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Modeling of Crude Oil and Other Petroleum Products Spot Prices in Nigeria: An Inter-quantile Regression Approach

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Abstract
Crude oil and other petroleum product spots prices are highly volatile and it has a great impact on economic growth. Change in the price of this oil has significant effect on economic growth and the wellbeing of the population around the world. This paper modeled the fluctuations of crude oil and other petroleum product spots prices at different range of thresholds (quantiles) using inter-quantile regression. The model was implemented on exchange rate data in Nigeria sourced from exchangerate.org and crude oil and other petroleum product spot prices from eia.gov.uk. The study covered the period from January, 2010 to August, 2023 (about 13 years); it revealed that crude oil and heating oil depreciates exchange rate, diesel fuel appreciates exchange rate while Kerosene (jet fuel) fluctuate the exchange rate as shown in the models presented at 0.05 alpha level of significance. The software used for analysis is STATA version 14.0.
Keywords: Crude oil, Exchange rate, Petroleum Products, Quantile and Spot Prices.

Introduction

According to [1] Central Bank of Nigeria's Balance of Payment (BOP) revealed that oil and gas sector accounted for 93.8% of the country's total export revenue in the 1st quarter of 2018. Crude oil accounted for 85% of Nigeria's gross domestic product (GDP) and over 80% of the country's revenue. According to [2] Nigeria as a country started commercial exploration of crude oil in 1958 when the Royal Dutch Shell started exportation of oil from Oloibiri and Afam oil fields in Port Harcourt, Rivers State of Nigeria [3].

One of the most important driving forces of the global economy is crude oil. Changes in the price of this oil have significant effects on economic growth and the wellbeing of the population around the world [4]. Crude oil prices are highly stochastic and it has a great impact on economic growth. It was observed that increase in oil prices is proportional to increase in national income for oil exporting countries [5].

Crude oil is a vital source of foreign exchange and the main source of revenue in Nigerian economy. Nigerian economy has been completely focused on oil and the basis upon which government budgeting, revenue distribution and capital allocations are determined. Volatility in oil price is an upward and downward movement of oil prices globally. Reportedly, 80% of Nigeria's energy revenues flow to the government; 16% cover operational costs, and the remaining 4% go to investors [6]. In Nigeria, the management of the exchange rate is monitored by the Central Bank of Nigeria. Following the adoption of structural adjustment policy in 1986, the country has moved from a peg regime to a flexible exchange rate regime. In practice, no exchange rate is clean or pure float, that is, a situation where it is left completely to be determined by market forces but rather the prevailing system is the managed float whereby monetary authorities intervene periodically in the foreign exchange market in order to attain some strategic objectives [7]. According to [8] "oil is an international trade commodity that attract foreign exchange and is a quick source of capital accumulation. Huge revenues are realized from the wide differential between unit production costs and economic rents, royalties, petroleum taxes, oil exports etc." The Nigerian government's annual budget has always been pegged to a specific amount of the international price of crude oil, thus, making both the government fiscal and monetary policy to be susceptible to fluctuation [9]. [10] investigated the causal relationship between oil price and key macroeconomic variables in Nigeria using simple ordinary least square (OLS) method and Granger causality test. The results of the study within the periods of 1980-2010 showed that there was a positive and insignificant relationship between oil price, gross domestic product and exchange rate in Nigeria. No evidence of causal relationship running from gross domestic product to oil price and from oil price to gross domestic product were seen. [11] evaluated the effect of oil price on the macroeconomic variables within the periods of 1990-2015 in Nigeria using multiple regression technique. The results showed that unemployment rate contributed positively and significantly to crude oil price. While interest rate contributed negatively and significantly on crude oil price. The result further revealed that inflation rate, exchange rate and real gross domestic product do not have any effect on crude oil price. [12] investigated the impact of oil price variations on real output growth in Nigeria within the periods of 1970-2011 using Dynamic Variable Auto-regressive (DVAR) analytical framework. The results revealed that the oil

price shocks do not directly contributes to output, exchange rate or inflation in the short run but showed significant and positive relationship with output growth in the long run. [13] investigated oil price volatility and infrastructural growth in Nigeria using co-integration and error correction modeling approach within the periods of 1981-2016. The findings showed that both the oil price volatility and inflation rate exert negative influence on infrastructural growth, whist the real exchange rate caused investment in infrastructure. [14] studied the relationship between crude oil price and economic growth of Nigeria within the periods of 1981-2013 using vector autoregressive (VAR) model and ordinary least square (OLS). The results from the VAR model revealed that the oil price changes have a significant impact on the economic growth of Nigeria. While the result from ordinary least square (OLS) method revealed that oil prices have positive relationship with gross domestic product (GDP), decrease in oil prices have a negative impact on GDP and also fluctuation in exchange rate has both negative and positive impact on crude oil price and the GDP.

[15] evaluated the impact of oil prices on economic growth in Nigeria within the periods of 1980-2016 using ordinary least squares (OLS) method. The study revealed a long-run association among the variables and a positive and significant association between oil price variations and economic growth. The aim of this paper is to model the fluctuations of crude oil and other petroleum products spot prices on Nigeria exchange rate using inter-quantile regression since the fluctuations in exchange rate, crude oil and other petroleum products spot prices are non-normal and skewed. This technique is used to estimate the difference in the conditional median distributional effect and check if there are significant differences among quantiles. The remaining part of the paper is organized as follows: inter-quantile regression is specified in Section 2. Section 3 presents the results obtained from the application of the model in Section 2 on crude oil and other petroleum product spot prices in Nigeria. In Section 4, the discussion of results is presented and concluding remarks are made in Section 5.

Methods

Inter-quantile Model

According to [16] consider a quantile-regression model where the q-th quantile is given by

$$Q_q(y) = a_q + b_{q.1}x_1 + \cdots + d_{q.n}x_n \quad (1)$$

The upper and lower quantiles (uq and lq) are given by (2) and (3) respectively

$$Q_{uq}(y) = a_{uq} + b_{uq.1}x_1 + \cdots + d_{uq.n}x_n \quad (2)$$

$$Q_{lq}(y) = a_{lq} + b_{lq.1}x_1 + \cdots d_{lq.n}x_n \quad (3)$$

The difference in the quantiles is then

$$Q_{uq}(y) - Q_{lq}(y) = (a_{uq} - a_{lq}) + (b_{uq.1} - b_{lq.1})x_1 + \cdots + (d_{uq.n} - d_{lq.n})x_n \quad (4)$$

Quantile regression estimate models such as (2) and (3). Inter-quantile regression estimates models such as (4). Let $Q_q(y) = Q_{uq}(y) - Q_{lq}(y)$

$$a_q = a_{uq} - a_{lq}$$

$$b_{q.1}x_1 = (b_{uq.1} - b_{lq.1})x_1$$

$$d_{q.n}x_n = (d_{uq.n} - d_{lq.n})x_n$$

Put the parameters above into (4) to obtain (1). Solving (1) above we obtained (5) the quantile regression proposed by [17] where $\rho_q(.)$ is called the "check function", θ_q^* is the vector of parameter at quantile (q), θ' is the transpose of the vectors of the parameters, X_t is the vectors of repressor, Y_t is the dependent variable and t = 1, 2, …, n.

$$\theta_q^* = min_\theta E\rho_q(Y_t - \theta' X_t) \quad (5)$$

From (5), we obtain an estimate of the (qth) conditional quantile of Y presented in (6).

$$X'\theta_q^* = Q_Y(q|X) \quad (6)$$

The solutions in (7)

$$\hat{\theta}(q) = min_\theta \sum_t \rho_q(Y_t - \theta^T X_t) \quad (7)$$

are the regression quantiles.

Given $\hat{\theta}(q)$, the qthconditional quantile function ofY_t given X_t can be estimated by (8) [18].

$$\hat{Q}_{Y_t}(q|X) = X_t^T \hat{\theta}(q) \quad (8)$$

Where X_t^T is the transpose of repressors and $\hat{\theta}(q)$ is the estimate of the vector parameters at a given quantile (q).

Data: The data used in this work is a secondary data sourced from eia.gov (U.S. Energy Information and Administration) and exchangerate.org.uk (2023). It is a data on Nigeria Exchange rates (NER) and crude oil and petroleum products spot prices covering the period of Thirteen (13) years on monthly basis from January, 2010 to August, 2023. This implies that the study period covers 156 months and STATA version 14.0 is used for the analysis.

Results and Discussion

The trend analysis of crude oil, heating oil, diesel fuel and kerosene (Jet fuel) displayed upward and downward fluctuations indicating volatility (figure 1 and 2) because the prices of the products rise and fall in the market as exchange rate fluctuates within the studied period.

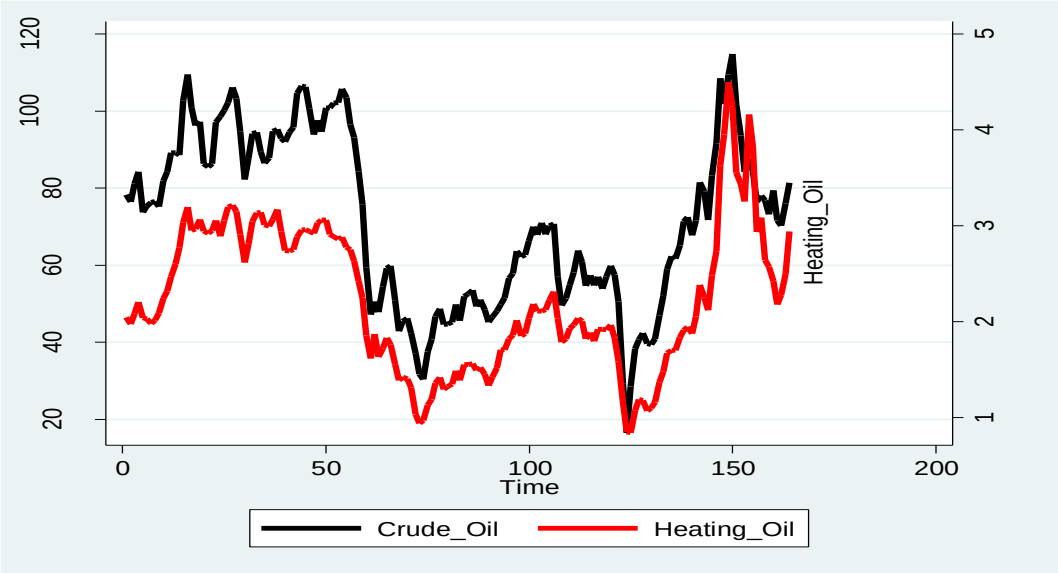

Figure 1: Line Plot of Crude oil and Heating oil

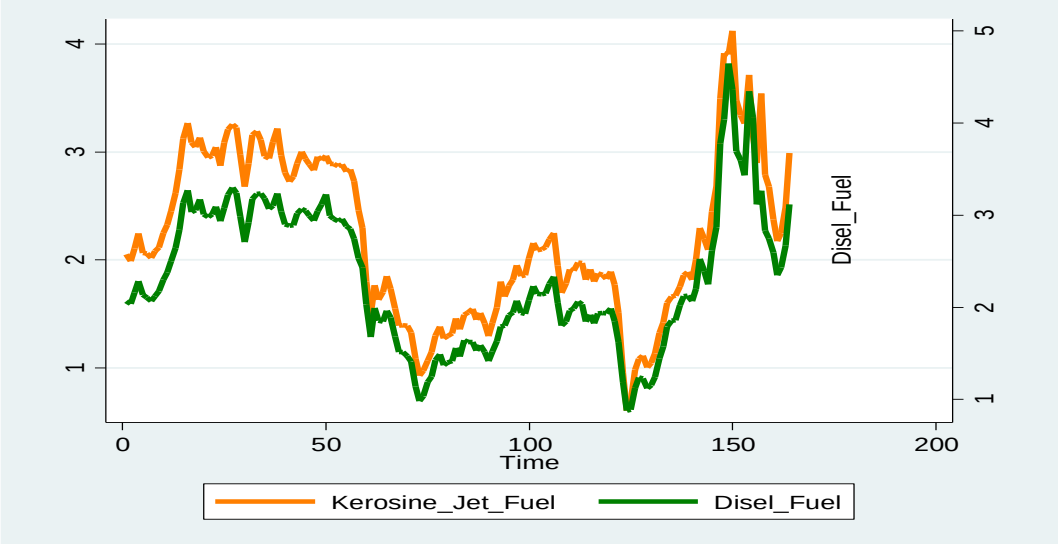

Figure 2: Line Plot of Kerosene and Diesel fuel

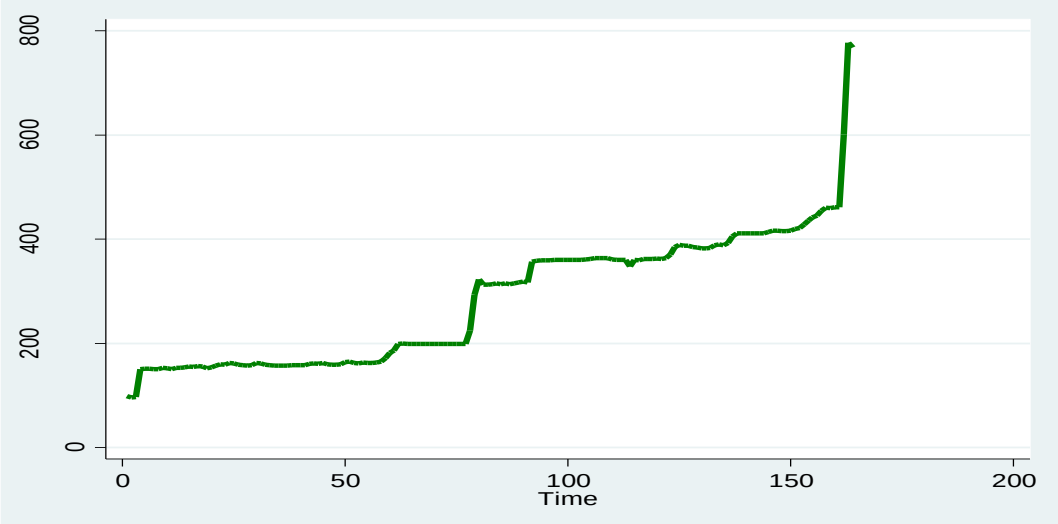

Figure 3: Line Plot of Nigeria Exchange Rate

The trend of Nigeria exchange rate showed continuous increase without any form of decline (figure 3) resulting to the rise in price of the petroleum products/crude oil. Crude oil in the model is significant at α = 0.05 with probability value of 0.003 resulting to the rejection of the null hypothesis while heating oil, diesel fuel and jet fuel are not significant because all the probability values are greater than 0.05 alpha level of significance and hence the null hypothesis is not rejected.

Table 1: 0.5 - 0.1 Inter-quantile regression

Variables	Coefficients	Std. Error.	t	P>|t|
Crude Oil	-6.64	2.22	-2.99	0.003
Heating Oil	-262.84	380.60	-0.69	0.491
Diesel Fuel	371.44	446.13	0.83	0.406
Kerosene (Jet Fuel)	40.44	243.15	0.17	0.868
Constant	222.79	33.33	6.69	0.000

Crude Oil = x_1, Heating Oil =x_2, Diesel Fuel =x_3, Kerosene (Jet Fuel) = x_4, and Exchange Rate = y

$$y = 222.79 - 6.64x_1 - 262.84x_2 + 371.44x_3 + 40.44x_4 \quad (9)$$

The model in (9) above revealed that crude oil and heating oil have negative impact on exchange rate although diesel fuel and jet fuel have positive impact on exchange rate in Nigeria but not statistically significant. A unit change in the price of crude oil and heating oil depreciate the exchange rate by $-6.64$and -262.84 naira respectively while diesel fuel and jet fuel appreciate the exchange rate by 371.44and 40.44 naira respectively (Table 1). Crude oil, heating oil and diesel fuel are significant in the model at 95% significant level with probability values (0.001, 0.007 and 0.0000) which are less than 0.05 alpha level leading to the rejection of the null hypotheses whereas Jet fuel in the model is not significant at 95% level of significance with probability value (0.639) which clearly is greater than 0.05 alpha level of significance, leading to the acceptance of the null hypothesis.

Table 2: 0.75 - 0.1 Inter-quantile regression

Variables	Coefficient	Std. Error	t	P>|t|
Crude Oil	-7.89	2.27	-3.48	0.001
Heating Oil	-675.50	246.99	-2.73	0.007
Diesel Fuel	964.13	265.01	3.64	0.000
Kerosene (Jet Fuel)	-102.16	215.61	-0.47	0.636
Constant	236.95	35.32	6.71	0.000

Crude Oil = x_1, Heating Oil =x_2, Diesel Fuel =x_3, Kerosene (Jet Fuel) = x_4, and Exchange Rate = y

$$y = 236.95 - 7.89x_1 - 675.50x_2 + 964.13x_3 - 102.16x_4 \quad (10)$$

The model in (10) above revealed that crude oil, heating oil and jet fuel had negative impact on exchange rate while diesel fuel had positive impact on exchange rate in Nigeria. A unit change in the prices of crude oil, heating oil and jet fuel depreciates the exchange rate by -7.89, -675.50and -102.16 naira respectively (Table 2). In 0.9 – 0.1 inter-quantile regression, only diesel fuel is significant with probability value of 0.025 with no other variables significant, even at 0.05 alpha level of significance.

Table 3: 0.9 - 0.1 Inter-quantile regression

Variables	Coefficient	Std. Error.	t	P>|t|
Crude Oil	-4.68	4.81	-0.97	0.332
Heating Oil	-599.77	440.76	-1.36	0.176
Diesel Fuel	883.49	389.90	2.27	0.025
Kerosene (Jet Fuel)	-146.51	283.89	-0.52	0.607
Constant	173.35	67.77	2.56	0.011

Crude Oil = x_1, Heating Oil =x_2, Diesel Fuel =x_3, Kerosene (Jet Fuel) =$x_4$and Exchange Rate = y

$$y = 173.35 - 4.68x_1 - 599.77x_2 + 883.49x_3 - 146.51x_4 \quad (11)$$

The model in (11) above revealed that crude oil, heating oil and kerosene (Jet fuel) have negative impact on exchange rate while diesel fuel has a positive impact on exchange rate in Nigeria. A unit change in the prices of crude oil, heating oil and jet fuel depreciates the exchange rate by -4.68, -599.77and -146.51 naira respectively (Table 3). Heating oil and diesel fuel are significant at 95% with probability value (0.005 and 0.001) less than 0.05 alpha level of significance resulting to the rejection of the null hypothesis while crude oil and jet fuel are not significant with probability value (0.052 and 0.341) greater than 0.05alpha level of significance leading to the acceptance of the null hypothesis

Table 4: 0.95 - 0.1 Inter-quantile regressions

Variables	Coefficient	Std. Error.	t	P>|t|
Crude Oil	-14.35	7.32	-1.96	0.052
Heating Oil	-1653.76	576.98	-2.87	0.005
Diesel Fuel	1671.97	498.09	3.36	0.001
Kerosene (Jet Fuel)	382.78	400.40	0.96	0.341
Constant	269.66	64.26	4.20	0.000

Crude Oil = x_1, Heating Oil =x_2, Diesel Fuel =x_3, Kerosene (Jet Fuel) =$x_4$and Exchange Rate = y

$$y = 269.66 - 14.35x_1 - 1653.76x_2 + 1671.97x_3 + 382.78x_4 \quad (12)$$

The model in (12) above revealed that crude oil and heating oil had negative impact on exchange rate while diesel fuel and jet fuel had positive impact on exchange rate in Nigeria. A unit change in crude oil and heating oil depreciate the exchange rate by -14.35 and-1653.76 naira respectively whist diesel fuel and jet fuel appreciate the exchange rate by 1671.97 and 382.78 naira respectively (Table 4).

Crude oil, heating oil and diesel fuel are significant at 95% with probability values (0.003, 0.001 and 0.002) which are less than the pre-specified level of significance (0.05) resulting to the rejection of the null hypothesis while jet fuel is not significant with probability value (0.065) which are greater than 0.05 alpha level of significance leading to the acceptance of the null hypothesis.

Table 5: 0.99 - 0.1 Inter-quantile regression

Variables	Coefficient	Std. Error.	t	P>|t|
Crude Oil	-20.47	6.70	-3.06	0.003
Heating Oil	-2897.78	891.78	-3.25	0.001
Diesel Fuel	2053.01	646.62	3.17	0.002
Kerosene (Jet Fuel)	1407.37	755.43	1.86	0.065
Constant	413.46	127.79	3.24	0.001

Crude Oil = x_1, Heating Oil =x_2, Diesel Fuel =x_3, Kerosene (Jet Fuel) =$x_4$and Exchange Rate = y

$$y = 413.46 - 20.47x_1 - 2897.78x_2 + 2053.01x_3 + 1407.37x_4 \quad (13)$$

The model in (13) above revealed that crude oil and heating oil had negative impact on exchange rate whist diesel fuel and kerosene (jet fuel) had positive impact on exchange rate in Nigeria. A unit change in crude oil and heating oil decreases the exchange rate by -20.47 and -2897.78 naira respectively whist diesel fuel and jet fuel appreciate the exchange rate by 2053.01 and 1407.37 naira respectively (Table 5).

Conclusion

This paper has demonstrated how the fluctuations of crude oil and other petroleum product spot prices could be modeled at different range of thresholds (quantiles) using inter-quantile regression. Crude oil and heating oil depreciates the exchange rate while diesel fuel appreciates the exchange rate. Kerosene (jet fuel) in table 1, 4 and 5 appreciate the exchange rate while Kerosene in table 2 and 3 depreciate (fluctuates) the exchange rate. The inter-quantile regression models revealed the current fluctuations in the prices of petroleum product and exchange rate in Nigeria at different range of quantiles. This paper agrees with the results of Apere and Eniekezimere (2016) using VAR and OLS, where it was asserted that oil price changes, have significant impact on the economy of Nigeria whereas exchange rate fluctuations have both positive and negative impact on crude oil prices in Nigeria respectively.

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