchange rates and its effects on market efficiency. In this paper, GARCH models are used and monthly data on Pak Rupee exchange rates in the terms of major currencies (US Dollar, British Pound, Canadian Dollar and Japanese Yen) are taken from April, 1982 to June, 2012 for a total of 363 monthly observations are used.

The structure of paper is as follows: Section II shows the literature review. Section III presents the methodology. Section IV presents empirical analysis. Section V provides conclusion.

2. Literature Review

A considerable amount of research is focused on modelling volatility in foreign exchange markets. ARCH model proposed by Engle (1982) is designed to incorporate conditional variance in order to model the financial volatility. For this purpose, conditional variance is modelled as function of past square error terms. GARCH model proposed by Bollerslev (1986) is introduced which consider conditional variance depends not only on past square error term but also on its past conditional variance.

The use of ARCH/GARCH models and its extensions and modifications in modelling and forecasting foreign exchange market volatility is now very common in finance and economics, such as French *et at.* (1987), Lau *et at.* (1990), Franses andVan Dijk (1996) and Choo *et al*. (1999). On the other hand, the ARCH model was first applied in modeling the currency exchange rate by Hsieh (1988). He has found that GARCH models can explain a large part of the nonlinearities for exchange rates and do well at removing conditional heteroscedasticity. Since then, applications of these models to currency exchange rates have increased tremendously, such as Hsieh (1989b), Bollerslev, (1990), Pesaran and Robinson (1993), Copeland and Wang (1994), Takezawa (1995), Episcopos and Davies (1995), Hopper (1997), Cheung and Wong (1997), Laopodis (1997), Brooks and Burke (1998), Lobo and Tuite (1998) and Duan and Jaso (1999).

Recent studies like West and Cho (1995), Chong *et al*.(2002), Balaban (2004) Antonakakis (2007) have studied GARCH models to estimate exchange rate volatility and compared the forecasting performance of GARCH models. The forecasting performances are evaluated by using ME, MAE, MSE and MAPE measures. These studies have suggested that symmetric GARCH models are relatively good in forecasting exchange rate volatility. While Longmore and Robinson (2004), Kar and Sarkar (2006), Yoon and Lee (2008) and Olowe(2009), have applied GARCH models to estimate exchange rate volatility and have found existence of asymmetry effect and leverage effect. They have concluded the asymmetric GARCH models are the best models in capturing volatility. Zakaria (2012) have concluded that GARCH models are adequately model exchange rate volatility. Siddiqui (2009a & b) and Kamal and Ghani (2012) have investigated the daily Pak Rupee exchange rates volatility using symmetric and asymmetric GARCH models.

The efficiency of foreign exchange markets has investigated by various studies. Most of the studies have tested the market efficiency based on Fama's (1970) classification system. Hakio (1981) has tested the efficiency market hypothesis on five exchange rates against US dollar and found rejection of efficiency market hypothesis. Fama (1984) has also tested the efficiency market hypothesis on nine exchange rates against US dollar and found rejection of efficiency market hypothesis. Similar results were found by Domowitz and Hakio (1985) and Hodrick and Srivastava (1986). The rejection of efficiency market hypothesis has attributed to various factors, like the measurement of technical trading rules, the existence of risk premiums in forward rates, experimental irregularities in regression tests, negative correlation between the expected future spot rates and forward risk premia, and the lack of use of suitable econometric procedures.

Wickrema singhe (2004), Chakrabarti (2005) and Nath (2006) have employed unit root tests to investigate market efficiency for Sri Lanka and Indian exchange markets. Their results support the market efficiency hypothesis. Ahmed, *et al*. (2005) and Hideki (2006) have applied serial correlation tests and run test to investigate the market efficiency for the South Asian foreign exchange markets and the Hong Kong FX market. They found rejection of the market efficiency hypothesis. Kimani (2007) has applied the unit root tests to the Kenya Shilling per US Dollar. They found rejection of the market efficiency hypothesis. Rose, *et al.* (2008) has analyzed the market efficiency of the foreign exchange market of Kenya and found it to be inefficient. They attributed their rejection of the hypothesis to significant patterns in the exchange rates, trend stationarity and autocorrelation in foreign exchange returns. Noman and Ahmed (2008) have applied various unit root tests and the variance ratio to test the market efficiency of seven SAARC countries; namely, Pakistan, India, Bangladesh, Sri Lanka, Bhutan, Nepal and Maldives. The results of their study supported the market efficiency. Attiya (2012) has examined market efficiency of four South Asian foreign exchange markets namely, Pakistan, India, Sri Lanka and Bangladesh; by using unit root tests. Results shown all four foreign exchange markets are consistent with the efficient market hypothesis. All these studies have used the same conventional market efficiency tests e.g serial correlation test, unit root test, variance ratio test which assume linear structure in the exchange rates returns generation process and are not able to capture non-linear behavior in exchange rate return series. Therefore, this study employs GARCH models to estimate exchange rates volatility and to test market efficiency.

3. Methodology

GARCH Models

In this paper, Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models are employed for modelling exchange rate volatility and for testing market efficiency. These models are able to capture the exchange rates dynamics which include fat tails, peakedness (leptokurtosis), skewness, volatility clustering, asymmetric and leverage effects.

Generalized Autoregressive Conditional heteroskedasticity (GARCH) model was proposed by Bollerslev (1986). The GARCH Model considers conditional variance depends not only on the squared error term past values but also on its conditional variance past values. The ARMA (m,n) -GARCH (p,q) is specified as

$$r_t = c + \sum_{i=1}^{m} \delta_i r_{t-i} + \sum_{j=1}^{n} \varphi_j \varepsilon_{t-j} + \varepsilon_t$$

$$h_t = \omega_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \qquad (1)$$

$\varepsilon_t = z_t \sqrt{ht}$

$\varepsilon_t \sim N(0, h_t)$ and $z_t \sim$ iid $N(0, 1)$

In the mean equation (1) , r_t is the exchange rate return and ε_t is residual, z_t, is a standardized error by conditional variance and normal iid random variable. Where $\omega_0 > 0$, $\alpha_i \geq 0$ and $\beta_j \geq 0$ ensure that the conditional variance is always non-negative

The GARCH model is extended to GARCH-M model by Engle, Lilien and Robins in 1987 in which conditional variance is added into conditional mean equation. The risk premium is generated by conditional volatility as part of expected returns. The ARMA (m,n)-GARCH-M (p,q) model is specified as follows:

$$r_t = c + \sum_{i=1}^{m} \delta_i r_{t-i} + \sum_{j=1}^{n} \varphi_j \varepsilon_{t-j} + \lambda ht + \varepsilon_t h_t = \omega_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \qquad (2)$$

The coefficient λ in mean equation (2) measures the risk premium indicating the relationship between exchange rate returns and their volatilities.

Furthermore, Glosten, Jagannathan and Runkle (1993) introduced GJR-GARCH model to allow asymmetric effects. The ARMA (m,n)- GJR-GARCH (p,q) model is specified as

$$r_t = c + \sum_{i=1}^{m} \delta_i r_{t-i} + \sum_{j=1}^{n} \varphi_j \varepsilon_{t-j} + \varepsilon_t$$

$$h_t = \omega_0 + \sum_{i=1}^{q} (\alpha_i \varepsilon_{t-i}^2 + \gamma_i \varepsilon_{t-i}^2 S_{t-i}) + \sum_{j=1}^{p} \beta_j h_{t-j} \qquad (3)$$

Where S_t (dummy variable) = 1 if $\gamma_i < 0$, and 0 if $\gamma_i > 0$. In the model, good news ($\varepsilon_{t-1} > 0$), and bad news ($\varepsilon_{t-1} < 0$), acts differentially on the conditional variance. If $\gamma_i > 0$, bad news increases volatility and leverage effect exists. If $\gamma_i = 0$, the news impact is symmetric i.e. past bad news (negative shocks) impacts similarly on current volatility as good news (positive shocks).

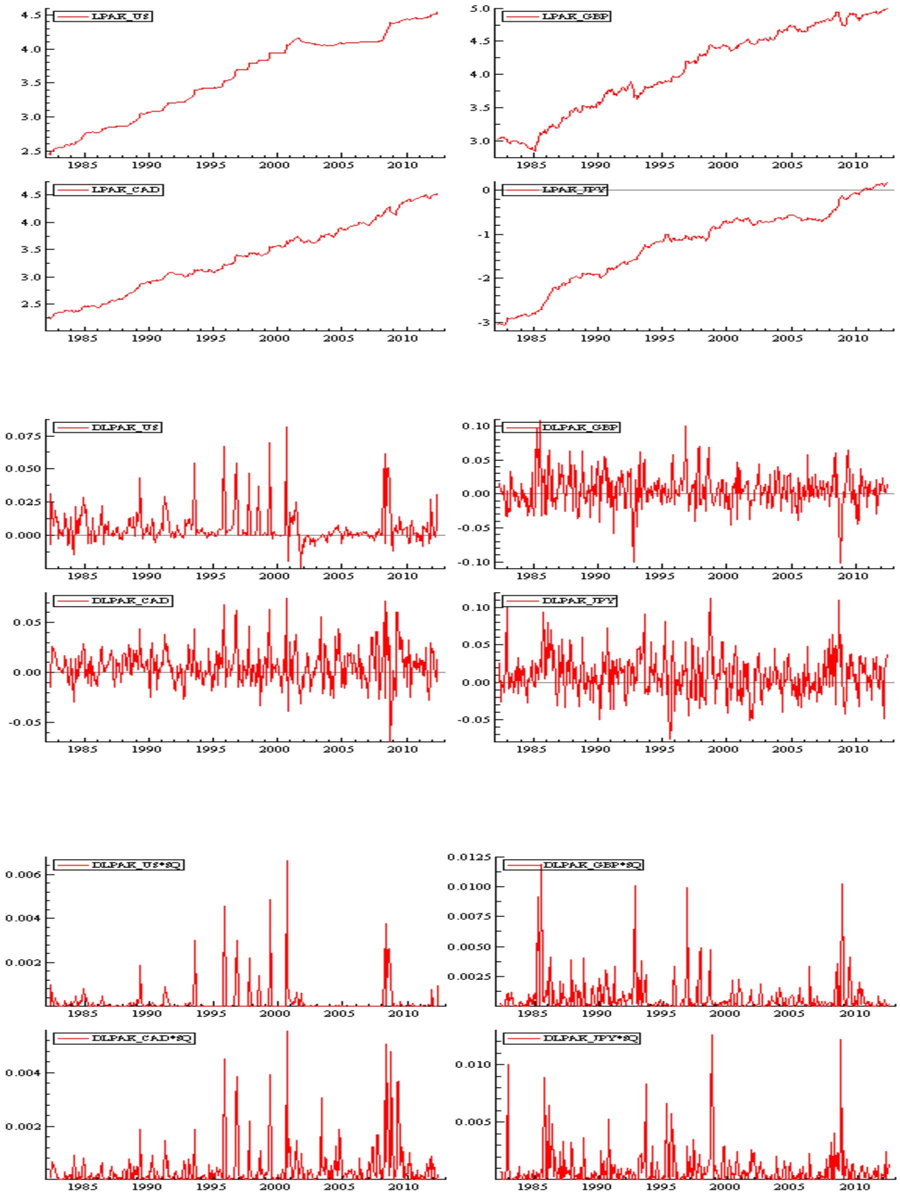
In the analysis GARCH (1,1)-M, GARCH (2,1)-M and GJR-GARCH(1,1)-M are employed for volatility modelling of the four Pak-Rupee exchange rate series. Various ARMA (m,n) model specifications for mean equation are used with the conditional variance equation simultaneously. The covariance matrix of the estimates (outer-product of gradients) is computed with the Maximum Likelihood Estimation (MLE) method. Further, normal distribution is used for conditional distribution of the error term.

4. Empirical Analysis

In our empirical analysis, the monthly data from April, 1982 to June, 2012 for a total of 363 monthly observations are used. The data is obtained from International Financial Statistics (IFS), Annual State Bank Reports. Bilateral Pak Rupee nominal exchange rates in the term of major currencies (US dollar, British pound sterling, Canadian dollar and Japanese yen) are examined. The monthly average data of these exchange rates are used and expressed in Pak Rupees for one unit of foreign currency. The monthly return series are constructed as logarithmic first difference of monthly Pak Rupee exchange rates of successive months [$r_t = \ln (E_t/E_{t-1})$]. Because exchange rate volatility is not directly observable, monthly squared return series is used as proxy of realized volatility.

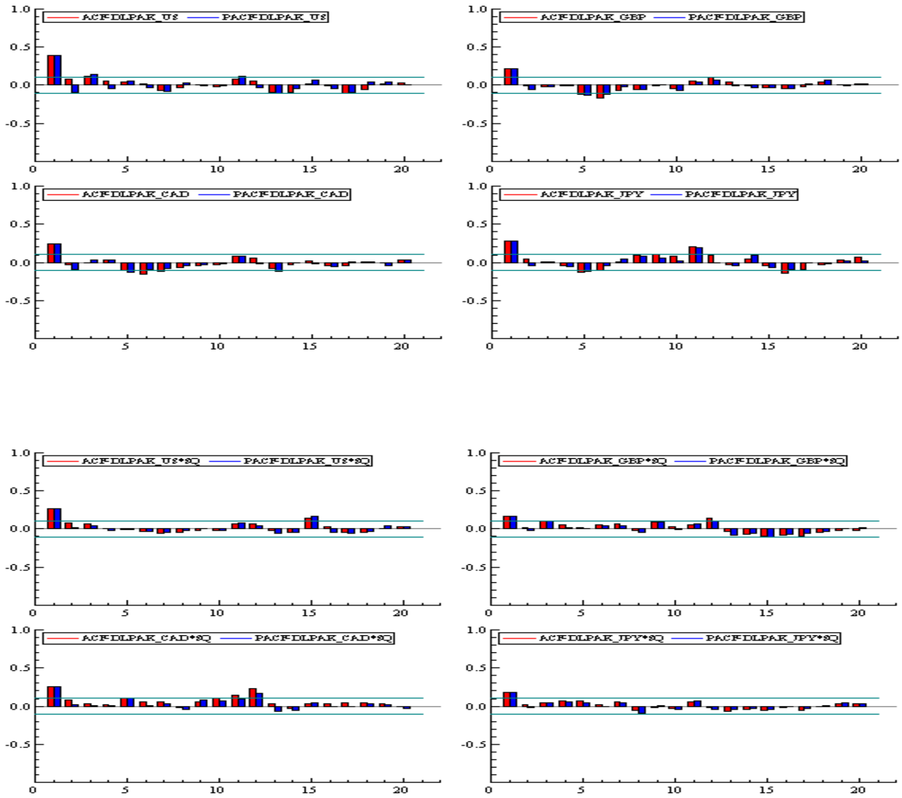
The plots of the monthly exchange rates in logarithmic level and exchange rate returns and squared returns are given in Figure 1. The plots of the monthly exchange rates reveal a general upward trend over the sample period. The plots of the monthly exchange rate returns as logarithmic changes in exchange rates indicate no definite pattern in the exchange rate returns and they revert quickly to their means. It also reveals that the variances change over time and volatility tends to cluster. The exchange rate returns are complying with the mean reverting and volatility clustering stylized facts. The squared returns are taken for the proxy of volatility. In Figure 1 plots of squared exchange rate returns are indicating variation in volatility.

Figure 1: Monthly Pak Rupee Exchange Rates , Returns and Squared Returns



In Figure 2, the plots of autocorrelation functions for monthly exchange rate returns and squared returns are given which show that autocorrelations are not persistent and die out very fast. In particular, they are insignificant after 1 lag exhibiting short memory process.

Figure 2: Autocorrelations and Partial Autocorrelations of Monthly Pak Rupee Exchange Rate Returns and Squared Returns



The Table 1 reports summary statistics for the monthly exchange rate returns series. The mean of monthly exchange returns are slightly positive as the exchange rates increase slightly overtime. The value of skewness is positive statistically significant in PKR-USD, PKR-GBP, PKR-CAD and PKR-JPY exchange rate returns which implies that depreciation are more probable in these exchange rates. The excess kurtosis is statistically significant and positive for each of Pak Rupee exchange rates returns which indicate the monthly exchange rate returns are heavy tailed and have leptokurtic distribution. The Jarque-Bera test statistics are positive and statistically significant for each of Pak Rupee exchange rates returns showing non-normality in each of Pak Rupee exchange rates returns distributions.

In order to test the stationarity of time series Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test is employed. The KPSS test is used with constant term and with constant and trend terms. The results in table 1 show stationarity of all the variables in first difference form.

In order to test conditional heteroskedasticiy, Lagrange Multiplier test and the Ljung-Box test are employed on exchange rate return series (PKR_USD, PKR_GBP, PKR_AUD, PKR_CAD, PKR_JPY) from April, 1982 to June, 2012. The Table 1 represents the Ljung-Box–Pierce Q-statistics and Q^2-statistics of exchange rate return series and ARCH LM test. The Ljung-Box–Pierce Q-statistics Q(10) are highly significant, showing there is serial correlation in residuals and square residuals and $Q^2(10)$ statistics shows evidence of ARCH effect. The significant Ljung-Box–Pierce Q-statistics Q(10) also shows foreign exchange market information inefficiency as investors can earn excess profits by using historical information from purchasing and selling foreign currencies. The LM test shows strong evidence that the square residuals exhibit an ARCH effect. These results support for the estimation of a conditional heteroscedasticity model for Pak Rupee exchange rate returns.

Table 1: Summary Statistics and Diagnostic Checks of Monthly Pak Rupee Exchange Returns

	Monthly Pak Rupee Exchange Returns			
	PKR-USD	**PKR-GBP**	**PKR-CAD**	**PKR-JPY**
Mean	0.0057689	0.0054297	0.0062427	0.0088838
Max	0.081364	0.1087	0.07463	0.11199
Min	-0.02412	-0.10127	-0.069189	-0.07589
Std.Dev.	0.012787	0.026399	0.018705	0.02819
Skewness	2.5608	0.14890	0.52231	0.50135
Excess Kurtosis	8.6990	2.0515	1.7930	0.92556
J-B test statistic	1537.0**	64.819**	64.952**	28.086**
Observations	363	363	363	363
KPSS test statistic (with constant)	0.202707 (1)	0.088708 (1)	0.0549032 (1)	0.289753 (1)
KPSS test statistic (with constant and trend)	0.0922526 (1)	0.0529174 (1)	0.0359339 (1)	0.0773787 (1)
LM-ARCH 1-2	13.899 [0.0000]**	5.2107 [0.0059]**	11.856 [0.0000]**	6.0987 [0.0025]**
LM-ARCH 1-5	5.6488 [0.0001]**	2.8025 [0.0169]*	5.5792 [0.0001]**	2.8601 [0.0151]*
LM-ARCH 1-10	2.8750 [0.0019]**	1.8952 [0.0448]*	3.1914 [0.0006]**	2.0780 [0.0256]*
LB- Q(10)	67.9733 [0.0000000]**	36.0902 [0.0000812]**	41.9169 [0.0000078]**	49.1270 [0.0000004]**
LB- $Q(10)^2$	32.9390 [0.0002789]**	21.1475 [0.0200883]*	37.4668 [0.0000470]**	18.9717 [0.0406231]*

Note: *p* – values are in parentheses, ** indicates significant at 1% and * significant at 5%.

The evidences of non-stationarity, non- normal distribution and significant volatility clustering of exchange rate returns series imply the use of non-linear models to model volatility. Hence, GARCH models are estimated. The table 2, 3 & 4 presents estimated GARCH-M (1,1) , GARCH -M(2,1) and GJR- GARCH –M (1,1) results for PKR-USD, PKR-GBP, PKR-CAD and PKR-JPY exchange rates returns series.

For exchange rate returns ARMA (1, 0) specification is chosen to incorporate the serial correlation in returns series as supported by ACF and PACF plots in GARCH-M (1,1) and GJR- GARCH –M (1,1) models for all exchange rates returns series as presented in table 2 & 4. The significant ARMA (1, 0) indicates that returns series shows prediction of exchange rates movements based on past information and suggests of market inefficiency.

The estimated parameters of GARCH-M (1,1) and GJR- GARCH-M (1,1) for Pak Rupee exchange rates series show ω is significant in PKR-USD and PKR-GBP exchange rates, α_1 is significant in all exchange rates except PKR-JPY exchange rates and β_1 is significant in all exchange rates except PKR-USD exchange rates in GJR- GARCH-M (1,1). The significance of α_1 shows the presence of volatility clustering. The insignificant α_1 indicates that the exchange rates do not react to past shocks and suggests that ARCH effects are not overwhelmingly strong. The significance of β_1 shows strong GARCH effect. The significance of both α_1 and β_1 indicates that lagged squared disturbance and lagged conditional variance have an impact on the conditional variance, indicating indicating that news about volatility from the previous periods have an explanatory power on current volatility. The positivity constraint ($\alpha_1 + \beta_1 \geq 0$) for the GARCH–M (1,1) is observed in all exchange rate series. The sum of estimated $\alpha_1 + \beta_1 < 1$which satisfy the stationarity constraint ($\alpha_1 + \beta_1 < 1$) in all exchange rate series. The estimated volatility persistence ($\alpha_1 + \beta_{1)}$ is very high and implies the shocks to volatility are very high. These results are in line with Siddiqui (2009a) and Kamal and Ghani (2012). The regularity condition ($\alpha_1 + \beta_1 + \gamma_1 / 2 < 1$) for GJR-GARCH (1,1)-M is satisfied as the sum of estimated $\alpha_1 + \beta_1 + \gamma_1 / 2 < 1$ in all exchange rate series. The estimated parameter γ_1 which captures the asymmetric effects is insignificant and negative in PKR-GBP, PKR-CAD and PKR-JPY exchange rates. This implies no leverage and asymmetric effects while the asymmetric effect is significant in PKR-USD exchange rates. Siddiqui (2009a) found asymmetric effects in PKR-GBP and PKR-CAD exchange rates and symmetric effects in and PKR-USD and PKR-JPY exchange rates. While Kamal and Ghani (2012) found asymmetric effect and leverage effect in PKR-USD exchange rates. The λ is positive and significant for PAK-USD exchange rates which reveals the principle of ‘the higher the risk the higher the returns’. The significance of λ in

PKR-USD exchange rates is consistent with the findings of Siddiqui (2009a). The λ is insignificant for other three Pak Rupee exchange rates and is negative for PAK-CAD exchange rates. The insignificance of λ suggests that higher risk, proxied by the conditional variance, will not necessarily lead to higher returns. The insignificance of λ in PKR-GBP exchange rates is in line with Siddiqui (2009a). The negative sign of λ indicates different reaction of returns on arrival of "bad" and "good news" (Glosten, Jagannathan & Runkle ,1993)

In order to test how quickly the past information is incorporated by the current volatility, the lags of GARCH terms are added in the variance equation. In GARCH –M (2,1) model ARMA (1, 0) for PKR-USD and PKR-JPY exchange rates returns series, ARMA (2, 0) for PKR-GBP exchange rates returns series and ARMA (3, 0) PKR-CAD exchange rates returns series are chosen which shows again market inefficiency.

The table 3 presents estimated GARCH-M (2,1) results for PKR-USD, PKR-GBP, PKR-CAD and PKR-JPY exchange rates returns series. The estimated parameters of GARCH-M (2,1) shows ω is significant in PKR-USD and PKR-GBP exchange rates, α_1 is significant in all exchange rates except PKR-JPY exchange rates, β_2 of GARCH – M (2,1) for Pak Rupee exchange rates series is significant in all exchange rates except PAK-JPY exchange rates while β_1 is insignificant in all exchange rates. This indicates inefficiency of Pakistan exchange market which implies that exchange rates are not likely to quickly incorporate past information.

The diagnostic tests of GARCH-M (1,1) , GARCH -M(2,1) and GJR-GARCH –M (1,1) of point out that Jarque-Bera statistics still shows that the standardized residuals are not normally distributed. Moverover, the LM-ARCH test shows no ARCH effects. The Q(10) statistic for the standardized residuals indicates no sign of serial autocorrelation in exchange rates. The Q^2 (10) statistic for squared standardized residuals indicates no sign of serial autocorrelation in exchange rates.

Table 2: GARCH -M (1,1)

Parameter	Monthly Pak Rupee Exchange Returns			
	PKR-USD	**PKR-GBP**	**PKR– CAD**	**PKR– JPY**
Mean Equation				
c (constant)	-0.003808 (0.2165)	0.000237 (0.9774)	0.006928 (0.2707)	0.008120 (0.7194)
δ_1 (AR(1))	0.421254 (0.0000)**	0.208152 (0.0020)**	0.282354 (0.0000)**	0.270099 (0.0000)**
λ	0.870320 (0.0056)**	0.172844 (0.6254)	-0.030937 (0.9328)	0.012150 (0.9886)
Variance Equation				
ω(constant)	0.072372 (0.0000)**	1.431567 (0.0088)**	0.135858 (0.0863)	1.577539 (0.2972)
α_1ARCH-Co	0.160371 (0.0000)**	0.237402 (0.0013)**	0.079375 (0.0004)**	0.086226 (0.1931)
β_1 GARCH-Co	0.820077 (0.0000)**	0.568352 (0.0000)**	0.882227 (0.0000)**	0.697205 (0.0080)**
$\alpha + \beta$	0.98045	0.80575	0.96160	0.78343
AIC	-6.164424	-4.501606	-5.232332	-4.369739
SIC	-6.099252	-4.436434	-5.167160	-4.304567
Log likelihood	1106.350	809. 537	939.971	785.998
Skewness	2.9814	0.073009	0.53470	0.46125
Excess Kurtosis	15.160	0.74378	1.4998	0.35369
Jarque-Bera	3947.3	8.5460	50.471	14.520
LM-ARCH 1-2	1.0177 [0.3625]	0.19118 [0.8261]	0.93459 [0.3937]	0.36332 [0.6956]
LM-ARCH 1-5	0.59581 [0.7032]	0.24873 [0.9403]	0.72169 [0.6075]	0.49899 [0.7770]
LM-ARCH 1-10	0.37974 [0.9551]	0.25460 [0.9899]	0.86045 [0.5708]	0.96842 [0.4708]
LB- Q(10)	13.0575 [0.1600233]	10.5111 [0.3107165]	21.9460 [0.2869496]	10.7828 [0.2908900]
LB- $Q(10)^2$	4.54355 [0.8050609]	2.58071 [0.9578612]	9.81076 [0.2785604]	7.54176 [0.4794607]
RBD(10)	3.97382 [0.9485205]	3.01007 [0.9811860]	10.2805 [0.4162418]	3.51647 [0.9665360]

Note: *p* – values are in parentheses, ** indicates significant at 1% and * significant at 5%.

Table 3: GARCH -M (2,1)

Parameter	Monthly Pak Rupee Exchange Returns			
	PKR-USD	**PKR-GBP**	**PKR– CAD**	**PKR– JPY**
Mean Equation				
c (constant)	-0.003223 (0.3062)	-0.000770 (0.9194)	0.006074 (0.2447)	0.004294 (0.8292)
δ_1 (AR(1))	0.406241 (0.0000)**	0.235999 (0.0009)**	0.335256 (0.0000)**	0.261936 (0.0000)**
δ_2 (AR(2))		-0.084585 (0.1345)	-0.161915 (0.0019)**	
δ_3 (AR(3))			0.090120 (0.1707)	
λ	0.804070 (0.0089)**	0.241899 (0.4492	0.008124 (0.9792)	0.157479 (0.8339)
Variance Equation				
ω(constant)	0.105537 (0.0000)**	1.522508 (0.0413)**	0.129545 (0.1007)	2.052631 (0.2628)
α_1ARCH-Co	0.233150 (0.0000)**	0.245666 (0.0005)**	0.122508 (0.0001)**	0.115767 (0.1345)
β_1 GARCH-Co	0.136021 (0.1882)	0.147089 (0.3054)	0.185370 (0.4544)	0.267570 (0.5192)
β_2 GARCH-Co	0.591000 (0.0000)**	0.391821 (0.0145)*	0.659151 (0.0071)*	0.334892 (0.4452)
$\alpha + \beta$	0.96017	0.78458	0.96703	0.71823
AIC	-6.211715	-4.497830	-5.250709	-4.365343
SIC	-6.135681	-4.410934	-5.152951	-4.289309
Log likelihood	1115.791	810.863	946.252	786.214
Skewness	2.9499	0.12016	0.50317	0.45691
Excess Kurtosis	15.072	0.77764	1.3619	0.32929
Jarque-Bera	3896.7	9.8543	42.653	14.034
LM-ARCH 1-2	0.57528 [0.5631]	0.10020 [0.9047]	1.2030 [0.3015]	0.15382 [0.8575]
LM-ARCH 1-5	0.40808 [0.8431]	0.16662 [0.9747]	0.66921 [0.6471]	0.53733 [0.7480]
LM-ARCH 1-10	0.28458 [0.9844]	0.14435 [0.9991]	0.82332 [0.6064]	0.99931 [0.4437]
LB- Q(10)	12.9857 [0.1632528]	9.22833 [0.3234019]	6.40569 [0.4932558]	10.5659 [0.3066376]
LB- $Q(10)^2$	3.34206 [0.8516605]	1.73319 [0.9731235]	9.45517 [0.2216065]	7.52694 [0.3761465]
RBD(10)	2.89085 [0.9838773]	1.50185 [0.9989296]	14.9496 [0.1339106]	5.51858 [0.8539600]

Note: *p* – values are in parentheses, ** indicates significant at 1% and * significant at 5%.

Table 4: GJR- GARCH -M (1, 1)

Parameter	Monthly Pak Rupee Exchange Returns			
	PKR-USD	**PKR-GBP**	**PKR– CAD**	**PKR– JPY**
Mean Equation				
c (constant)	-0.000105 (0.9654)	0.000089 (0.9917)	0.008364 (0.2380)	0.008916 (0.6839)
δ_1 (AR(1))	0.357140 (0.0001)**	0.211838 (0.0012)**	0.301141 (0.0000)**	0.269864 (0.0001)**
λ	0.520617 (0.0145)*	0.208981 (0.5666)	-0.091121 (0.8277)	-0.001008 (0.9990)
Variance Equation				
ω(constant)	0.749745 (0.0000)**	1.546178 (0.0014)**	0.215280 (0.0294)*	1.626480 (0.1514)
α_1ARCH-Co	0.847332 (0.0000)**	0.363213 (0.0042)**	0.122650 (0.0022)**	0.134502 (0.1041)
β_1 GARCH-Co	0.004645 (0.9465)	0.529628 (0.0000)**	0.859950 (0.0000)**	0.695070 (0.0006)**
γ GJR-Co	-0.667435 (0.0014)**	-0.197307 (0.1239)	-0.100230 (0.1307)	-0.115913 (0.2124)
$\alpha + \beta + \gamma/2$	0.51826	0.794187	0.932485.	0.771615
AIC	-6.301553	-4.502403	-5.232449	-4.370896
SIC	-6.236381	-4.426369	-5.156415	-4.294862
Log likelihood	1133.681	810.679	940.992	787.205
Skewness	3.3883	0.013151	0.60496	0.40999
Excess Kurtosis	21.528	0.71637	1.5684	0.23482
Jarque-Bera	7576.9	7.6439	58.366	10.821
LM-ARCH 1-2	0.064738 [0.9373]	0.093040 [0.9112]	0.46086 [0.6311]	0.35522 [0.7013]
LM-ARCH 1-5	0.10504 [0.9911]	0.15918 [0.9771]	0.45061 [0.8128]	0.37813 [0.8637]
LM-ARCH 1-10	0.13580 [0.9993]	0.20086 [0.9961]	0.73094 [0.6952]	0.80139 [0.6275]
LB- Q(10)	10.0565 [0.3459268]	11.5052 [0.2426634]	12.8425 [0.1698657]	11.1489 [0.2656410]
LB- $Q(10)^2$	1.44951 [0.9935149]	1.90964 [0.9836577]	8.26587 [0.4079392]	6.48450 [0.5931271]
RBD(10)	1.55913 [0.9987391]	2.18570 [0.9947085]	8.54255 [0.5759957]	8.02237 [0.6266520]

Note: Note: *p* – values are in parentheses, ** indicates significant at 1% and * significant at 5%.

Stability

To check the stability of GARCH models Nyblom Test for parameter stability is applied. The Nyblom test for individual and joint parameter stability suggests there is no any statistically significant parameter instability in parameters of GARCH Models in all exchange rates.

Table 5: Nyblom Test for Parameter Stability

Parameters	GARCH (1,1)-M				GJR- GARCH (1,1)-M			
	PAK-USD	PAK-GBP	PAK-CAD	PAK-JPY	PAK-USD	PAK-GBP	PAK-CAD	PAK-JPY
Cst(M)	0.06910	0.05878	0.02654	0.24253	0.21595	0.07331	0.03843	0.24546
AR(1)	0.08925	0.04670	0.09920	0.06597	0.26958	0.03879	0.08668	0.08461
Cst(V)	0.07521	0.15662	0.46925	0.14364	0.09839	0.14760	0.55066	0.13712
ARCH(Alpha1)	0.06034	0.16134	0.24625	0.07581	0.11389	0.14768	0.30868	0.11987
GARCH(Beta1)	0.07781	0.21905	0.26194	0.11570	0.08753	0.18916	0.34080	0.11366
GJR(Gamma1)					0.14345	0.12185	0.25859	0.11977
ARCH-in-mean(std)	0.04430	0.04145	0.02339	0.22621	0.19207	0.05296	0.04304	0.24094
Joint Lc	1.9056	0.618407	1.756	1.02586	1.77489	0.636982	1.74597	1.02739
For individual statistics 1% and 5% critical values = 0.75 and 0.47 GARCH(1,1) For joint statistics 1% and 5 % critical values = 2.12 and 1.68 GJR- GARCH(1,1) For joint statistics 1% and 5 % critical values = 2.35 and 1.90								

5. Conclusion

This paper empirically investigates the volatility dynamics of Pak Rupee exchange rates and its effects on market efficiency through using GARCH models. The results show that Pak Rupee exchange rates are characterized by different dynamics of conditional volatility. These exchange rates depict high persistence in conditional volatility across GARCH models. There are no evidences of asymmetry and risk premium in Pak Rupee exchange rates except PKR-USD. Further, both GARCH models i-e GARCH –M (1,1) and GJR-GARCH-M(1,1), are adequate in capturing the volatility dynamics in exchange rates evidenced by diagnostic tests and shows individual and joint parameter stability evidenced by Nyblom test. Therefore, GARCH models are appropriate in modelling Pak Rupee exchange rate volatility.

Moreover, results indicate inefficiency of Pakistan exchange market which implies that the past information is not quickly incorporated by the current volatility. The investors can earn excess profits by using historical information from purchasing and selling foreign currencies. The government authorities can reduce exchange rate volatility by influencing exchange rates.

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