# Panel Vector Autoregressive Modeling of Macroeconomic Interaction in Nigeria, Ghana and Cameroon.

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## ABSTRACT

**Aims:** The aim of this study is to apply Panel VAR (Vector Autoregressive) modeling and estimation to analyze the macroeconomic interaction and interdependence within the context of Nigeria, Ghana, and Cameroon. The study aims to understand the trends of key macroeconomic variables, namely gross domestic product (GDP), exchange rate, and foreign reserves.

**Methodology:**The study adopted three macroeconomic variables—GDP, exchange rate, and foreign reserve—and utilized annual secondary data from the World Bank spanning from 1960 to 2022. Pretests, including unit root and cointegration tests, were conducted on the variables. The panel unit root tests (Levin, Lin, and Chu t, Augmented Dickey-Fuller Fisher Chi-Square, and Phillips-Perron Fisher Chi-Square) indicated that the series had unit roots at levels but were stationary at first difference, implying integration of order one. The absence of co-integration in the panel co-integration test established the necessary conditions for estimating a panel vector autoregressive model.

**Results:**The trend analysis revealed that the variables were relatively low in the 1960s and 1970s but exhibited an increasing and fluctuating pattern afterward. Descriptive statistics showed variations among the countries, with Cameroon having higher GDP per capita and greater standard deviation, indicating more significant fluctuations. Ghana, in contrast, displayed lower per capita income with a lower standard deviation. The foreign exchange rate varied, with Cameroon having the highest and Ghana the lowest mean rates.

**Conclusion:**The fixed effect model was estimated after the Hausman Test rejected the random effect model. The results indicated that foreign exchange rates had joint significance on GDP per capita, while foreign reserves did not. The study concludes that the economies of Nigeria, Ghana, and Cameroon are responsive to GDP per capita, foreign exchange rates, and foreign reserves. The policy implication is that economic practitioners in these countries should closely monitor these variables to anticipate changes in economic indicators. Therefore, the study recommends active monitoring of the economic variables used in this research to facilitate informed decision-making.

*Keywords: Exchange Rate Foreign Reserve, GDP, Panel VAR.*



## 1. INTRODUCTION

Panel data (also known as longitudinal or cross-sectional time-series data) is a dataset in which the behavior of entities (i) are observed across time (t). Panel (data) analysis is a statistical method, widely used in social science, epidemiology, and econometrics to analyze two-dimensional (typically cross sectional and longitudinal) panel data. The data are usually collected over time and over the same individuals and then a regression is run over these two dimensions. The panel data regression models have become one of the most widely applied statistical approaches in different fields of research, including social, behavioral, environmental sciences, and econometrics. A panel dataset, as defined, is a cross-sectional time-series dataset, which, ideally, provides repeated measurements of a certain number of variables over a period of time on observed units, such as individuals, households, firms, cities, and states. A cross-sectional data set consists of observations on a certain number of variables at certain point of time whereas a time-series data set consists of a variable or several variables of observations over a number of periods. In a panel dataset, the number of repeated measurements on the same variables on the same population or sample can be as small as two. This is particularly the case for ''one-7shot'' experiments (Eom et al., 2008). A panel data is easily conceptualized as a three-dimensional structure for each variable: the vertical dimension as time and the horizontal dimension as multiple observations for each variable. In general, observations in the samples are the same across all periods, while in some cases, particularly in random surveys, the observations in the samples from one period are not identical to those from another. The former is termed as a balanced panel dataset whereas the latter is termed an unbalanced panel dataset. Panel data examples can be found in economics, social sciences, medicine and epidemiology, finance, and the physical sciences.

Macroeconomic analyses and policy evaluations increasingly require taking the interdependencies existing across sectors, markets and countries into account, and national economic issues, while often idiosyncratic, need now to be tackled from a global perspective. Thus, when formulating policies, a number of different channels of transmission need to be considered and spillovers are likely to be important, even for large and developed economies.

There are two ways of examining economic issues in interdependent economies. One is to build a multi-sector, multi-market, multi-country dynamic stochastic general equilibrium (DSGE) model, where agents are optimizers, and where preferences, technologies, and constraints are fully specified. Structures like these are now extensively used in the policy arena. The models are useful because they offer sharp answers to important policy questions and provide easy-to-understand welfare prescriptions. However, by construction, these models impose a lot of restrictions, not always in line with the statistical properties of the data.
Panel VARs are built with the same logic of standard VARs but, by adding a cross sectional dimension, they are a much more powerful tool to address interesting policy questions related e.g. to the transmission of shocks across borders. The large dimension of panel VAR typically makes the curse of dimensionality an issue especially when researchers are interested in examining the input-output links of a region or an area, where the time series dimension of the panel is short.

All in all, panel VAR has the potential to become more important as VAR to answer relevant economic questions that do not require specification of the entire structure of the economy, (Fabio and Matteo, 2013).

The goal of this work is to describe what panel VAR is and what is the use in applied work; how it can capture the heterogeneities present in interdependent economies and how the restricted specifications typically employed in the literature are nested in the general panel VAR framework we consider.

Estimating unrestricted reduced form VAR models is straight forwards computation. James and Watson (2001) standard practice in VAR analysis is to report results from Granger – causality test, impulse responses and forecast error variance decompositions. These statistics are computed automatically (or nearly so) by many econometrics and statistics packages (R, E-views and SPSS). Because of the complicated dynamics in the VAR, these statistics are more informative.

Odusola and Akinlo (2001) examine the link between the naira depreciation, inflation and output in Nigeria, adopting vector autoregressive (VAR) and its exchange rate system does not necessarily lead output expansion, particularly in short term. Issues such as discipline, confidence and credibility on the part of the government are essential. Evidence from impulse response functions and structural VAR models suggested that the impacts of the lending rate
and inflation on the output were negative.

Ciccarelli et al. (2012a) investigate the heterogeneity in macro-financial linkages across developed economies and compare the transmission of real and financial shocks with emphasis on the most recent recession. Caivano (2006) investigates how disturbances generated in the Euro area are transmitted to U.S. and vice versa, when these two units are included into a world economy. Lane and Benetrix (2010) look at the transmission of government spending. Finally, Love and Zicchino (2006) measure the effect of shocks to financial factors on a cross section of U.S. firms. Panel VARs have also been frequently used to construct average effects, possibly across heterogeneous groups of units and to characterize unit specific differences relative to the average. For example, one may want to know if government expenditure is more countercyclical, on average, in countries or states which have fiscal restrictions included in the constitution, or whether the instantaneous fiscal rule depends on the type of fiscal restrictions that are in place (see Canova and Pappa, 2004). One may also be interested in knowing whether dynamics in a monetary union may depend on geographical, political, institutional or cultural characteristics, or on whether fiscal and monetary interactions are relevant (see Canova and Pappa, 2007).

## 2. MATERIAL AND METHODS

### 2.1 Data

The data type and source of this study will employ mainly, the secondary macroeconomic time series data in its analysis. All data used in the analysis will be sourced from the World Bank, Statistical Bulletin. Other augmenting sources of this study will include published articles and journals, working papers, textbooks and relevant internet resources.

### 2.2: Methodology

#### 2.2.1 Unit Root Test

A number of alternative tests are available for testing whether a series is stationary or not. The Augmented Dickey – fuller (ADF), Dickey and Fuller (1967) for (ADF) test, where k is chosen to ensure that the residuals follow a pure random process. ADF unit root, tests the null hypothesis is that the series is not stationary and this is either accepted or rejected by examination of the t-ratio of the lagged term $x_{E-1}$ compared with the tabulated values. If the t-ratio is less than the critical value the null hypothesis of a unit root (i.e., the series is not stationary) is accepted. If so the first difference of the series is evaluated and if the null hypothesis is rejected the series is considered stationary and the assumption is that the series is integrated of order one I(1).

The ADF regression test is as follows:

$$\Delta x_t = \lambda_0 + \lambda_1 x_{t-1} + \lambda_2 T + \sum_{i=1}^{n} \Psi_i \Delta x_{t-1} + \varepsilon \qquad (2.1)$$

Where $\Delta$ is the difference operator.
x is the natural logarithm of the series
T is a trend variable
$\lambda$ and $\Psi$ are the parameters to be estimated and
$\varepsilon$ is the error term

### 2.2.2 Model Selection Criteria

The standard model selection criteria which are used in this context chosen the VAR order which minimizes them over a set of possible orders

$$m = 0, 1\ 2 \ldots \ldots Pmax$$

The general form of a set of such criteria is (Lutkepohl, 2007)

$$C(m) = \log\det\left(\sum_m^{\wedge}\right) + CT\varphi(m) \qquad (2.2)$$

Where $\sum_m^{\wedge} = T^{-1}\sum_{t=1}^{T} \hat{u}_t \hat{u}_t^{'}$ is the residual covariance matrix estimator for a model of order $(m)$.

$\varphi$(m) Is a function of the order m which penalizes large VAR orders.

CT is a sequence which may depend on the sample size and identifies the specific criterion. The term $logdet(\hat{\epsilon}_m)$is a monincreasing function of the order $m$ which $\varphi(m)$ increases with$m$.

The lag order is chosen which optimally balances these two forces.

Gebhard and Jurgen (2007), to estimate the system, the order p ie the maximal lag of the system has to be determined. The multivariate case with k variables, T observations, a constant term and a maximal lag of p, these criteria are as follows:

**Final prediction error (FPE)**

$$FPE(P) = \left[\frac{T+kp+1}{T-kp-1}\right]^k / \sum \hat{u}\hat{u}(p) / \qquad (2.3)$$

**Akaike information criterion (AIC)**

$$AIC(p) = In\ / \sum \hat{u}\hat{u}(p) / + (k + pk^2)\frac{2}{T} \qquad (2.4)$$

**Hannan – Quinn criterion (HQ)**

$$HQ(p) = In / \sum \hat{u}\hat{u}(p) / + (k + pk^2)\frac{2In(In(T))}{T} \qquad (2.5)$$

**Shwarz criterion (SC)**

$$SC(p) = In / \sum \hat{u}\hat{u}(p) / + (k + pk^2)\frac{In(T)}{T} \qquad (2.6)$$

The stochastic part $y_t$ is a assumed to be generated by a VAR process of order p (VAR(p)) of the form.

$$Y_t = A_{1y_{t-1}} + A_{2y_{t-2}} + \cdots + A_{py_{t-p}} + \mu_t + \varepsilon_t \qquad (2.7)$$

Where,

$A_i \quad \forall i = 1,2, \ldots p$ are $(kxk)$ parameter matrices.

The error process $\mu_t = (\mu_{1t}\mu_{2t}, \ldots \mu_{kt})^{'}$ is a k – dimensional zero mean white noise process with covariance matrix:

$$E(\mu_t, \mu_t^{'}) = \varepsilon_\mu$$

In matrix notations the m time series

$y_{it}, \quad i = 1,2, \ldots m,$and $\quad t = 1, \ldots T$

Where, t is the common length of the time series.
Then a Vector Autoregressive Model is defined as

$$\begin{pmatrix} Y_{1t} \\ Y_{2t} \\ \vdots \\ Y_{mt} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ . \\ \mu_m \end{pmatrix} + \begin{pmatrix} A_{11}^{(1)} & A_{12}^{(1)} & A_{1m}^{(1)} \\ A_{21}^{(1)} & A_{22}^{(1)} & A_{2m}^{(1)} \\ \vdots & \vdots & \vdots \\ A_{m1}^{(1)} & A_{m1}^{(1)} & A_{mm}^{(1)} \end{pmatrix} \begin{pmatrix} y_{1,t-1} \\ y_{2,t-1} \\ \vdots \\ y_{m,t-1} \end{pmatrix}$$

$$+ \cdots + \begin{pmatrix} A_{11}^{(p)} & A_{12}^{(p)} & A_{1m}^{(p)} \\ A_{21}^{(1)} & A_{22}^{(1)} & A_{2m}^{(p)} \\ \vdots & \vdots & \vdots \\ A_{m1}^{(p)} & A_{m1}^{(p)} & A_{mm}^{(p)} \end{pmatrix} \begin{pmatrix} y_{1,t-p} \\ y_{2,t-p} \\ \vdots \\ y_{m,t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{mt} \end{pmatrix} \quad (2.8)$$

Where

$Y_t = (y_{1t}, y_{2t}, \dots y_{mt})'$ denote $(nx1)$ vector of time series variables
$A_i$ are $(nxn)$ coefficient matrices
$\varepsilon_t$ is an $(nx\ 1)$ unobservable zero mean white noise vector process.

**2.2.3 The Panel VAR**

Consider a k-variate homogeneous panel VAR of order p with panel-specific fixed effects represented by the following system of linear equations, we have

$$Y_{it} = Y_{it-1}A_1 + Y_{it-2}A_2 + Y_{it-3}A_3 + \cdots + Y_{it-p+1}A_{p-1} + Y_{it-p}A_p + X_{it}B + \mu_t + e_{it} \quad (2.9)$$
$$i \in \{1,2, \dots . N\}, t \in \{1,2, \dots T_i\}$$

Where $Y_{it}$ is a (1×k) vector of dependent variables, $X_{it}$ is a (1×l) vector of exogenous covariates, and $\mu_t$ and $e_{it}$ are (1 × k) vectors of dependent variable-specific panel fixed effects and idiosyncratic errors, respectively. The (k×k) matrices $A_1$, $A_2$,..., $A_{p-1}$, $A_p$ and the (l×k) matrix B are parameters to be estimated.

**2.3.4 Model Specification**

$$GDPPC_{it} = K_1 + GDPPC_{t-1} + GDPPC_{t-2} + EXR_{t-1} + EXR_{t-2} + FR_{t-1} + FR_{t-2} + U_{i1t}$$

$$EXR_{it} = K_2 + GDPPC_{t-1} + GDPPC_{t-2} + EXR_{t-1} + EXR_{t-2} + FR_{t-1} + FR_{t-2} + U_{i2t}$$

$$FR_{it} = K_3 + GDPPC_{t-1} + GDPPC_{t-2} + EXR_{t-1} + EXR_{t-2} + FR_{t-1} + FR_{t-2} + U_{i3t}$$

Where
$U_{it}$ = Random disturbances
$GDPPC_{it}$ = Gross Domestic Product Per Capita
$EXR_{it}$ = Foreign Exchange Rate
$FR_{it}$ = Foreign Reserve
t-1 = Lag 1
t-2 = Lag 2

Writing the model in matrix form;

$$\begin{bmatrix} GDPPC_{it} \\ EXR_{It} \\ FR_{it} \end{bmatrix} = \begin{bmatrix} K_1 \\ K_2 \\ K_3 \end{bmatrix} + \begin{bmatrix} A_{111} & A_{121} & A_{131} \\ B_{211} & B_{221} & B_{231} \\ C_{311} & C_{321} & C_{331} \end{bmatrix} \begin{bmatrix} GDPPC_{it-1} \\ EXR_{It-1} \\ FR_{it-1} \end{bmatrix} + \begin{bmatrix} A_{112} & A_{122} & A_{132} \\ B_{212} & B_{222} & B_{232} \\ C_{312} & C_{322} & C_{332} \end{bmatrix} \begin{bmatrix} GDPPC_{it-2} \\ EXR_{It-2} \\ FR_{it-2} \end{bmatrix} + \begin{bmatrix} U_{i1t} \\ U_{i2t} \\ U_{i3t} \end{bmatrix}$$

(3.10)

Where:

$\begin{bmatrix} GDPPC_{it} \\ EXR_{It} \\ FR_{it} \end{bmatrix}$ = 3 X 1 Vector of endogenous variables, the variables as defined earlier

$\begin{bmatrix} K_1 \\ K_2 \\ K_3 \end{bmatrix}$ = 3 X 1 Vector of constant, $K_1$, $K_2$, and $K_3$ are the intercept for model 1, 2 and 3.

$\begin{bmatrix} U_{i1t} \\ U_{i2t} \\ U_{i3t} \end{bmatrix}$ = n X 1 Vector of random disturbances, i ∀= 1, 2, and 3 (Nigeria, Ghana, and Cameroon respectively).

$\begin{bmatrix} A_{111} & A_{121} & A_{131} \\ B_{211} & B_{221} & B_{231} \\ C_{311} & C_{321} & C_{331} \end{bmatrix}$ = 3 X 3 Matrix of coefficient of the first lag

$\begin{bmatrix} A_{112} & A_{122} & A_{132} \\ B_{212} & B_{222} & B_{232} \\ C_{312} & C_{322} & C_{332} \end{bmatrix}$ = 3 X 3 Matrix of coefficient of the second lag

## 3. RESULTS AND DISCUSSION

### 3.1 Results

#### 3.1.1 Data Presentation and Stationarity Test

**Table 1 Summary of Descriptive Statistics on All Variables**
Source: Researcher's computation with Eviews 13.0

| Statistics | Nigeria GDP_PC | Ghana GDP_PC | Cameroon GDP_PC | Nigeria EXR | Ghana EXR | Cameroon EXR | Nigeria FR | Ghana FR | Cameroon FR | Pooled GDP_PC | Pooled FR | Pooled EXR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 265680.7 | 3077.5 | 733969.6 | 74.394 | 0.976 | 404.547 | 13,500,000,000 | 1,840,000,000 | 940,000,000 | 334,242.60 | 5,410,000,000 | 159.97 |
| Median | 250500.9 | 2845.9 | 747889 | 9.909 | 0.037 | 381.066 | 4,680,000,000 | 437,000,000 | 80,796,978 | 250,500.90 | 636,000,000 | 9.91 |
| Maximum | 379251.6 | 5331.8 | 1091113 | 358.811 | 8.272 | 732.398 | 53,000,000,000 | 9,920,000,000 | 3,680,000,000 | 1,091,113.00 | 53,000,000,000 | 732.4 |
| Minimum | 173173 | 1858.9 | 512049.8 | 0.547 | 0.000 | 211.280 | 112,000,000 | 42,579,200 | 9,555,391 | 1,858.90 | 9,555,391 | 0 |
| Std. Dev. | 61261.23 | 925.71 | 142717.7 | 103.126 | 1.790 | 155.944 | 16,800,000,000 | 2,620,000,000 | 1,380,000,000 | 315,951.80 | 11,300,000,000 | 206.15 |
| Skewness | 0.356 | 1.129 | 0.448 | 1.314 | 2.219 | 0.299 | 1.014 | 1.482 | 1.074 | 0.55 | 2.7 | 1.05 |
| Kurtosis | 1.670 | 3.238 | 2.544 | 3.639 | 7.408 | 1.669 | 2.398 | 3.818 | 2.301 | 2.03 | 9.14 | 2.85 |
| Jarque-Bera | 5.978338 | 13.522 | 2.651521 | 19.2 | 102.7 | 5.586888 | 11.74048 | 24.80716 | 13.39758 | 17.07 | 526.03 | 34.88 |
| Probability | 0.050329 | 0.0012 | 0.265601 | 7E-05 | 0 | 0.06121 | 0.002822 | 0.000004 | 0.001232 | 0.000 | 0.000 | 0.000 |
| Sum | 16737887 | 193882 | 46240086 | | | | 8.48E+11 | 1.16E+11 | 5.92E+10 | 63,171,855 | 1.E+12 | |
| Sum Sq. Dev. | 2.33E+11 | 5E+07 | 1.26E+12 | 659367 | 198.6 | 1507749 | 1.75E+22 | 4.25E+20 | 1.18E+20 | 2.00E+13 | 2.00E+22 | 7.9E+6 |
| Observations | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 189 | 189 | 189 |

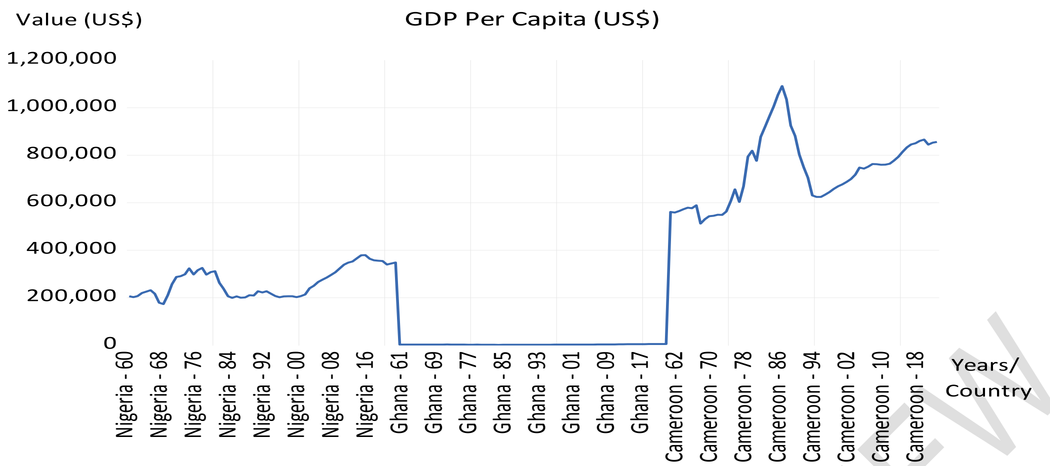



**Figure 1** **Time Plot of Gross Domestic Product Per Capita**

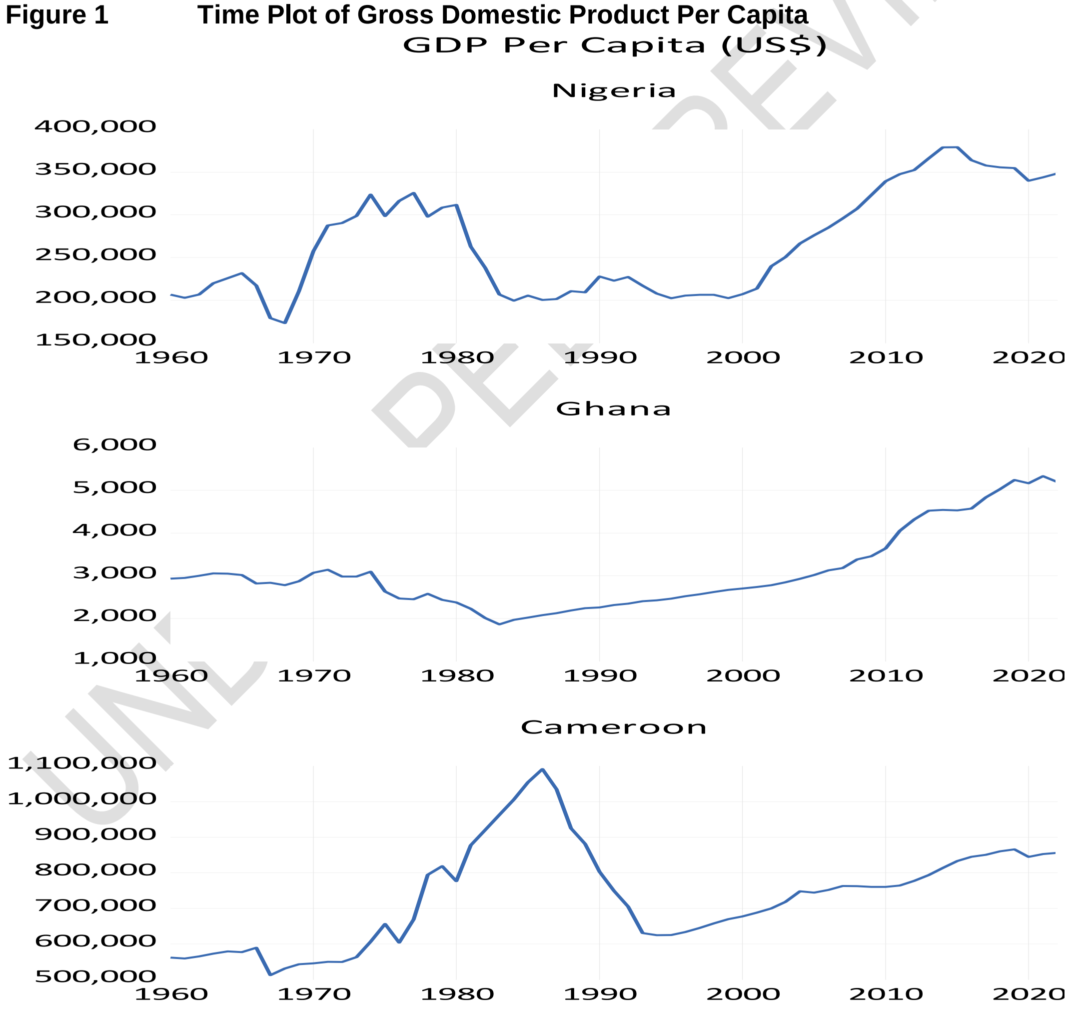
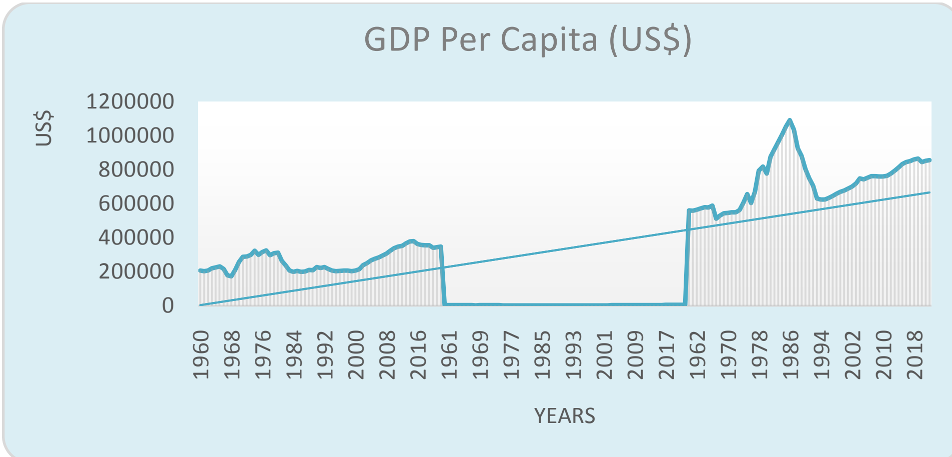


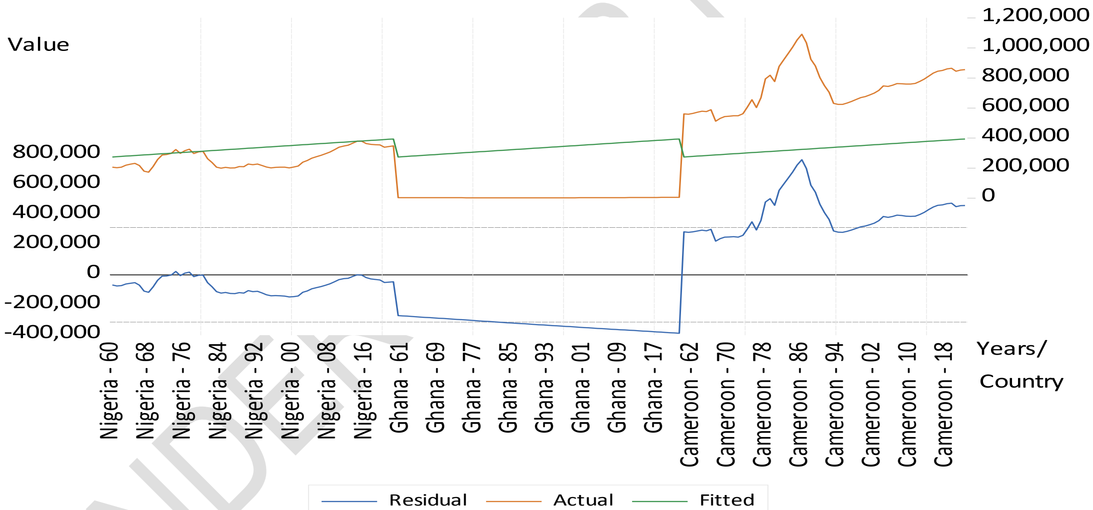

**Figure 2** **Individual Time Plot of Gross Domestic Product Per Capita**

**Trend Analysis of Gross Domestic Product Per Capita**




**GDP_PC = -3515643.4 + 1933.64*T**

**Figure 3 Trend Plot ofGross Domestic Product Per Capita**




**GDP_PC = -3515643.4 + 1933.64*T**

**Figure4 Actual, Fitted and Residual Plot ofGross Domestic Product Per Capita**

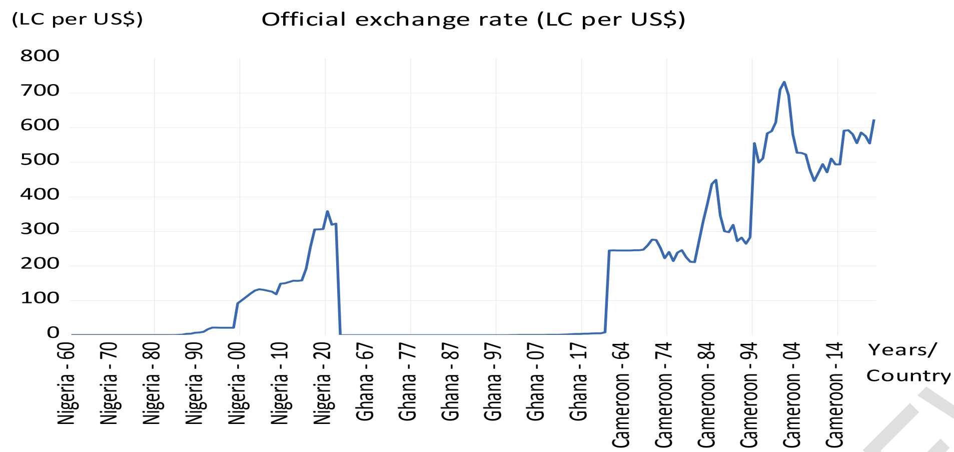



**Figure 5** Time Plot of Foreign Exchange Rate

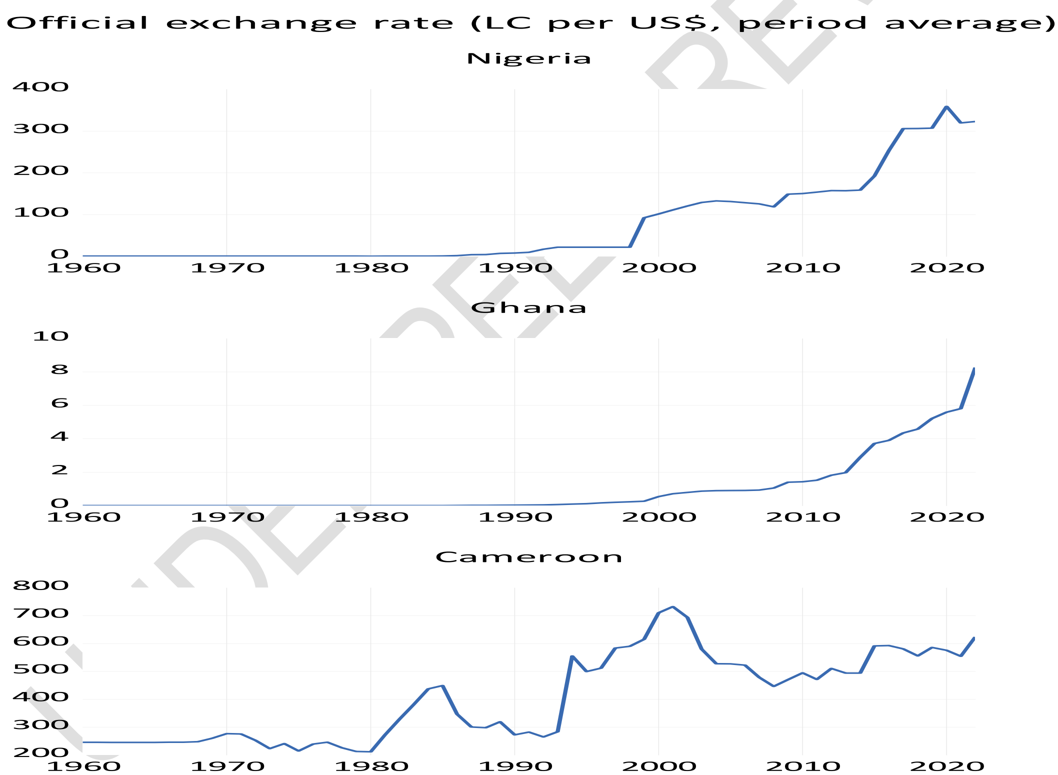
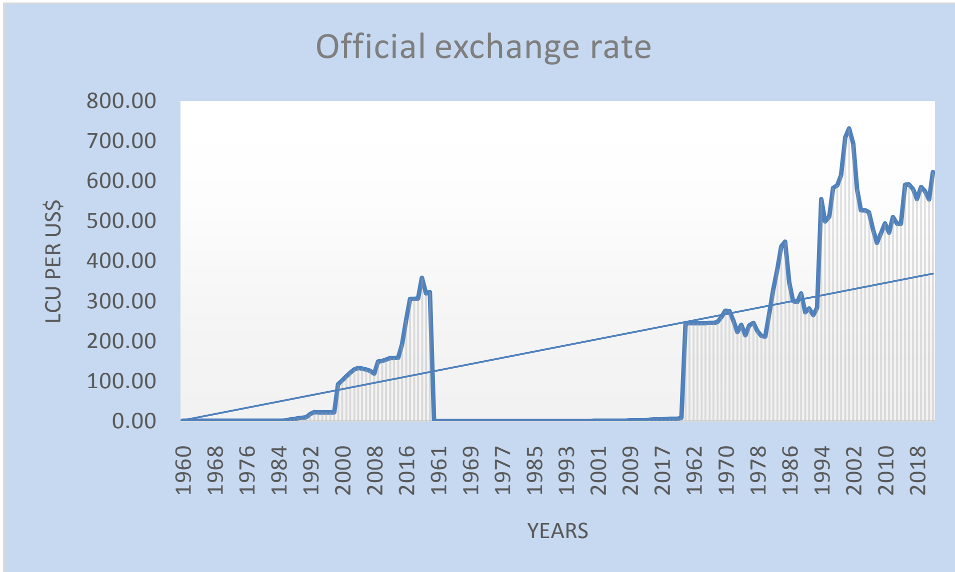


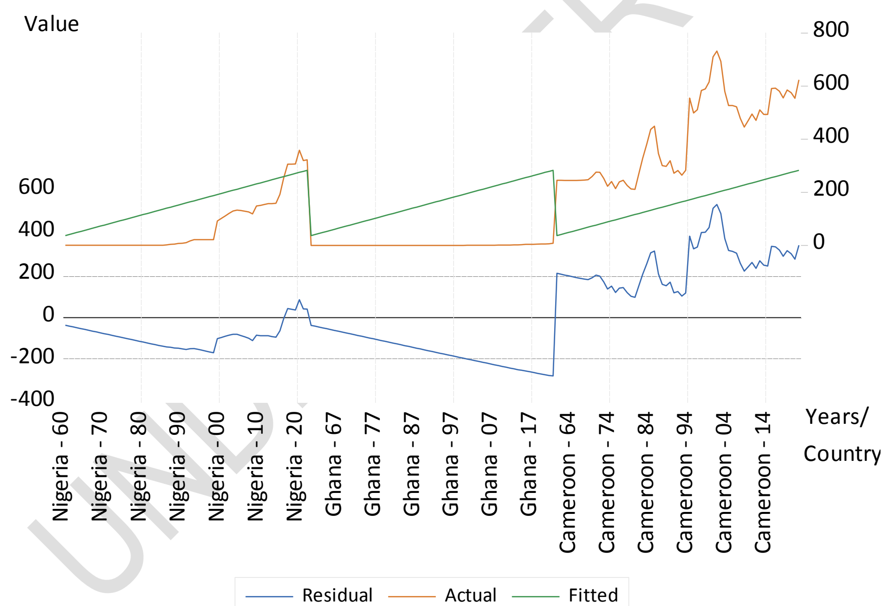

**Figure 6** Individual Time Plot of Foreign Exchange Rate

**4.2.1.2 Trend Analysis of Foreign Exchange Rate**




**EXR = -7748.71 + 3.97*T**

**Figure 7 Trend Plot ofForeign Exchange Rate**




**EXR = -7748.71 + 3.97*T**

**Figure 8 Actual, Fitted and Residual Plot ofForeign Exchange Rate**

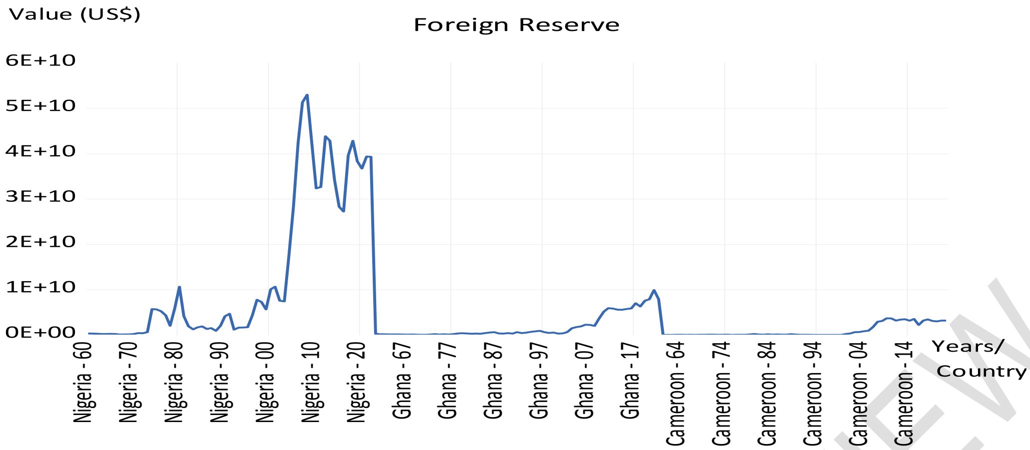



**Figure 9** **Time Plot of Foreign Reserve**

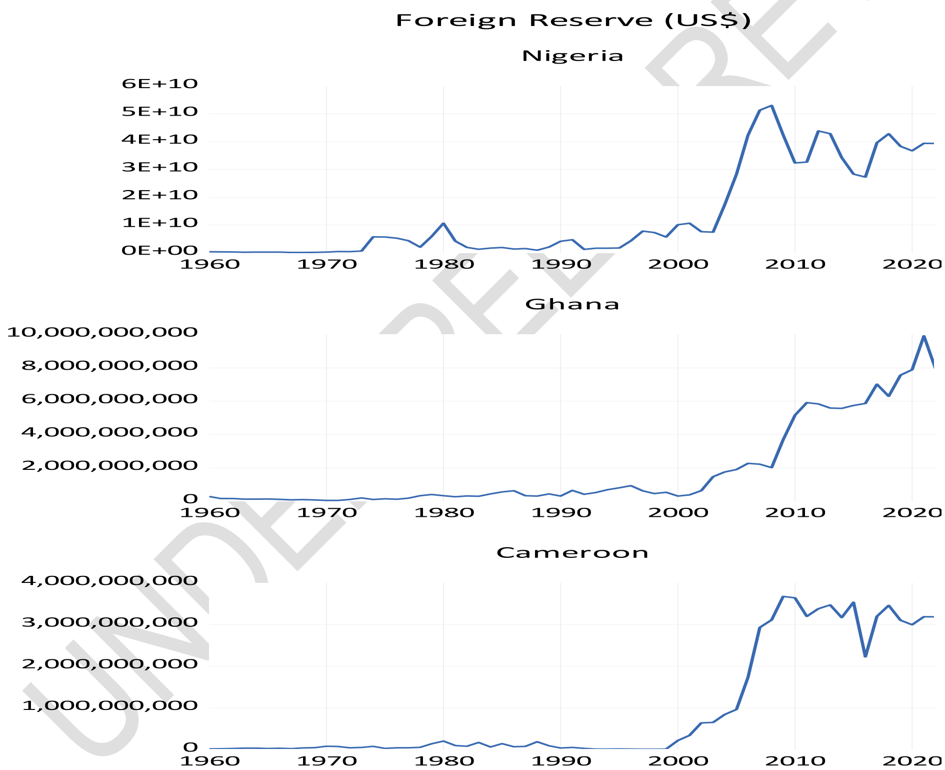
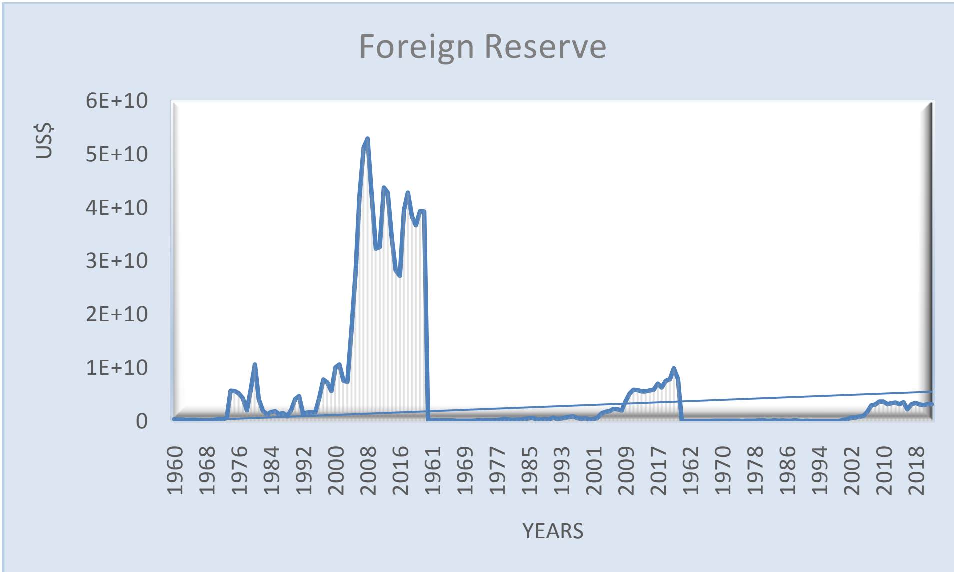


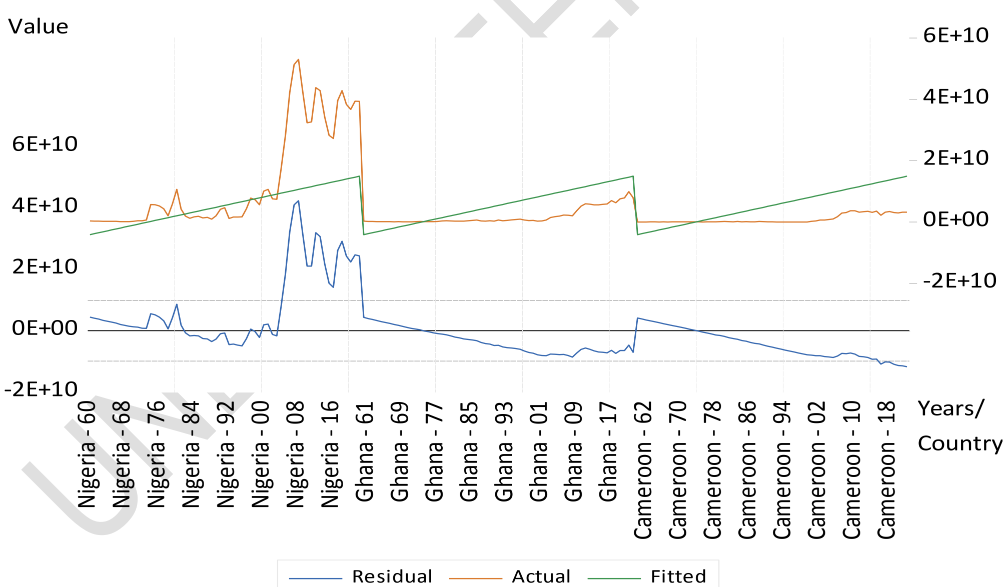

**Figure 10** **Individual Time Plot of Foreign Reserve**

#### 4.2.1.1 Trend Analysis of Foreign Reserve




**FR = -605,959,287,005 + 307067840.12*T**

**Figure 11 Trend Plot ofForeign Reserve**




**FR = -605,959,287,005 + 307067840.12*T**

**Table 2: VAR Lag Order Selection for Panel VAR Model**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | -1131.011 | NA | 187.1587 | 13.74559 | 13.80206 | 13.76851 |
| 1 | 146.4304 | 2492.946 | 3.93e-05 | -1.629459 | -1.403572 | -1.537763 |
| 2 | 170.9155 | 46.89285 | 3.26e-05* | -1.817158* | -1.421856* | -1.656691* |
| 3 | 173.2254 | 4.339765 | 3.54e-05 | -1.736066 | -1.171348 | -1.506827 |
| 4 | 178.0310 | 8.853880 | 3.72e-05 | -1.685224 | -0.951091 | -1.387214 |
| 5 | 184.7114 | 12.06532 | 3.83e-05 | -1.657108 | -0.753561 | -1.290327 |
| 6 | 191.2357 | 11.54598 | 3.96e-05 | -1.627100 | -0.554137 | -1.191547 |
| 7 | 199.3613 | 14.08435 | 4.01e-05 | -1.616501 | -0.374122 | -1.112176 |
| 8 | 209.7759 | 17.67323* | 3.95e-05 | -1.633647 | -0.221854 | -1.060551 |

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

**Table 3 Summary of Panel VAR Model (Fixed Effect) showing the Effects of Foreign Exchange Rates and Foreign Reserve on Gross Domestic Product Per Capita**

| Variable | Coefficient | t-Statistic | Prob. |
|---|---|---|---|
| C | 0.569426 | 2.518457 | 0.0127 |
| $LNGDPPC_{t-1}$ | 1.305972 | 18.24165 | 0.0000 |
| $LNGDPPC_{t-2}$ | -0.355348 | -4.968444 | 0.0000 |
| $LNEXR_{t-1}$ | 0.014815 | 0.823366 | 0.4114 |
| $LNEXR_{t-2}$ | -0.010203 | -0.560243 | 0.5760 |
| $LNFR_{t-1}$ | 0.006964 | 0.884095 | 0.3779 |
| $LNFR_{t-2}$ | -0.007625 | -0.959098 | 0.3388 |
| **Effects Specification** | | | |
| **Cross-section fixed (dummy variables)** | | | |
| Root MSE | 0.048917 | R-squared | 0.999585 |
| Mean dependent var | 11.32035 | Adjusted R-squared | 0.999566 |
| S.D. dependent var | 2.407647 | S.E. of regression | 0.050166 |
| Akaike info criterion | -3.099027 | Sum squared resid | 0.437894 |
| Schwarz criterion | -2.941184 | Log-likelihood | 292.5610 |
| Hannan-Quinn criteria. | -3.035046 | F-statistic | 52380.23 |
| Durbin-Watson stat | 1.978280 | Prob(F-statistic) | 0.000000 |

$$LNGDPPC = 0.569 + 1.306*LNGDPPC_{t-1} - 0.355*LNGDPPC_{t-2} + 0.015*LNEXR_{t-1} - 0.010*LNEXR_{t-2} + 0.007*LNFR_{t-1} - 0.008*LNFR_{t-2} \quad (3.1)$$

**Similarly we have**

**Summary of Panel VAR Model (Fixed Effect) showing the Effects of Gross Domestic Product Per Capita and Foreign Reserve on Foreign Exchange Rates**

LNEXR = 2.946 - 0.4781*$LNGDPPC_{t-1}$ + 0.182*$LNGDPPC_{t-2}$ + 1.252*$LNEXR_{t-1}$ - 0.252*$LNEXR_{t-2}$ - 0.028*$LNFR_{t-1}$ + 0.052*$LNFR_{t-2}$ (3.2)

**Summary of Panel VAR Model (Fixed Effect) showing the Effects of Gross Domestic Product Per Capita and Foreign Exchange Rates on Foreign Reserve**

LNFR = 0.924 + 1.079*$LNGDPPC_{t-1}$ - 1.031*$LNGDPPC_{t-2}$ + 0.070*$LNEXR_{t-1}$ - 0.041*$LNEXR_{t-2}$ + 0.972*$LNFR_{t-1}$ - 0.042*$LNFR_{t-2}$ (3.3)

**The Model Specification**

The models can be represented explicitly thus for the Panel Vector Autoregressive Model;

$$\begin{bmatrix} GDPPC_{it} \\ EXR_{It} \\ FR_{it} \end{bmatrix} = \begin{bmatrix} 0.569 \\ 2.946 \\ 0.924 \end{bmatrix} + \begin{bmatrix} 1.306 & 0.015 & 0.007 \\ -0.478 & 1.252 & -0.028 \\ 1.079 & 0.070 & 0.972 \end{bmatrix} \begin{bmatrix} GDPPC_{it-1} \\ EXR_{It-1} \\ FR_{it-1} \end{bmatrix} +$$

$$\begin{bmatrix} -0.355 & -0.010 & -0.008 \\ 0.182 & -0.252 & 0.052 \\ 1.031 & -0.041 & -0.042 \end{bmatrix} \begin{bmatrix} GDPPC_{it-2} \\ EXR_{It-2} \\ FR_{it-2} \end{bmatrix} \quad (3.4)$$

**Impulse Response**

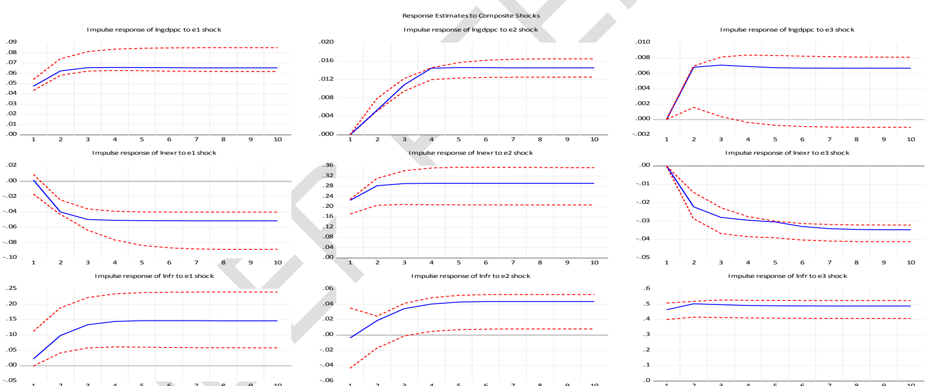



**Figure 12: Plots of Impulse Response due to composite shock**

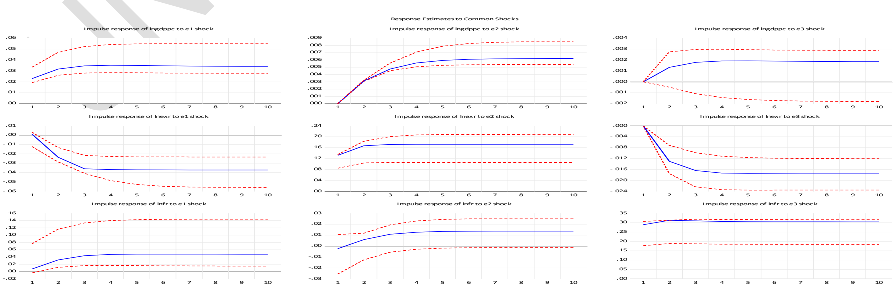



**Figure 13: Plots of Impulse Response due to common shock**

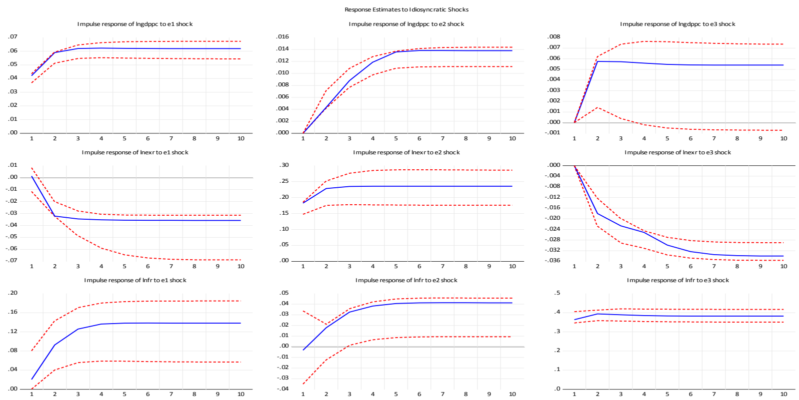


**Figure 14: Plots of Impulse Response due to idiosyncratic**

## Variance Decomposition

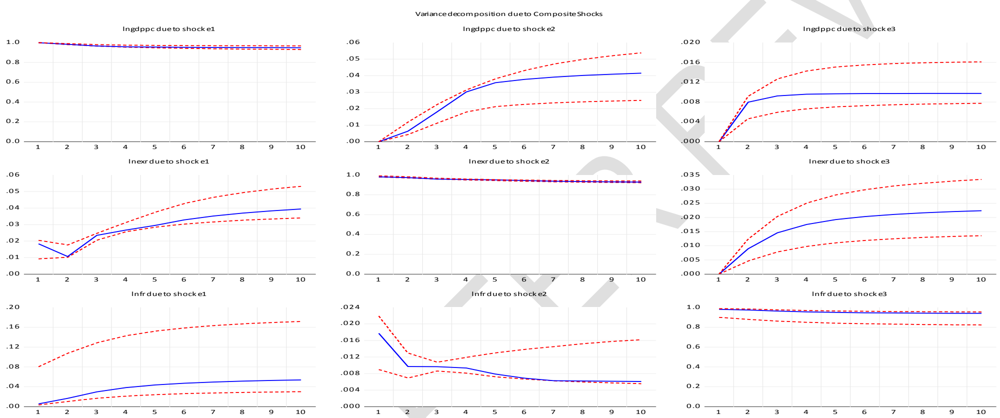


**Figure 15: Plots of Variance Decomposition due to composite shock**

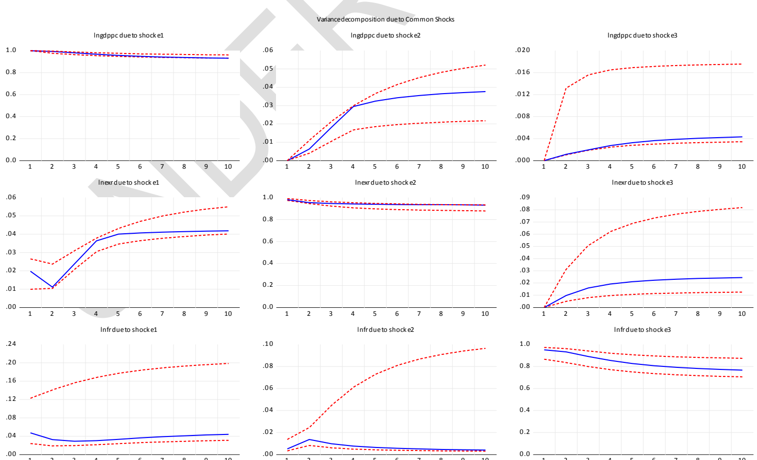


**Figure 16: Plots of Variance Decomposition due to a common shock**

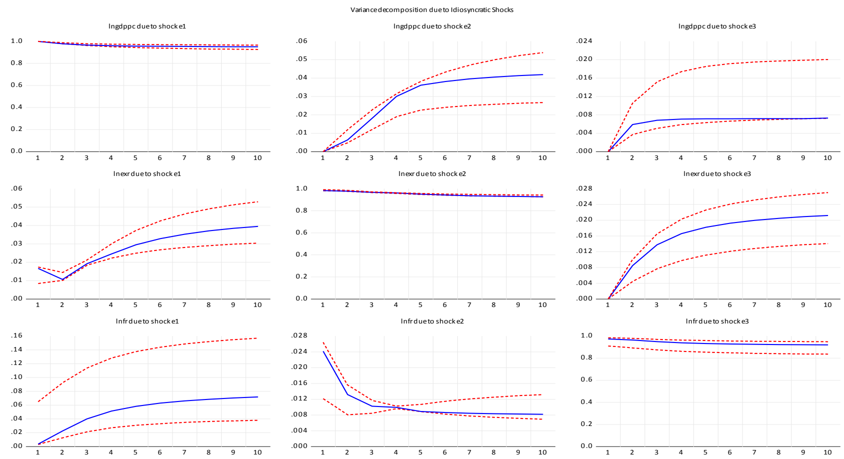



**Figure 17: Plots of Variance Decomposition due to idiosyncratic shock**

## 3.2. Discussion

he cointegration analysis revealed no cointegration among the variables, leading to the choice of the panel VAR method due to the study's panel data nature. Lag length selection criteria indicated a lag length of 2 as the most suitable, confirmed by various information criteria. The Akaike Information Criteria was adopted for lag length 2 in model estimation. The panel VAR was applied to data spanning 1960 to 2022, offering a substantial time dimension for parameter estimation. Both Random and fixed effects were considered, and the Hausman Test favored the fixed effect model, prompting its adoption in the final estimation.

Following the model specification presented in Equation (3.1) and The above result as also presented in Table 2 shows an adjusted coefficient of determination($\bar{R}^2$) of 0.99. This implied that a 99% variation in GDP per capita is explained by variations in the foreign exchange rate and foreign reserve. The result showed that GDP per capita at lag 1 and lag 2 significantly influenced GDP per capita. Both lags of foreign exchange rate and also both lags of foreign reserve were not significant, the first lag of both variables showed positive effects while the second lag showed negative effects.

Also, in Equation (3.2), **t**he result on the effects of gross domestic product per capita and foreign reserve on foreign exchange rates and summarized above shows an adjusted coefficient of determination($\bar{R}^2$) of 0.998. This implied that the 99.8% variation in the foreign exchange rate is explained by variations in GDP per capita and foreign reserve. The result showed that GDP per capita at lag 1 and lag 2, and both legs of the foreign reserve were not significant in influencing the foreign exchange rate. Both lags in foreign exchange rates were indeed significant. The first leg of GDP per capita, foreign reserve, and the second leg of foreign exchange rate showed negative effects on foreign exchange while others showed positive effects.
In Equation (3.3), the result model on the effects of gross domestic product per capita and foreign exchange rate on foreign reserve presented in Table 3 and summarized in the equation above shows that the adjusted coefficient of determination($\bar{R}^2$) of 0.952. This inferred that the 95.2% variation in foreign reserve is explained by variations in GDP per capita and foreign exchange rate. Detailed analysis showed that only foreign exchange lag 1 had a significant effect on foreign reserves.

**The Impulse Response Function**
The panel VAR model allows the effects of shocks, shocks to endogenous variables do not only directly impact an endogenous variable but are also transmitted to other endogenous variables via the dynamic (lag) structure of the VAR. To ascertain the effect of a one-time shock on the present and future values of the endogenous variables, the impulse response is utilized. The dynamics of the model as shown in Figure 12 =14 in Chapter 4. This study revealed three fundamental innovations: I a shock to GDP per capita,; (ii) a shock to foreign exchange rate; and (iv) a shock to foreign reserve; both shocks are one standard deviation
Figure 12 shows the impulse response due to composite shock, Figure 13 shows the impulse response due to common shock, while Figure 14 shows the impulse response due to idiosyncratic shock, The top row of each graph shows the response of GDP per capita to one standard deviations shock to GDP per capita, foreign exchange rate, and foreign reserve respectively. Row two shows the response of foreign exchange rate to one standard deviations shock to GDP per capita, foreign exchange rate, and foreign reserve respectively, while row three shows the response of foreign reserve to one standard deviations shock to GDP per capita, foreign exchange rate, and foreign reserve respectively.

**Variance Decomposition**
One of the methods used in the study of the dynamic interaction among the variables is the variance decomposition. It was also important to isolate the variance in an endogenous variable into the effects of the shocks on the system. Variance decomposition gives information about the comparative significance of each random innovation as it affects variables in the system differently.
Figure 15 shows the variance decomposition due to composite shock, Figure 16 shows the variance decomposition due to common shock, while Figure 17 shows the variance decomposition due to idiosyncratic shock, The top row of each graph shows the variance decomposition of GDP per capita due to shock to GDP per capita, foreign exchange rate, and foreign reserve respectively. Row two shows the variance decomposition of foreign exchange rate due to GDP per capita, foreign exchange rate, and foreign reserve respectively, while row three shows the variance decomposition of the foreign reserve due to shock to GDP per capita, foreign exchange rate, and foreign reserve respectively.

4. Conclusion

The study employs a panel vector autoregressive model to analyze the macroeconomic interaction in Nigeria, Ghana, and Cameroon, focusing on the dynamic relationships among economic variables such as exchange rates, foreign reserves, and gross domestic product (GDP) from 1960 to 2022. The results indicate that variations in GDP per capita and foreign reserves significantly explain 99.8% of the variation in foreign exchange rates over the study period. However, the study concludes that GDP per capita and foreign reserves were not consistently significant in influencing foreign exchange rates at certain lags. Cointegration tests suggest no long-run relationships among variables, supporting the appropriateness of the panel VAR for the data. Unit root tests confirm the stationarity of the data. Impulse response analysis reveals the model's ability to describe the evolution of variables in response to shocks. The study employs both random and fixed effects models, with the Hausman Test favoring the fixed effect model. Hypothesis testing shows that foreign exchange rates and GDP per capita have joint significance, while foreign reserves do not, highlighting the complex relationships among these economic indicators in the studied countries.

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