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The Relationship Between Gross Domestic Product and Exchange Rates in Nigeria: A Quantile Regression Approach

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Abstract

Exchange rate is an important microeconomic variable in the general economic policy making and reform program. This paper modelled Gross domestic product (GDP) and exchange rate at different quantiles using quantile regression (QR). The model was implemented on GDP and exchange rate data obtained from Central Bank of Nigeria (CBN) annual statistical bulletin. The study covers the period from first quarter (Q1), 2019 to second quarter (Q2), 2024. The software used for analysis was STATA version 14.0. The study revealed that GDP and exchange rate were-non-stationary and contained unit root at all levels. Exchange rate is significant at 95% and had positive impact on GDP at all quantiles. The study concludes that exchange rate should be handled by experts to avoid decline in the GDP and economy of Nigeria. The study recommends the adoption of good policies to reduce/stabilize exchange rate and boost the performance of GDP in the country.

Keywords: Quantile Regression, Median, Exchange rate, Unit root and Gross domestic product.

Introduction

Exchange rate rest at the middle of the world financial system and sets the terms on which Nations buy and sell each other's goods and services. It determines the pace at which a nation economic activity will grow.

According [1], the Nigerian economy is highly dependent on imports for both consumption and production. According [2], the exchange rate of the Naira was relatively stable between 1970 and 1979 during the oil boom era and when agricultural produce contributed above 70% of the nation's Gross Domestic Products (GDP).

According to [3], many oil producing nations are exposed to fluctuations in exchange rate due their large oil wealth. These fluctuations which acts as tax on investment in trade goods production has adverse impact on growth especially on agricultural and manufacturing sectors. The inconsistency and lack of continuity in exchange rate policies resulted to the fluctuating nature of the Naira rate [4]. According to [5], many efforts by the government to stabilize exchange rate, the Naira continued to depreciate.

Gross National Product (GNP) was similarly affected. The combined effects of exchange rate fluctuations on GDP and GNP and unemployment lead to poor level of per capital income of Nigerians [6]. [7] examined the effect of unemployment rate on growth rate of GDP in South Africa by using quarterly data during the period (the first quarter of 1994– the fourth quarter of 2016) employing Auto Regressive Distribution Lag (ARDL). This study established a relationship between unemployment rate and growth rate of GDP and a negative effect of unemployment rate on growth rate of GDP in both the long run and the short run. [8] applied Autoregressive Distributed Lag (ARDL) to examined the effect of unemployment rate on growth rate of GDP in Pakistan using annual data from1980 to 2010. The result revealed that there is a relationship between unemployment rate and growth rate of GDP in Pakistan in the long run within the studied period. Also, [9] applied Autoregressive Distributed Lag (ARDL) to investigate the impact of unemployment rate on growth rate of GDP in Nigeria using yearly data 1986 to 2015. This result revealed there is no relationship between unemployment rate and growth rate of GDP in Nigeria and there is a positive effect of unemployment rate on growth rate of GDP in the third period in the informal sector. [10] investigated the effect of unemployment rate on growth rate of GDP for Nigeria using yearly data from 1970 to 2016 employing Johanson Cointegration Estimation and Error Correction models. The study found that there is a relationship between unemployment rate and growth rate of GDP in the long run in Nigeria, there is a positive effect of unemployment rate on growth rate of GDP in the long run and short run and there is a unidirectional causality from unemployment to growth rate of GDP. [11] employed Vector Autoregressive (VAR) to investigate the effect of unemployment on growth rate of GDP in Nigeria using yearly data from 1986 to 2015. The result showed that there is an impact of unemployment on growth rate of GDP. Also, [12] investigated the effect of unemployment on growth rate of GDP in Nigeria using yearly data from1980 to 2010 and Ordinary least squares regression (OLSR) method was applied. The result revealed

that unemployment does not have any effect on growth rate of GDP in Nigeria for this period [13].
The aim of this paper is to model the effect of exchange rate on GDP in Nigeria at different thresholds (quantiles) using Quantile regression (QR) approach. This technique is used to establish a relationship between the dependent (GDP) and independent (exchange rate) variable at different quantiles. It takes care of over-dispersion and under-dispersion in the data. The traditional OLS shows the relationship between the dependent and independent variable based on the conditional mean and fails to describe the relationship at different point of the dependent variable. QR uses the conditional median function (other quantiles) instead of the mean function. QR is more robust to non-normal data and outliers. The remaining part of the paper is organized as follows: QR is specified in Section 2. Section 3 presents the results using the model in Section 2 on exchange rate in Nigeria. In Section 4, the results are discussed and concluding remarks are made in Section 5.

Materials and Methods

Data

The data was sourced from Central Bank of Nigeria (CBN) annual statistical bulletin. The secondary data on GDP and exchange rate covers the period from first quarter (Q1), 2019 to second quarter (Q2), 2024. The software for estimation is STATA version 14.0.

Conditional quantile function

According [14] the *quantile function* of a scalar random variable *Y* is the inverse of its distribution function. The *conditional quantile function* of *Y* given *X* is the inverse of the corresponding conditional distribution function denoted by Equation (1).$Q_Y(\tau|X) = F_Y^{-1}(\tau|X) = \inf\{y: F_Y(y|X) \geq \tau$ (1)

Where

$F_Y(y|X) = P(Y \leq y|X)$ (2)

The *conditional* quantile function of *Y* given *X* fully captures the relationship between *Y* and *X*.

Quantile regression

According [14] Quantile regression–based methods provide a complementary way to study the relationship between *X* and *Y*. The classical linear model is presented in Equation (3).

$Y_t = \theta' X_t + \mu_t$ (3)

Where X_t is a vector of regressors and a constant, μ_t are identical and independent (iid) with mean zero and independent to X_t.

$t = 1, 2, \dots, n$

The regression of Equation (3) above can be conducted based on the following optimization problem presented in Equation (4).

$\hat{\theta} = min \sum_{t=1}^{n} \rho(Y_t - \theta' X_t)$ (4)

Where ρ is a loss function. Under appropriate regularity assumptions, solution of Equation (4), $\hat{\theta}$, is a consistent estimate of the vectors of parameters θ^* presented in Equation (5).

$\theta^* = minE\rho(Y_t - \theta' X_t)$ (5)

Applying a quadratic loss function presented in Equation (6), the ordinary least square estimator is obtained from Equation (5).

$\rho(u) = u^2$ (6)

$\theta_{OLS}^* = min_\theta E(Y_t - \theta' X_t)^2$ (7)

Solving Equation (7) results to Equation (8) which is the conditional mean of the least square regression.

$X'\theta_{OLS}^* = E(Y|X)$ (8)

Using Equation (9), the least absolute deviation (LAD) estimator $\hat{\theta}_{LAD}$ is obtained.

$\rho(u) = |u|$ (9)

$\theta_{LAD}^* = min_\theta E(Y_t - \theta' X_t)^2$ (10)

Solving the LAD regression in Equation (10) above results to the estimate of the conditional median and hence is known as median regression presented in Equation (11).

$X'\theta_{LAD}^* = Median(Y|X)$ (11)

The Quantile Regression (QR) proposed by [15] uses an asymmetric loss function presented in Equation (12).

$\rho(u) = \rho_\tau(u) = u(\tau - I(u < 0))$ (12)

Where $\tau \in (0,1)$ and $I(.)$ is the indicator function. Solving the (τth) quantile regression presented in Equation (13)

$\theta_\tau^* = min_\theta E\rho_\tau(Y_t - \theta' X_t)$ (13)

We obtain an estimate of the (τth) conditional quantile of Y presented in Equation (14).

$X'\theta_\tau^* = Q_Y(\tau|X)$ (14)

The criterion function $\rho_\tau(.)$ is called the "check function" in the study by [15], and the solutions in Equation (15)

$\hat{\theta}(\tau) = min_\theta \sum_t \rho_\tau(Y_t - \theta^T X_t)$ (15)

are the regression quantiles. Given $\hat{\theta}(\tau)$, the τth conditional quantile function of Y_t given X_t can be estimated by Equation (16)

$\hat{Q}_{Y_t}(\tau|X) = X_t^T \hat{\theta}(\tau)$ (16)

And the conditional density of Y_t at

$y = \hat{Q}_{Y_t}(\tau|X)$ (17)

Can be estimated by the difference in quotient presented in Equation (18)

$\hat{f}_{Y_t}(\tau|X) = \frac{2h}{\hat{Q}_{Y_t}(\tau + h|X_t) - \hat{Q}_{Y_t}(\tau - h|X_t)'}$ (18)

For some approximately chosen sequence of $h = h(n) \rightarrow 0$

Unit root quantile regression

According [14] Quantile regression can also be applied to unit root time series. One of the most widely used unit root model is the following Augmented Dickey-Fuller (ADF) regression model

$Y_t = \alpha_i Y_{t-1} + \sum_{j=1}^{q} \alpha_{j+1} \Delta Y_{t-1} + \mu_t$ (19)

Where μ_t is identical and independent (i.i.d) (0, σ^2) under assumptions that all the roots of $A(L) = 1 - \sum_{j=1}^{q} \alpha_{j+1} L^j$ lie outside the unit circle. If $\alpha_1 = 1, Y_t$ contains a unit root; and if $|\alpha_1| < 1, Y_t$ is stationary. If we denote the $\sigma -$ field generated by $\{\mu_s, s \leq t\}$ by F_t, then

Conditional quantile of F_{t-1}, the τ-*th* conditional quantile of Y_t is given by

$Q_{Y_t}(\tau|F_{t-1}) = Q_u(\tau) + \alpha_1 Y_{t-1} + \sum_{j=1}^{q} \alpha_{j+1} \Delta Y_{t-1}$

(20)

From Equation (20), we obtain Equation (21)

$Q_{Y_t}(\tau|F_{t-1}) = x_t' \alpha(\tau)$ (21)

The unit root quantile autoregressive model can be estimated by;

$min \sum_{t=1}^{n} \rho_t (Y_t - X_t^T \alpha)$

Results and Discussion

The trend analysis of the Nigeria GDP on quarterly basis revealed upward and downward movement (Figure 1) whist the Nigeria exchange rate continue to increase without a decline (Figure 2).

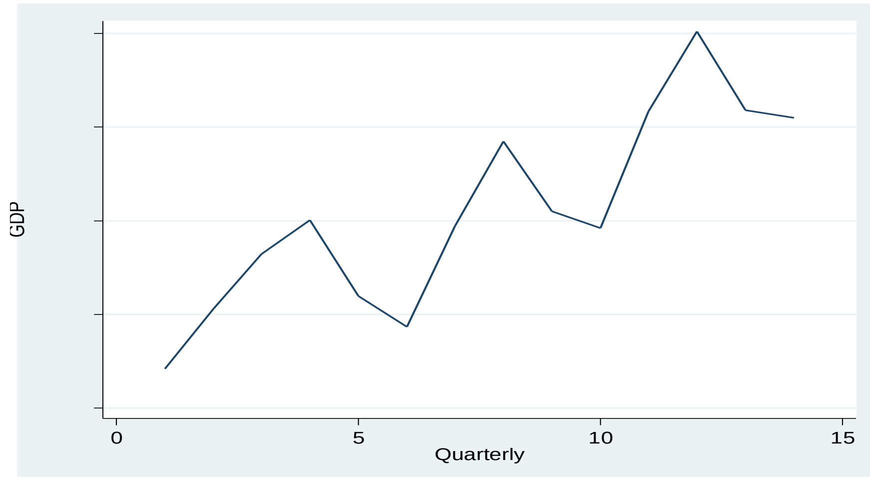

Figure 1: Line Plot of GDP

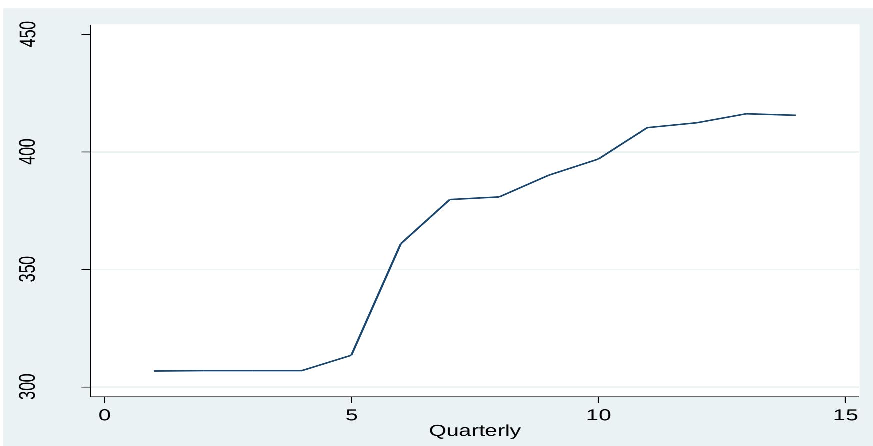

Figure 2: Line Plot of Exchange Rate

The GDP had the highest mean value (4.05e+07) and the highest median value (3.99e+07) compared to that of exchange rate in Nigeria. GDP is positively skewed to the right since the mean is greater than the median and the value of Skewness (0.1523414) is greater than zero whist exchange rate is negatively skewed to the left since the mean is less than the median and the value of the Skewness (-0.2977502) is negative.

Table 1: Descriptive Statistics of GDP and Exchange rate from Q1, 2019 to Q2, 2024

Variables	Mean	Median	Skewness	Kurtosis	CV
GDP	4.05e+07	3.99e+07	0.1523414	2.100087	0.1284207
Exchange Rate	364.6423	380.365	-0.2977502	1.383283	0.1268263

GDP = Gross domestic product.

The distribution of GDP and exchange rate leptokurtic (less flat top) in nature since the value of kurtosis is greater than zero (K > 0). The coefficient of variation (CV) of GDP is high compared to that of exchange rate. The degree of dispersion of GDP around the mean is 12.84% and 12.68% in exchange rate. The difference between GDP and exchange rate is 16.0% (Table 1). The ADF unit root test revealed that exchange rate and GDP are non-stationary. This is because the absolute value of the test statistics

Table 2: Augmented Dickey-Fuller (ADF) test for unit root

Variables	Test Stat.	1% Crit. Val.	5% Crit. Val.	10% Crit. Val.
Exchange rate	-1.078	-3.750	-3.000	-2.630
GDP	-1.741	-3.750	-3.000	-2.630

Crit. Val. = Critical value

is less than the absolute value of the critical values at 1%, 5% and 10% level of significance (alpha) (Table 2).

At 0.25 quantile regression, exchange rate is significant at 95%. This is because the probability value is less than 0.05 level of significance. The 95% confidence interval revealed that exchange rate is significant since the confidence

Table 3: 0.25 Quantile regression

Variables	Coefficient	Std. Error	t	P>|t|	[95% Conf. Interval]	
Exchange rate	101022.1	31006.21	3.26	0.007	33465.36	168578.8
Constant	1087854	1.14e+07	0.10	0.925	-2.37e+07	2.59e+07

Raw sum of deviations 2.25e+07 (about 35300956), Min sum of deviations 1.39e+07, Exchange rate = x_1 and GDP = y

$$\hat{y} = 1087854 + 101022.1x_1 \quad (22)$$

interval does not contain zero. Equation (22) revealed that exchange rate had positive impact on GDP. A unit change in the exchange rate yields GDP of 1,188,876.1 Naira Table (3). At 0.5 quantile regression (median regression), exchange rate is significant at 95%. This is because the probability value is less than 0.05 alpha. The 95% confidence interval revealed that exchange rate is still significant in the model (23) since

Table 4: 0.5 Quantile regression (Median Regression)

Variables	Coefficient	Std. Error	t	P>|t|	[95% Conf. Interval]	
Exchange rate	93310.34	33865.84	2.76	0.017	19523	167097.7
Constant	6716174	1.24e+07	0.54	0.599	-2.04e+07	3.38e+07

Raw sum of deviations = 2.84e+07 (about 39714720, Min sum of deviations = 1.71e+07, Exchange rate = x_1 and GDP = y

$$\hat{y} = 6716174 + 93310.34x_1 \quad (23)$$

the interval does not contain zero. Equation (23) showed that exchange rate had positive impact on GDP. A unit change in the exchange rate yields GDP of 6,809,484.34 Naira (Table 4). At 0.75 quantile regression, the exchange rate is significant at 95%. This is because the probability value is less than the pre-specified level of significance (0.05).

Table 5: 0.75 Quantile regression

Variables	Coefficient	Std. Error	t	P>|t|	[95% Conf. Interval]	
Exchange rate	73699.56	25334.62	2.91	0.013	18500.17	128898.9
Constant	1.56e+07	9306808	1.68	0.119	-4676021	3.59e+07

Raw sum of deviations = 2.28e+07, Min sum of deviations = 1.33e+07, Exchange rate = x_1 and GDP = y

$$\hat{y} = 1.56e + 07 + 73699.56x_1 \quad (24)$$

The 95% confidence interval revealed that exchange rate is significant since the interval does not contain zero. Equation (24) showed that exchange rate had positive contributions to the growth of GDP. A unit change in exchange rate yields GDP of 15, 673, 699.56 Naira (Table 5).

Conclusion

This paper presented the application of quantile regression (QR) to establish relationship between GDP and exchange rate at various quantiles (thresholds). Exchange rate is significant at different quantiles, non-stationary and contain a unit root at all levels. The models revealed that exchange rate had positive impact on GDP at different quantiles. The study concludes that exchange rate should be monitored by experts to avoid decline in the GDP and economy of Nigeria. The study recommends the adoption of favorable policies to reduce/stabilize the exchange rate and boost the performance of GDP in the country.

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