Financial Statistical Journal (2020) Volume 3 Issue 1
doi:10.24294/fsj.v3i1.738

Crude Oil Price-Exchange Rate Nexus in Pakistan

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ABSTRACT

This paper studies the association between price of crude oil and the Pakistani Rupee-US Dollar exchange. Asymmetric power autoregressive conditional heteroscedastic (APARCH) model is used to measure the influence of oil price on the nominal exchange rate using daily data of extreme oil price volatility (2006 – 2013). This model is found to fit the data well and the results reveal a high degree of volatility persistence and leverage effect in returns. This study also establishes a positive association between currency exchange rate and oil price. These findings provide insight into the transmission link between the global oil market and exchange rate.

***Keywords*:** APARCH; Exchange Rate; Oil Price; Volatility Clustering

1.Introduction

World economy has been influenced by many factors and among those crude oil price may be considered as one of the leading factors. Due to this importance, researchers and policy makers have been paying close attention to crude oil price and its relationship with various financial variables. Higher volatility is evident from the historical price of crude oil and hence created uncertainty among market participants. Hamilton (1983) studied the relationship between oil prices and US business cycle. Since then many researchers have studied the association of oil prices with other financial variables such as real gross domestic product and stock market (see Sadorsky, 2003; Prasad *et al*., 2007 and references therein).

The currency exchange rate is considered to play a vital part in the economy of a country and its dependence on oil price needs to be examined in detail. The US dollar exchange rate is the primary channel through which changes in oil prices are transmitted to the real economy and financial markets since oil prices are quoted in US dollar (Reboredo, 2012). Krugman (1983) and Golub (1983) noted the prospective significance of oil price for exchange rate movements. A country would have to fluctuate the nominal exchange rate when a larger shock in the oil prices is observed. This may lead to either appreciation or depreciation of the domestic currency depending on the level and significance of its dependence on oil prices.

Using monthly data (1972:02 – 1993:01), Amano and van Norden (1998) observed that increasing oil price is an indication of appreciation of US dollar. Using quarterly data from 1970 – 2003, Olomola (2006) found an appreciation of the currency exchange of Nigeria. For China, The relationship between these two variables was also studied by Huang and Guo (2007) using monthly data from 1990 to 2005. They also found an appreciation of the actual exchange rate of China. In Benassy-Quere *et al*. (2007), a study of the monthly actual oil price and dollar from January 1974 to November 2004, an appreciation of the dollar was reported. Daily data from 2000-2006 are employed by Narayan *et al*. (2008) to inspect this connection for Fiji Islands and established that an appreciation in Fiji dollar is linked with the rise in oil price.

Depreciation in exchange rate due to increase in oil price is also reported in the literature. Rautava (2004) studied the role of real exchange rate and crude oil price in Russian economy on the quarterly data from 1995 to 2002 and found that oil price increase is linked with depreciation of the rubel. Monthly data of Kazakhstan from January 1996 to November 2003 were used by Kutan and Wyzan (2005) and a depreciation of the local currency was reported. Chen and Chen (2007) also reported a devaluation in the long-run of the real exchange rate using monthly data from January 1972

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to October 2005 for a panel of G7 countries. Using daily data from July 2007 to November 2008, Ghosh (2011) surveyed the crude oil price and exchange rate relationship for India. His study revealed a depreciation of Indian currency with increasing oil prices.

Various methodologies have been adopted to inspect the interaction of oil and exchange rate markets. Among the large literature, few commonly used methods are as follows: the Granger causality and conitegration (Benassy-Quere *et al*., 2007; Chen and Chen, 2007; Lizardo and Mollick, 2010); univariate generalized autoregressive conditional heteroscedastic (GARCH) models (Narayan *et al*., 2008; Ghosh, 2011); wavelet based method (Benhamd, 2012; Tiwari *et al*., 2013); vector autoregression, vector error-correction and multivariate GARCH and stochastic volatility models (Rautava, 2004; Ding and Vo, 2012; Basher *et al*., 2012, Beckmann and Czudaj, 2013).

The symmetric GARCH model of Bollerslev (1986) and the asymmetric exponential GARCH (EGARCH) model of Nelson (1991) are popular choices among practitioners for modelling the volatility of financial returns. The EGARCH model includes leverage effects and provides a better fit for asymmetrical data. In the present study asymmetric power autoregressive conditional heteroscedastic (APARCH) model of Ding *et al*. (1993) is used. This model allows the flexibility of estimating volatility power and leverage in a single model. This model is also chosen in the present study to answer a question whether the effect of volatility power in the relationship of price of oil and currency exchange rate is desirable.

The main aim of this article is to empirically investigate the effect of crude oil prices and Pakistan's currency exchange rates. To the best of our knowledge no previous studies exist on this issue. This paper aims to fill this literature gap and contributes on Pakistan's macroeconomy by examining the impact of changing oil prices on Pakistani rupees. Pakistan is an oil importer and studying the effect of oil price volatility on currency exchange rate is important for emerging economy. Hence, analysis of this interaction is not only crucial for issues of risk management and investment but also for the economic and financial stability of the country (Turhan *et al*., 2014). The findings of this study may also have important implications for portfolio management and central bank policy design. The present study establishes this important association between crude oil price and currency exchange rate of Pakistan using daily data for the time period July 03, 2006 – December 31, 2013. This time period includes high volatility of both oil prices and exchange rates and therefore can provide a better insight of the relationship between these variables.

The rest of the paper is laid out as follows: the next section provides the framework for modelling the relationship between oil price and Pakistani rupees vis-à-vis US dollar. In Section 3, the preliminary analysis of data set is presented followed by the results of fitting APARCH model. Finally, Section 4 concludes the article.

2. Conditional Volatility Modelling of Oil Price and Currency Exchange Rate

This study aims to examine the relationship between two variables, the US West Texas Intermediate (WTI) crude oil price and exchange rate of Pakistan rupees per US dollar (USD). In the absence of daily consumer price index, the nominal variables are used. As pointed in Narayan *et al*. (2008), knowledge of real values are not required for tracking the daily behaviour of oil price and exchange rate. The daily return for oil price is computed as

$$y_t^o = \log(P_t/P_{t-1}) \times 100 \tag{1}$$

where P_t is the daily closing price of oil at tth day. Similarly, the daily return for exchange rate y_t^e is computed using the exchange rate price.

The GARCH model of Bollerslev (1986) is a popular choices among practitioners for modelling financial returns. The GARCH(1,1) model is generally fitted to capture the volatility clustering of returns. The following specification for mean is used.

$$y_t^e = \mu + \phi y_t^o + \epsilon_t \tag{2}$$

where μ and ϕ are parameters of the mean model and $\{\epsilon_t; 1 \leq t \leq T\}$ are assumed to be white noise with zero mean and variance σ_t^2. The parameter ϕ represents the mean change in the currency returns for one unit of change in the oil return. The GARCH(1,1) model for volatility is then given by

$$\sigma_t^2 = \omega + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \quad (3)$$

with $\omega > 0,\ \alpha \geq 0,\ \beta \geq\ 0$ and $\alpha\ + \beta\ < 1$ ensure stationarity. An alternative specification for mean called GARCH in the mean (GARCH-M) is also considered. This integrates the effect of the volatility of the series on the mean. The mean specification in GARCH-M model has the following form:

$$y_t^e\ = \mu + \phi\, y_t^o + \lambda\, \sigma_t^2 \quad (4)$$

where λ is called the risk parameter and the variance equation is same as in GARCH(1,1) model. In Equation (4), serial correlations are introduced by the volatility process $\{\sigma_t^2\}$. Hence, the return y_t^e is expected to be positively related to its volatility when $\lambda > 0$.

The GARCH model can not capture the asymmetriy between negative and positive asset returns. In addition, this model can not express the fat tails and excess kurtosis. In order to overcome these limitations of GARCH model various extensions have been proposed. One such extension is the asymmetric power ARCH (APARCH) model of Ding *et al*. (1993). A simple APARCH(1,1) model or APARCH(1,1)-M model has the following variance equation

$$\sigma_t^\delta\ = \omega + \alpha(|\epsilon_{t-1}| - \gamma\epsilon_{t-1})^\delta + \beta\sigma_{t-1}^\delta \quad (5)$$

with $\omega,\delta > 0,\ \alpha,\beta \geq\ 0,\ -1 < \gamma < 1$ and $\alpha\ + \beta\ < 1$ as usual constraints on the model. The asymmetry or the leverage effect is measured by the parameter γ. A negative asymmetry term implies that negative shocks have a greater impact on volatility than the positive shocks of the same magnitude. The APARCH(1,1) model nests many standard ARCH and GARCH formulations. For example, with $\delta = 2$ and $\gamma = \beta = 0$, it reduces to the well-known ARCH(1,1) model of Engle (1982). Similarly, with $\delta = 2$ and $\gamma = 0$, it reduces to the GARCH(1,1) model. Another important formulation is the asymmetric GJR-GARCH(1,1) model introduced by Glosten *et al*. (1993) with $\delta = 2$. The flexibility of using APARCH model is that a single model enables one to analyze all the important parameters at once and not to worry about fitting separate symmetric and asymmetric models to the same data set.

In this study, the APARCH(1,1) model is fitted with mean specifications outlined in Equation (2) and (4). The method of maximum likelihood assuming Gaussian distribution for errors is used for estimating the unkown parameters of the model. The model is fitted to the data set and quasi maximum likelihood estimates of the parameters of Equation (2), (4) and (5) are obtained. These parameters help us inspect the connection between exchange rate returns and oil prices.

3. Empirical Results and Discussion

3.1 Data and Preliminary Analysis

The data used in this research are the daily spot prices of crude oil (West Texas Intermediate – Cushing Oklahoma) per barrel and Pakistani rupee-dollar exchange rates (PKR-USD) for the period Jan 03, 2006 to Dec 31, 2013 (2002 observations). Within this time period, the oil prices has raised from \$63 per barrel to \$145 (July 23, 2008), came down to \$30 (December 23, 2008) due to global financial crisis and ended up at \$98 per barrel. Daily data are collected from http://uk.investing.com and converted to log-returns using Equation (1). All data appearing at the same date in both time series are selected to ensure the consistency and comparability. **Figure 1** shows the daily log-returns for oil and exchange rate. Volatility clustering is evident from both series, with oil returns showing high magnitude of volatility and more clustering.

Descriptive statistics of both oil price and exchange rate are displayed in Table 1. The means of both returns are found small and similar. The large difference between the minimum (-5.57) and maximum (7.13) values is the evidence of significant variations in oil returns. The unconditional standard deviation in oil returns is also found higher than that of exchange returns indicating that it is more volatile. The higher volatility in oil returns were also evident in **Figure 1.** Negative skewness and very high kurtosis are observed in exchange rates. High values of the Jarque-Bera (Jarque and Bera, 1980) test rejects the hypothesis of normal returns at 1% significance level and confirm the non-normality in return series. The dependence in the squared returns are tested using the Ljung-Box Q statistic (Ljung and Box, 1978). Significant values of this statistic at lag length of 10 and 20 reject the hypothesis of no autocorrelation in squared returns. In summary, both returns show strong linear dependence in squared returns and departure from normality.

The stationarity of both series is examined using various unit root tests. More specifically, the null hypothesis of unit root in returns is tested using traditional Augmented Dickey-Fuller (ADF) statistic (Dickey and Fuller, 1979) and Phillips-Perron (PP) statistic (Phillips and Perron, 1998). Schwarz information criterion (SIC) of (Schwarz, 1978) is used for the selection of optimal lag length of the ADF test. In addition, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) statistic (Kwiatkowski *et al*., 1992) is also applied to test the null hypothesis of stationary returns. Newey-West criterion (Newey and West, 1994) is used for the selection of optimal bandwidths of PP and KPSS tests. The results of these three test statistics on the level of the returns are reported in **Table 2**. Significant values of ADF and PP statistics with the constant term and linear trend reveal stationarity of both time series. These findings are further confirmed by non-significant values of KPSS statistic.

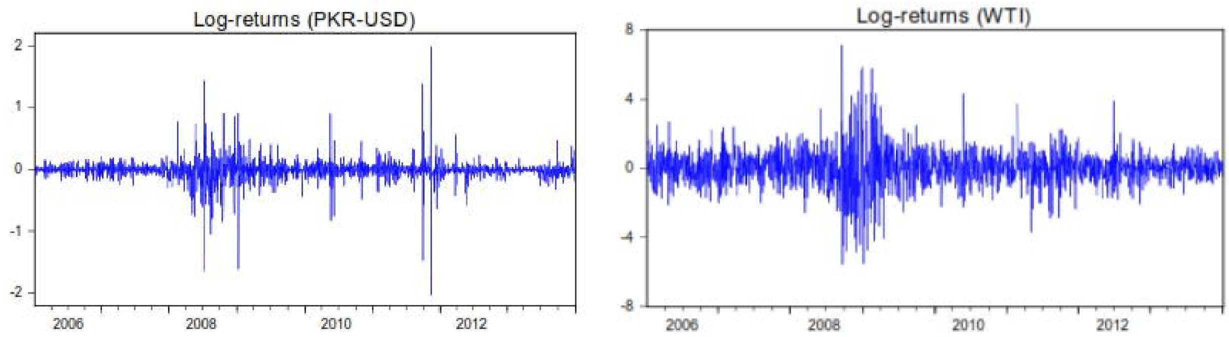

Figure 1; Log returns of exchange rates and oil prices**.**

	PKR-USD	**WTI**
Mean	–0.012295	0.010301
Minimum	–2.029903	–5.570574
Maximum	1.982682	7.128381
Std. dev.	0.174800	1.045486
Skewness	–0.743814	0.099029
Kurtosis	38.24949	8.536918
JB	103832.0*	2560.615*
Q(10)	412.1772*	1283.4969
Q(20)	422.9739*	2458.3495

Table 1. Descriptive statistics of exchange rate and oil price return

Note: JB is the Jarque-Bera test for normality of returns. Q(l) is the Ljung-Box test for the lth order serial dependence in the squared returns. * denotes significance at 1% significance level.

***Source*:** Authors' calculations.

	ADF	**PP**	**KPSS**
Without trend			
PKR-USD	–38.653	–56.378	0.1524
WTI	–45.074	–45.104	0.0454
Without trend			
PKR-USD	–38.645	–56.367	0.1566
WTI	–45.063	-45.093	0.0444

Table 2. Results of unit root tests of level of return

Note: ADF: Augmented Dickey-Fuller, PP: Phillips-Perron and KPSS: Kwiatkowski- Phillips-Schmidt-Shin are tests for unit root.

Source: Authors' calculations.

Next, assuming homoscedastic variance, residuals from Equation (2) are obtained using ordinary least square method. Lagrange multiplier (LM) test of Engle (1982) is used to evaluate the significance of ARCH effect in the residuals of the mean equation. The test statistic in this test is TR^2, where R is the sample multiple correlation coefficient computed from the autoregression of squared residuals and T is the sample size. The estimated p-values of ARCH-LM test at lag 1, 6, 15, and 30 are all found smaller than 1%. Hence, based on these statistically significant values, the hypothesis of ARCH effect can not be rejected so it is appropriate and effective to employ GARCH modeling for returns.

3.2 APARCH model estimation

In this subsection, the APARCH(1,1) and APARCH(1,1)-M models are fitted and estimates of parameters are obtained. The results of estimation and diagnostics are displayed in Table 3 and the main findings are as follows. The coefficient ϕ is found statistically significant in the mean equation of both models at 1% level. This is the evidence that the nominal exchange rate of currency is positively associated to the price of oil. A 10% rise in the returns of oil prices indicates an appreciation of Pakistani rupees vis-à-vis US dollar by around 0.6%. These finding are inline with Amano and van Norden (1998), Olomola (2006), Huang and Guo (2007), Benassy-Quere *et al*. (2007), and Narayan *et al*. (2008). The risk parameter λ in the mean equation of APARCH(1,1)-M model is not found significant revealing that the volatility of exchange rate has no effect on exchange rate itself.

All the parameters in the variance equation of both models are found statistically significant at 5% or less. The estimates of coefficients $\alpha + \beta$ are quite close to unity with large estimates of β. This is the indication of the high volatility persistence in the exchange rate. The leverage coefficient γ is found significant in both models with negative sign. This implies that negative shocks in returns have a greater impact on exchange rate volatility than the positive shocks of the same magnitude. In other words, higher volatility in exchange rate is associated with the negative shocks. The parameter δ is also found significant with estimated value close to 2, implying the volatility evolves in squared form as in most of the GARCH models. Hence, this provides an answer to the question raised in this study about the effect of volatility power in the oil-exchange rate relationship.

The results of diagnostics on the squared standardized residuals are also shown in the lower part of Table 3. Using the Ljung-Box test, no significant serial correlations are found at lag 10 and 20. The F-statistics of Engle's LM test also confirm these findings with non-significant values. The results of residual diagnostics imply that both the model can satisfactorily capture the ARCH effect in the returns of exchange rate. Since the estimate of coefficient λ is not found statistically significant in APARCH(1,1)-M model, it is reasonable to use the simple APARCH(1,1) model for modeling the exchange rate. Finally, this study shows that a single conditional heteroscedastic model such as APARCH can fit the data well and avoid the need of multiple models for the same data set.

	APARCH(1,1)	**APARCH(1,1)-M**
Mean equation		
μ	–0.0058***	–0.0041*
	(0.0021)	(0.0023)
φ	0.0065***	0.0058***
	(0.0021)	(0.0022)
λ	NA	-0.1969
		(0.1419)
Variance equation		
ω	9.63×10^{-5} ***	0.0001***
	(1.35×10^{-5})	(1.99×10^{-5})
	(0.0041)	(0.0042)
γ	–0.0648***	–0.0533**
	(0.0233)	(0.0244)
β	0.9107***	0.9138***
	(0.0038)	(0.0035)
δ	2.0541***	1.9872***
	(0.0706)	(0.0763)
Diagnostic test		
Q(10)	6.1001	6.3680
	[0.807]	[0.783]
Q(20)	9.1007	9.2757
	[0.982]	[0.979]
ARCH(10)	0.6217	0.5942
	[0.797]	[0.820]
ARCH(20)	0.4332	0.4252
	[0.986]	[0.988]

Table 3. Estimation results of the models

Note: Standard errors are reported in parentheses. Q(l) is the Ljung-Box test for the lth order serial dependence in the squared standardized residuals. ARCH(l) is the Engle's LM test for nonheteroscedasticity of order l. p-values of the statistics are reported in square brackets. *,**,*** denote significance at 10%, 5% and 1%, respectively.

Source: Authors' calculations.

4. Conclusion

The cross-market association between the crude oil price and currency exchange rate has attracted the attention of researchers, investors and policy makers. In this paper, the association between crude oil price (WTI) and the Pak-US dollar exchange rate is examined. The APARCH model that can measure the leverage in returns is fitted to the daily data for the period 2006 – 2013that includes extreme oil price volatility. The empirical results revealed a positive relationship between price of oil and currency exchange rate. It is also found that shocks to exchange rates have high persistence and asymmetric effect that are commonly observed in financial returns. Our findings have important implications and provide insight into the transmission link between the global oil market and local exchange rate. The observations in this study may have important implications for risk and portfolio management and central bank policy design. These would also provide significant insight to the central bank of Pakistan to deal with the volatility of exchange rate caused fluctuating of oil price. The findings may also have impact on domestic stock market with investors investing more on foreign assets than domestic during the period of high oil prices.

A future study would be to model the relationship between these variables using multivariate framework and consider structural breaks in the volatility. It would also the interesting to study the dynamic relationship between Pakistan stock market, currency exchange rate and energy prices.

Acknowledgement

The first author acknowledges the financial support of Higher Education Commission, Pakistan for this research at the University of Sheffield, UK.

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