Oil Prices and Exchanges Rate Co-Movements: Empirical Evidence from Sudan

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Abstract

This study applies exponential generalized autoregressive conditional heteroscedastic approach to model oil price and exchange rate in the context of the Sudanese economy. Daily observations are used in the analysis covering the period January 2008 to December 2018. The findings of the study illustrated that oil returns (fluctuations) have statistically significant impact on the current values of returns on exchange rate. Specifically, the results indicate that that an increase of 10% in crude oil price returns will lead to approximately 0.39% depreciation of the Sudanese Pound against the US dollar. Regarding the volatility transmission, the estimated results indicate that exchange rate fluctuations measured by the conditional volatility is significantly influenced by volatility experienced in oil market. These results may have important implications and of great interest for monetary policies aiming at controlling oil inflationary pressures.

Keywords: Crude oil price; exchange rate; EGARCH; Sudan.

1. Introduction

During the last few decades, the world economy has experienced several episodes of large fluctuations in crude oil prices which have raised serious concerns among economists and policy makers and led to a vast amount of empirical research to understand oil dynamics and their potential impacts on aggregate economic activity. From theoretical point of view it is anticipated that the possible impact of oil price fluctuations is to some extent different between oil-exporting countries compared to oil-importing ones. For oil-importing economies, it is expected that when oil prices tend to be they may induce increases in costs of production, price inflation, and lowering the expenditure on non-oil goods (Barsky and Kilian, 2004). When oil-exporting economies are considered, higher oil prices will generate higher income; this is simply because of low price elasticity of crude oil demand (Jung and Park, 2011).

It worth noting here that the work pioneered by James Hamilton in 1983 has been extensively used to illustrate that all but one of the U.S. recessions since World War II have been immediately preceded by a dramatic increase in the price of crude petroleum. In particular, oil price fluctuations seen during 1970 1973 and 1979 are considerably regarded as the major driving force of stagflation and macroeconomic volatility experienced by many economies in the world during that point of time. Since that, the co-movements between macroeconomic variables and fluctuations originating from oil market have become an active area of empirical research. For example, a large number of researchers considered the impacts of oil price volatility on stock market performance (Sadorsky, 1999; Malik and Hammoudeh, 2007; Arouri, 2011; Basher et al., 2012,). Other researchers considered the impacts on economic growth (Eika and Magnussen, 2000; Ferderer, 1996; Prasad et al., 2007; Kilian and Vigfusson, 2012), while some others look at the impacts on industrial production (Tiwari, 2012). Similarly, Dogrul, 2010 illustrates the co-movements between oil price fluctuations and interest rate and unemployment. Finally, Chen, 2009 considered the impacts on inflation.

One active branch of literature regarding the interdependences between macroeconomic fundamentals has been focusing on oil prices-exchange rates nexus given the fact that exchange rate represents an important channel through which fluctuations originated from oil market transmitted to real economy and financial markets. From a theoretical standpoint of view, oil prices-exchange rates relationship was pioneered by Krugman (1980) who illustrate empirically that the initial impacts of oil prices increase on exchange rates vary from their long-run impacts; it is an appreciation in the first case and depreciation in the second case. Likewise, the co-movements between the two variables have also been considered from the viewpoint of the potential impact of exchange rates can have on oil price movements.

Given the fact that U.S. dollar is usually utilized as a main invoicing and settlement currency in international oil markets, volatility experienced in the USD exchange rate is considered to affect oil prices movements from the perception of "law of one price (LOP) for tradable goods" which confirms that weakening of USD relative to other currencies will induce the international buyers to pay more USD for crude oil (see, e.g., Akram, 2009; Benhmad, 2012). The main objective of this paper is to investigate the co-movements between oil price fluctuations and US exchange rate in the Sudanese economy. The remainder of this paper is structured as follows. Section 2 illustrates the theoretical framework and provides some previous work on the relationship between the two variables. Section 3 briefly describes the methodology employed. Section 4 looks at data issues and section 5 provides the empirical findings of the study. Finally, Section 6 concludes the paper.

2. Theoretical framework and empirical literature

There are many theoretical explanations provided in the literature regarding the co-movements between oil price and exchange rate with the direction of causality runs in both directions. The argument for this relation is based on the fact that oil price fluctuations may have significant impacts on exchange rate movements of the trading countries through the USD, this simply because oil is commonly quoted in USD. The theoretical framework used for modeling this interrelationship was first introduced by Golub (1983) and Krugman (1983). It worth mentioning here that the law of one price (LOP) is usually used in the literature to understand this relationship. This can be illustrated as follows: as oil is completely homogeneous and internationally traded commodity priced in USD, the oil price in foreign currency is given by:

$$p_t^* = e + p_t \tag{1}$$

In this equation p_t^* represents the log of oil prices in units of foreign currency, p_t represents the log of oil prices in US dollar and e is the (log) nominal US dollar exchange rate. That being so, the US Dollar depreciation (the reduction in the term e) will lead to reduction in oil prices for the foreigners relative to commodities being priced in the foreign currencies, thus increasing the purchasing power and the demand for crude oil by foreign consumers; this, in contrast, will increase the oil price.

A simple theoretical model regarding the co-movement between exchange rates and crude oil prices has also been illustrated as follows. Suppose that both traded and non traded goods are produced in the home and foreign countries. Let the log-linear approximation of the home and foreign country consumer price indexes be:

$$\mathrm{p_t} = \emptyset \mathrm{p_t^T} + (1-\emptyset)\mathrm{p_t^N}, \tag{2}$$

$$\mathrm{p_t^*} = \emptyset^* \mathrm{p_t^{T^*}} + (1-\emptyset^*)\mathrm{p_t^{N^*}}, \tag{3}$$

where $p_t^T(p_t^{T^*})$ and $p_t^N(p_t^{N^*})$ correspond to the logarithm of prices of tradable and non-tradable goods for the home (foreign) country, respectively. The weights $\emptyset$ and $\emptyset^*$ give the corresponding expenditure shares on tradable goods near the point of approximation for the home and foreign countries, respectively (Chen and Chen, 2007). Crude oil enters both production functions as an input factor while the price of non-tradable goods is determined solely by labor costs (Beckmann and Czudaj, 2013).

$$\mathrm{e} = \left(\mathrm{p_t^N} - \mathrm{p_t^{N^*}}\right) + (1-\emptyset^*)\left(\mathrm{p_t^{T^*}} - \mathrm{p_t^{N^*}}\right) - (1-\emptyset)(\mathrm{p_t^T} - \mathrm{p_t^N}), \tag{4}$$

Hence, under the assumption that the price of a tradable good is internationally fixed, and that $\emptyset \simeq \emptyset^*$, the impact of crude oil price on exchange rate rely on its impact on the relative price of traded goods in the home country with respect to the relative price of traded goods in the foreign country. as a consequence, if the home country is more dependent on imported oil, an oil price increase would increase the relative prices of traded goods in the home country proportionally more than in the foreign country, thereby causing depreciation in the home currency Otherwise, the oil price rise causes the home currency to appreciate (Reboredo and Rivera-Castro, 2013)..

Consistent with the above mentioned discussion, several efforts have emerged to empirically investigate the reciprocal influences between the two quantities; generally the findings have been mixed. For example, empirical research by Golub (1983), Amano and van Norden (1998), Camarero and Tamarit (2002), Benassy-Querea et al. (2007), Chaudhuri and Daniel (1998), Chen and Chen (2007), Coudert et al. (2008), Lizardo and Mollick (2010) and Beckman and Czudaj (2013) provides evidence supporting the direction of relationship from oil price to exchange rate. On the other hand, the potential importance of exchange rates for explaining crude oil price movements, highlighted by Yousefi and Wirjanto (2004), Krichene (2005), Sadorsky, 2000 and Zhang et al. (2008). Other empirical studies however find a bidirectional aspect, having influences over each other for the variables (see e.g., Chen et al., 2010; Ding and Vo, 2012), among others. Various econometric techniques have been applied to investigate the co-movement between oil prices and the US dollar exchange rate.

Just to mention few examples: Amano and van Norden (1998) applied the Engle and Granger (1987) causality test to investigate this relationship; they find that the two variables are cointegrated with a unidirectional causality behavior running from oil prices to exchange rates., Chaudhuri and Daniel (1998) employed Engle-Granger cointegration test investigate the relationship in selected OECD countries and find that the non-stationary behavior of the USD exchange rates is due to the non-stationary behavior of real oil prices.

By using Hansen's Generalized Method of Moments model, Yousefi and Wirjanto (2004) find a negative correlation between oil prices and the USD exchange rate. Based on vector error correction model, Krichene (2005) illustrate that the falling nominal effective exchange rate could lead to a surge in oil prices, and inversely either long-term or short-term effects. Some empirical evidences have been provided by Sari et al. (2009) in the framework of variance decompositions (VD) and impulse response functions (IRF). Specifically, they find some evidence of a weak long-run equilibrium relationship but with strong feedback in the short run. Furthermore, Cifarelli and Paladino (2010) find strong evidence that oil price fluctuations are negatively related to exchange rate changes based on multivariate CCC GARCH-M model. Selmi et al. (2012) applied the generalized autoregressive conditional heteroscedastic (GARCH) model and find a negative impact of crude oil price on real exchange rate volatility for an oil importing economy (Morocco) and for a small oil-exporting country (Tunisia). Several applications of wavelet analysis have also been presented in the literature (see, e.g., Benhmad, 2012; Tiwari et al., 2013). Additionally Benhmad (2012) concludes that there is a strong bidirectional causal relationship between the two variables for low frequencies. Lastly, Tiwari et al. (2013), documented a bidirectional causal relationships between the crude oil price fluctuations and the REER of the Indian rupee higher timescales. Notwithstanding the mixed implications, all these empirical studies indicate that oil prices fluctuations and exchange rates include information that can affect each other.

3. Econometric Methodology

As mentioned earlier in this paper, this study tried to model the co-movements between oil price and exchange rate in the framework of the generalized autoregressive conditional heteroscedasticity (GARCH) model. It worth noting here that this class of models has become commonly used in the literature; particularly in modelling and forecasting financial variables and commodity prices (Agnolucci, 2009; Aloui and Mabrouk, 2010; Cheong, 2009; Fong and See, 2002). Accordingly, the current paper applies the exponential generalized autoregressive conditional heteroscedastic EGARCH(1,1)-M model. It is a common fact in the literature that this model captures a large part of the stylized facts regarding the return series of a given index; this includes for example, volatility clustering and leverage effect. The EGARCH-M model used in this paper is considered one important extension of GARCH framework; it is commonly used in the literature to allow the conditional mean of a given series to depend on its conditional variance or conditional standard deviation. Accordingly, the following specification EGARCH (1,1) -M is used:

Mean equation $$r_t = \mu + \lambda\sigma_t^2 + \varepsilon_t \tag{5}$$

$$Ln(\sigma_t^2) = \omega + \beta_1 Ln(\sigma_{t-1}^2) + \alpha_1\left\{\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| - \sqrt{\frac{2}{\pi}}\right\} - \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} \tag{6}$$

where $\omega > 0$ and $\alpha_1 \geq 0$ and $\beta_1 \geq 0$, and.

r_t = the return of the series at time t.

μ = the average value of the returns series.

ε_t = residual of the returns series, defined as:

$$\varepsilon_t = \sigma_t z_t \tag{7}$$

where z_t is standardized residual returns (i.e. realization of iid random variable with zero mean and variance 1), and σ_t^2 is conditional variance.

In the variance equation: ω, β_1, α_1 and γ are constant parameters, $Ln(\sigma_t^2)$ is the forecast of volatility associated with one-period ahead. This indicates that the leverage effect is exponential rather than quadratic and the forecast of volatility is assumed to be nonnegative, ω is the average value, is the persistence coefficient, $Ln(\sigma_{t-1}^2)$ is the variance in the past period. Unlike the GARCH framework, the EGARCH can be used to allow for the leverage effect. If γ has a negative sign, then the leverage effect exists.

In literature this can be interpreted as follows: the unexpected drops in the prices (bad news) increase the conditional volatility more than unexpected increases in prices (good news) of similar magnitude (Black, 1976; Christie, 1982). Additionally, if the term α is positive, then the conditional volatility tends to increase (fall) when the absolute value of the standardized residuals is larger (smaller).

4. Data and Preliminary Analysis

The current study uses daily observations on crude oil prices and US dollar exchange rate. Daily observations are used because they help in capturing the intensity of the dynamics and interrelationship between the two variables. The data set covers the period January 2, 2008 to December 30, 2018. Oil prices are expressed in US dollar per barrel for Brent spot prices to represent the international crude oil market given that they serve as pricing benchmark for two thirds of the world's internationally traded crude oil supplies (see Alloui et al., 2013). Exchange rate used in this paper corresponds to the amount the domestic currency with respect to the US dollar. The analysis begins by computing the daily returns on the two variables. In this process, the difference in logarithm of two successive values is taken to give the following equations:

$$r_t^o = log\left(\frac{P_t^o}{P_{t-1}^o}\right) \quad (8)$$

$$r_t^e = log\left(\frac{P_t^e}{P_{t-1}^e}\right) \quad (9)$$

Where, P_t^o and r_t^o represent daily oil prices and their returns, P_t^e and r_t^e are the exchange rates and their returns.

Table 1 provides some useful descriptive statistics as well as the distributional characteristics of the returns for the two series. The results of Table 1 indicate that the daily return of crude oil has a positive mean value. This result reflects the surge in oil prices since 1999 which has been attributed to increasing demand from emerging markets (Breitenfellner and Cuaresma, 2008). For the exchange rate, the series has small mean implying that for some periods daily exchange rate did not change. When considering the maximum and minimum values of the two; one can easily observe that the fluctuations in crude oil prices are greater than those associated with exchange rates during the period of analysis. Similarly, the standard deviation can be considered as another evidence of high volatility and risky nature of oil market compared to exchange rate. These results come consistent with some empirical studies in this regards (see, e.g., Ding and Vo, 2012; Wu et al., 2012; Alloui et al., 2013; Tiwari et al., 2013; Reboredo et el., 2014). Table 1 also provide evidence that the return series are not normally distributed; instead they display positive skewness (the distribution has a long right tail). Moreover, a highly leptokurtic distribution is another characteristic seen for the returns series. The Jarque-Bera statistic indicates that the returns distribution regarding the crude oil prices and exchange rate are non-normal at a p-value of almost 1%.

In addition to that some statistics regarding the autocorrelation function are also provided in Table 1. The Ljung–Box statistic for serial autocorrelation on returns and squared returns shows that the null hypothesis of no auto-correlations up to the 36th order is rejected at 1% significant level. This result confirms indicates the existence of autocorrelations in the returns on the two series. Furthermore, the ARCH tests up to 36 lags reject the null hypothesis of homoscedasticity in the datasets. Finally, the unconditional correlation of crude oil and US dollar exchange rate indicates negative correlations. Figs. 1 and 2 provide an illustration of the original series of oil prices and exchange rate and their returns respectively.

Table 1: Summary statistics for oil price and exchange rate returns

Measures	Exchange rate		Oil prices	
	Value	Returns	Value	Returns
Mean	7.009365	0.109632	74.43865	0.027591
Std. dev.	9.655119	2.808715	24.12193	2.484510
Maximum	47.61880	97.28559	145.3100	16.41370
Minimum	2.003400	-18.61152	26.19000	-12.82672
Skewness	3.389350	29.75789	0.153214	0.138410
Excess Kurtosis	14.15861	978.6114	2.064693	7.198040
Jarque-Bera	20377.72*	1.14E+08*	115.7998*	2115.907*
Ljung-Box $Q(36)$	353.44*	345.78*	432.78*	554.22*
Ljung-Box $Q^2(36)$	218.21*	188.43*	543.23*	965.32*
ARCH(36)	233.6*	111.67*	1089.33*	1121.23*
Correlation with Oil	-0.331	-0.00193	-	-

Note: Jarque-Bera is used for normality test. Ljung-Box $Q(36)$ lagged from 1 to 36 is applied for autocorrelation test of the series whereas its squared $Q^2(36)$ is used to check the heteroscedasticity of price series. * indicates statistical significance at 1% significance level.

Figure 1:

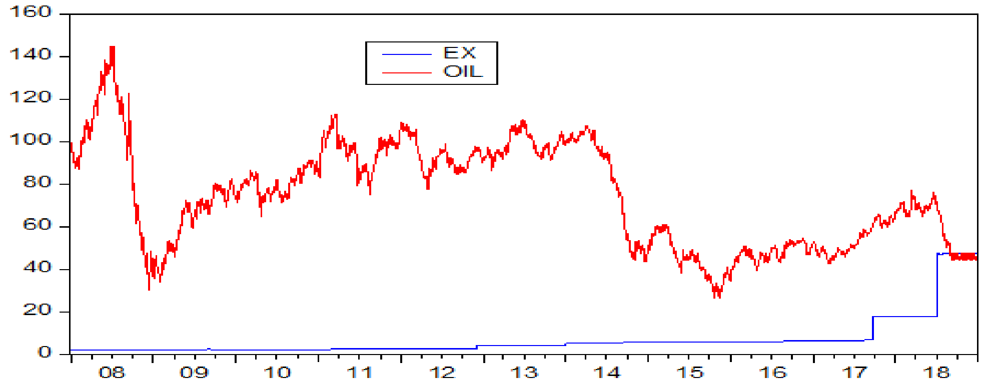
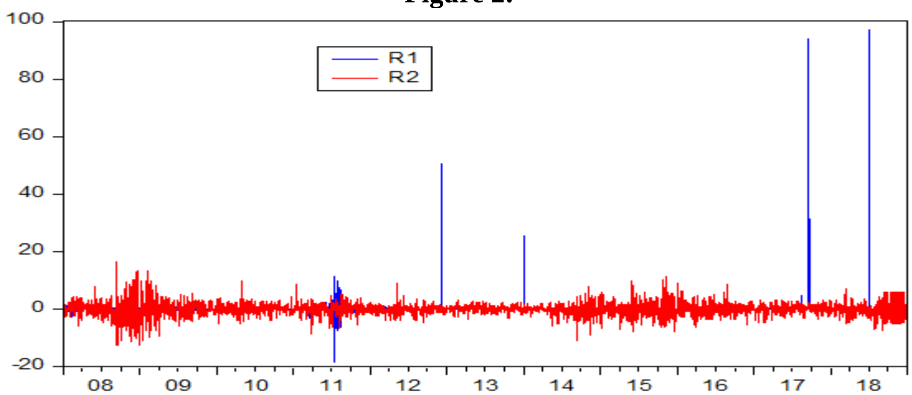


Figure 2:



5. Empirical Results

As illustrated in the previous section, there is strong evidence for the existence of ARCH effects in the residual series for returns series on the crude oil prices and exchange rate. This result shows that it is possible now to go further with modeling the interdependences between the two markets by employing the EGARCH(1,1)-M model. To that end, maximum likelihood method under the assumption of multivariate normal distributed error is applied. The proposed model is estimated using. The log likelihood function is maximized using Marquardt's numerical iterative algorithm to search for optimal parameters. In addition to EGARCH estimation, the study also employed some diagnostics test for the purpose of checking if ARCH effects still exist in the estimated model. Estimation results are presented in Tables 2 for both conditional mean and conditional variance equations respectively.

Table 2: Estimation results of the EGARCH(1,1)-M model

	Coefficients	Probability
Conditional Mean Equation		
μ	-4.11E-10	0.7484
δ	-0.000116	0.9125
λ	-1.19E-06	0.9538
Oil(-1)	-0.03921	0.0000
Conditional Variance Equation		
ω	-3.430556	0.0000
α	0.168593	0.0000
β	-0.174368	0.0000
γ	0.483524	0.0000
Oil(-1)	0.016023	0.0000
Log-Likelihood		5410.825
LB(36)	15.52	0.987
ARCH(36)	4.11	0.675

Notes: LB(36) is the Ljung-Box test for autocorrelation up to order 36. ARCH(36) is the Engle (1982) test for conditional heteroscedasticity of order 36.

Table 2 shows that the coefficient associated with one-period lagged of crude oil returns, Oil(-1), has a highly significant negative impact on the current values of exchange rate returns. By implication, a higher crude oil prices will lead to depreciation for the Sudanese Pound. Generally speaking, this means that a 10% increase in crude oil price returns will result in approximately 0.39% depreciation of the Sudanese Pound against the US dollar. This behavior of exchange rate as a consequence of increased crude oil prices is compatible with many findings from previous studies in this regards; including for example: Benassy-Querea et al. (2007) for China, Coudert et al. (2008) for the United States, Narayan et al., (2008) for Fiji, Ghosh (2011) for India, and Salisu and Mobolaji (2013) for Nigeria. Most of these papers provide evidences with completely different methodologies. As for the shock dependence and the persistent of conditional volatility (as represented by ARCH and GARCH parameters) in the conditional variance equation, the results provided in Table 2 show highly statistically significant for the two parameters.

Volatility transmission from oil market to exchange rate market is represented by the empirical results provided in the conditional variance equation. The results show that exchange rate returns volatility of the exchange rate returns is influenced by the shocks originated from crude oil market. This conclusion is described by the significance of the parameter of oil(-1); this means that a shock arise from oil market will lead to an increase in the conditional volatility of exchange rate returns. This volatility transmission from oil market to exchange rate behavior is confirmed in many empirical results; including for example the findings provided by Ding and Vo (2012) and Saliso and Mobolaji (2013) who also detect the same relationship and co-movements between the two variables.

In addition to that the study applies the Ljung–Box in order to test for autocorrelation and the ARCH LM for the purpose of checking whether ARCH effects are still exist in the estimated model. The results are reported in Table 2. From results of Ljung–Box statistic it is very clear that there is strong evidence to accept the null hypothesis of no autocorrelation. Accordingly, we conclude that the residuals of the estimated model are free of autocorrelation. As for the null hypothesis of no ARCH effects are left, the results of ARCH-LM test indicate it cannot be rejected. This implies that that the residuals of the estimated model do not suffer from the ARCH effects. This result means that the employed EGARCH(1,1)-M model is good choice for modelling the co-movements between oil price fluctuations and exchange rate behavior as it effectively captured the ARCH effects.

6. Concluding Remarks and Implications

As indicated by many empirical studies, the prices of crude oil and the USD exchange rate have experienced many periods of higher volatility and fluctuations; the relationship between the two variables is generally comes in opposite directions. Wu (2012) shows that the negative relationship between oil prices and USD exchange rate has enabled the two variables to serve as important tools that can be used in many ways; including for example: asset allocation and risk management. For these reasons and many others, modeling the interrelationship between the two variables has attracted much attention among economists and policy makers. Having this in mind, the current study tries to look at the relationship within the Sudanese economy by using daily observations covering the period January 2008 to December 2018. The study employs a EGARCH(1,1)-M model for the purpose of estimating the conditional mean and conditional variance equations that include both the returns on the crude oil prices and the USD exchange rate. The results associated with the conditional mean equation reveal that crude oil price has statistically significant impact on the exchange rate. Specifically, a 10% increase in crude oil price returns will result in approximately 0.39%, depreciation of the Sudanese Pound against the US dollar. In addition to that, volatility transmission between the two variables is also investigated in this study. The empirical results in the conditional variance equation, empirical findings illustrate that conditional volatility of exchange rate is affected by fluctuations originated from the oil market over the period of study.

The empirical results provided in this study have some important implications for monetary policies aimed at controlling oil inflationary pressures. The results can also be very useful for effective fiscal policy management in oil-exporting countries, and for risk management for oil importing and oil exporting countries faced with crude oil shock, an, for risk management and the pricing of currencies and oil-related assets.

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