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Exchange Rate, Interest Rate and Agricultural Export Earnings: An analysis Using Panel Data Vector Autoregressive Model

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Abstract
*The study modeled the dynamic interaction between exchange rate, interest rate and agricultural export earnings using panel VAR Model. The specific objectives of the study include to**;** interdependencies in the dynamic interaction between exchange rate, interest rate and agricultural export earnings, parameters of panel VAR model using **PVAR** Stata code developed by Abrigo and love, determine the shocks associated with their dynamic interactions between these variables, investigate direction of causality between interest rate, exchange rate and agricultural export earnings from six African countries and make appropriate recommendations. The data used for the study was secondary data extracted from index mundi website and world data indicators for the period of 40 years (1980-2020). The data was on exchange rate, interest rate and agricultural export earnings. Geographically, the six African countries include; Algeria, Angola, Egypt, Libya, Gabon and Nigeria. The study uses vector Autoregressive model estimation results with **PVAR** Stata code developed by Abrigo and love. The post estimation test on the Vector Autoregressive (VAR) model shows a contemporary Co-efficient of Correlation analysis. It was found that lending interest rate and exchange rate are negatively associated with Co-efficient of Correlation of (-0.0873). Also, it was found that there exist a positive association between exchange rate and agricultural export earnings. Also, there is a positive association between lending interest rate and agricultural export earnings. The inverse roots of a characteristic polynomial of the estimated Panel VAR model satisfied the stability condition (of the diagnostic test) since no root lied outside the unit root circle. Therefore, the estimated VAR is stable. However, it was confirmed that there is no directional relationship that exist between the variables. Also, the results show that exchange rate and lending rate have positive on agricultural export earnings, whereas exchange rate is likely to reduce the level of lending interest rate slightly. Therefore, it is recommended that in estimating the dynamic interaction between variables in a panel data system, there is need for the inclusion of the lags of the response variable among the determinants to measures the dynamic interaction as well capture heterogeneities in the series and also, policies should be formulated to stabilized exchange and lending rates in order to improve and strengthen the countries' agricultural economy amongst others.*

Keywords: *Dynamic, Interaction. Exchange Rate, Interest Rate, Export, Earnings*

1.1 Background to the study

Agricultural export earnings used to be vital foreign exchange source of livelihood in major west African countries. Then, majorities of these countries were self-sufficient in terms of food production in the 1960s and early 1970s (Nigeria National Bureau of Statistics, 2017) and also major employers of the West African countries' working population. The proportion of the GDP accrued from the agricultural sector as at the fourth quarter of 2016 was about 24 percent (Nigeria National Bureau of Statistics, 2017). The sector was identified to have recorded an annual growth rate of about 3.5 percent (Nigeria Data Fora, 2016) and now employs about 30 percent of the total labour force (World Bank, 2011).

Exchange and lending interest rate on the other hand, have been shown to play a considerable role in determining the profit earned from agricultural export (World Bank, 2011). This was due to the fact that they are macroeconomic indicators with unique statistical stylized facts in finance, economics, econometrics, and statistics (Deebom & Aboko, 2022).

Exchange and lending interest rate are important indicators of the country's economic health. Several studies have done by researchers to examined the impact of exchange rate (Julien, Robert & Grace, 2017) and interest rate volatility on agricultural production, incomes, and other macro and microeconomic variables in West African countries (Olalekan & Essi,2020). Some of these studies were conducted to investigate the functions of exchange rates and interest rates in economic development as well as to determine the nation's economy (Olalekan & Essi,2020). Other investigations were also carried out to examine the challenges associated with the relationship between exchange rates, interest rates and its effect on economic development (Akinbode, &Ojo, 2018), interest rate and other economic indicators (Julien, Robert & Grace.2017).

The findings of past empirical literatures on exchange rate, interest rate and agricultural export earnings nexus are mixed and conflicting (Ufoeze *et al*, 2018). The role of exchange rate, interest rate and agricultural export earnings in economic growth nexus need to be thoroughly explored, because exchange rate and agricultural export earnings have the capacity to influence economic growth.

Besides, many empirical studies emphasized on the importance of exchange rate, interest rate and agricultural export earnings in economic growth. However, the research findings of past empirical studies are contradicting. For example, the studies of Julien, Robert and Grace (2017), Yu-chin and Kenneth (2003), Ali; Michael and Wyzan (2005), Abass (2020), x-rayed the effect of exchange rate, inflation rate, interest rate and economic growth on agriculture export earnings in Tanzania. The findings of the study showed insignificant relationship between exchange rate and agriculture export earnings while also, economic growth was found to have positive significant influence on agricultural export earnings and similarly, interest rate was significant and positively influenced agriculture export earnings. Karuraa (2017), Mwangi *et al.*, (2014) and Dawson (2005), revealed that exchange rate volatility has influence on performance of French beans exports from Kenya to the European Union market. The results of the co-integration analysis indicate the presence of a long run equilibrium relationship between French agricultural export earnings and exchange rate volatility. Similarly, Sanjuan and Dawnson (2010),found existence of long run relationship between agriculture export elasticity of gross domestic product and non-agriculture export elasticity of gross domestic product, Oluwatoyese *et al* (2015) Rutto and Ondiek (2014), Ngondo and Khobai (2018) Batten and Belongia (1984) , Nora and Pradeep (2018) found the positive impacts of avocado export earnings on economic growth while negative impacts found on grape export earnings on economic growth and Nasirpour and Jorjorzadeh (2014) reported negative link. However, there is no studies related to the dynamic interaction between exchange rate, interest rate and agricultural export earnings using panel data vector autoregressive model. This gap is a most feasible one as using panel data vector autoregressive model will provide an in-depth understanding of the dynamic stability level in panel data system, interdependencies among the variables and shock identification with a view to conduct inference with the results from the panel data model estimation.

This study, therefore investigate the dynamic interaction between exchange rate, interest rate and agricultural export earnings using panel vector autoregressive model analysis, specifically to determine how heterogeneities present in interdependencies in the dynamic interaction between exchange rate, interest rate and agricultural export earnings can be captured. We also investigate how parameters of panel VAR models can be estimated, shock identification is performed and also to conduct inference with parameters of estimated from the model. Finally, the study discussed some of the challenges confronting researchers when dealing with dynamic heterogeneous and interdependency in panel data (of countries, industries or markets). It is hoped that the findings of this study will be useful and of immense benefits to policy makers and other regulatory authorities in formulating appropriate policies to stabilized the dynamic relationship between exchange rate, lending interest rate and agricultural export earnings.

Methodology

3.1 Source of Data

The data for the study was sourced using secondary data that was extracted from index mundi website and the World Data Indicators for the period of 40 years (1980-2020). The data were on exchange rate, interest rate and cotton prices. Geographically, the study was carried out in six African countries and they include; Algeria, Angola, Egypt, Libya, Gabon and Nigeria.

3.2. Panel Data Vector Autoregressive (VAR) Model Specification

We consider a k-variate panel VAR of order p with panel-specific fixed effects represented by the following system of linear equations:

$$Y_{it} = Y_{it-1} A_1 + Y_{it-2} A_2 + \cdots + Y_{it-p+1} A_{p-1} + Y_{it-p} A_p + X_{it} B + u_{it} + e_{it}$$

$$i \in \{1,2,\ldots,N\}, t \in \{1,2,\ldots,T_i\} \quad (3.1)$$

Where Y_{it} is a $(1xk)$ vector of dependent variables; X_{it} is a $(1xk)$ vector of exogenous covariates;

μ_i e_{it} and are $(1xk)$ vectors of dependent variable-specific fixed-effects and idiosyncratic errors, respectively. The (kxk) matrices A_1, $A_{2,}$….. $A_{p-1,}$ A_p and the (lxk) matrix $\boldsymbol{B}$ are parameters to be estimated. We assume that the innovations have the following characteristics: $E[e_{it}]=0, E[e'_{it}\, e_{it}]=\Sigma$ and $E[e'_{it}\, e_{is}]=0$ for all $t > s$.

3.2 Parameter Estimation of a Panel Data Vector Autoregressive (VAR) Model

Abrigo & Love, (2015) revealed that parameter estimation of a panel data Vector Autoregressive (VAR) Model can be done jointly with the fixed effects or alternatively, independently of the fixed effects after some transformation using equation-by-equation ordinary least squares (OLS). With the presence of lagged dependent variables in the right-hand side of the system of equations, the estimates would be biased even with large N. Although, the bias approaches zero as T gets larger, simulations and it will be significantly bias when (T = 30). Another approach to parameter estimation of a panel data Vector Autoregressive (VAR) Model is the use of Generalized Method of Moment (GMM). This study uses method of estimation of parameters developed by Abrigo and Love in 2015 using panel data VAR Model (PVAR) stata code (Abrigo & Love,2015)

3.3 Procedure for Estimating Panel Data VAR Model

The procedure for estimating panel data VAR model include; Pre-estimation and Post – estimation tests.

3.3.1 Pre-estimation Procedure

Pre-estimation Procedure include; time plots, co-integration test, and optimal lag length selection test. Time plots is the graphical representation of macroeconomic variables on the vertical axis against time (months) on the horizontal axis (Years with respect to the countries) to visualize the movement, trend, and variation in the variables with time. According to Deebom and Essi (2017), it is the representation of variables on the vertical axis (y-axis) against time, in a sequence taken at successive equally spaced points via a chart. This is done to visualize whether there is the presence of trend and variations which may cause biased estimation if it is not properly handled.

Also the co-integgration test**,** according to Sayed (2008), the idea of testing cointegration between variables was developed by Engle and Granger in 1987. This tells us about the presence of a long-run relationship between two or more variables. Although, in testing for cointegration there are several underlying assumptions and this includes: all variables are said to be non-stationary, they are all integrated of the same order and where they are not integrated of the same order then will continue with cointegration analysis using multi cointegration. However, Sayed (2008) further explained that there exists a Long-run relationship among variables and they include: Engel-Granger's residual-based test and Johansen-Juselius (JJ) test. Since the Engel, Johansen-Juselius (JJ) test is most preferred (Sayed, 2018) in his study adopted the Johansen maximum likelihood approach by using trace and maximum eigen value test. According to Wassell and Saunders (2000), this approach is preferable to other methods due to its robust properties of trace statistics for using both skewness and kurtosis in the residents of the series. However, panel data co-integgration test in this context is done using Kao (Engle-Granger based) Cointegration Tests. The Kao test follows the same basic approach as the Pedroni tests,

but specifies cross-section specific intercepts and homogeneous coefficients on the first-stage regressors.
According to Bai and Kao (2004), to estimate the homogeneous cointegrating relationship by pooled regression which allow for individual fixed effects estimation. To test for optimal lag length selection, panel VAR analysis is predicated upon choosing the optimal lag order in both panel VAR specification and moment condition. Andrews and Lu (2001) proposed consistent moment and model selection criteria (MMSC) for GMM models based on Hansen's (1982) Joint statistic of over-identifying restrictions. The proposed MMSC are analogous to various commonly used maximum likelihood-based model selection criteria, namely the Akaike information criteria (AIC), the Bayesian information criteria (BIC) and the Hannan-Quinn information criteria (HQIC). Applying Andrews and Lu's MMSC to the GMM estimator in (3.3), the proposed criteria select the pair of vectors (p, q) that minimizes and therefore, the models were represented as thus:

$$MMSC_{BIC,n}(k,p,q) = J_n\left(k^2p, k^2q\right) - \left(|q| - |p|\right)k^2 Inn \qquad (3.2)$$

$$MMSC_{AIC,n}(k,p,q) = J_n\left(k^2p, k^2q\right) - \left(|q| - |p|\right) \qquad (3.3)$$

$$MMSC_{HQIC,n}(p,q) = J_n\left(k^2p, k^2q\right) - Rk^2\left(|q| - |p|\right) In\ In\ n,\ R > 2 \qquad (3.4)$$

where J_n (k, p, q) is the j statistic of over-identifying restriction for a k-variate panel VAR of order p and moment conditions based on q lags of the dependent variables with sample size n. The above MMSC are available only when $q > p$. As an alternative criterion, the overall coefficient of determination (CD) may be calculated even with just-identified GMM models. Suppose we denote the $(k\ x\ k)$ unconstrained covariance matrix of the dependent variables by Ψ. CD captures the proportion of variation explained by the panel VAR model, and may be calculated as

$$\text{CD} = 1 - \frac{\det(\Sigma)}{\det(\Psi)} \qquad (3.5)$$

3.3.3 Post –estimation tests

The post –estimation tests carried out in this study include; model dynamic stability, impulse response, forecast-error variance decomposition and granger causality test.

For dynamic stability of the model, a set of n time series variables $y_t = (y_{1t}, y_{2t,}, \dots, y_{nt})'$, a VAR model of order p(VAR(p)) can be written as: $y_t = A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + u_t$. Where the A_i's are (nxn) coefficient matrices and $u_t = (u_{1t}, u_{2t}, \dots, u_{nt})'$ is an unobservable i.i.d. zero mean error term. The stability of the stationary VAR system, according to Halkos and Tsilika (2012), the stability of a VAR can be examined by calculating the roots of: $(I_n - A_1 L - A_2 L^2 - \dots.)y_t = A(L)y_t$

The characteristic polynomial is defined as: $\Pi(z) = (I_n - A_1 z - A_2 z^2 - \dots.)$

The roots of $|\Pi(z)| = 0$ will give the necessary information about the stationarity or non-stationarity of the process. The necessary and sufficient condition for stability is that all

characteristic roots lie inside the unit circle.
In another development, for the impulse response without loss of generality, we drop the exogenous variables in our notation and focus on the autoregressive structure of the panel VAR in equation (3.1). Lutkepohl (2005) and Hamilton (1994) show that a VAR model is stable if all moduli of the companion matrix $\overline{A}$ are strictly less than one, where the companion matrix is formed by

$$\overline{A}\begin{bmatrix} A_1 & A_2 \cdots A_p & A_{p-1} \\ 1_k & 0_k \cdots 0_k & 0_k \\ 0_k & 1_k \cdots 0_k & 0_k \\ \vdots & \vdots \ddots \vdots & \vdots \\ 0_k & 0_k \cdots 1_k & 0_k \end{bmatrix} \quad (3.6)$$

Stability implies that the panel VAR is invertible and has an infinite-order vector moving-average (VMA) representation, providing known interpretation to estimated impulse-response functions and forecast- error variance decompositions. The simple impulse-response function Φ_1 may be computed by rewriting the model as an infinite vector moving-average, where Φ_1 are the VMA parameters.

$$\Phi_i = \{I_k \quad , \quad i = 0$$
$$\sum_{j=1}^{i} \Phi_{t-j} A_j, i = 1,2,.. \quad (3.7)$$

The simple IRFs have no causal interpretation, however, since the innovations $\mathbf{e_{it}}$ are correlated contemporaneously, a shock on one variable is likely to be accompanied by shocks in other variables, as well. Suppose we have a matrix ***P*,** such that ***P'P*** $= \Sigma$. Then ***P*** may be used to orthogonalize the innovations as $\mathbf{e_{it}}\boldsymbol{p}^{\mathbf{-1}}$ and to transform the VMA parameters into the orthogonalized impulse-responses $P\Phi_i$. The matrix ***P*** effectively imposes identification restrictions on the system of dynamic equations. Sims (1980) proposed the Cholesky decomposition of Σ to impose a recursive structure on a VAR. The decomposition, however, is not unique but depends on the ordering of variables in Σ. Impulse-response function confidence intervals may be derived analytically based on the asymptotic distribution of the panel VAR parameters and the cross-equation error variance-covariance matrix. Alternatively, the confidence interval may likewise be estimated using Monte Carlo simulation and bootstrap resampling methods.
Also, forecast-error variance decomposition has to do with the *h*-step ahead forecast-error and it can be expressed as

$$Y_{it+h} - E[Y_{it+h}] = \sum_{t=0}^{h-1} e_{i(t+h-i)} \Phi_i \quad (3.8)$$

Where $Y_{it=h}$ is the observed vector at time $t + h$ and $\boldsymbol{E}$ $[\boldsymbol{Y_{it+h}}]$ is the h-step ahead predicted vector made at time *t*. Similar to impulse-response functions, we orthogonalized the shocks using the matrix ***P*** to isolate each variable's contribution to the forecast-error variance. The orthogonalized shocks $e_{it}P^{-1}$ have a covariance matrix I_k which allows straightforward decomposition of the forecast-error variance. Specifically, the contribution of a variable m to the h-step ahead forecast-error variance of variable n may be calculated as

$$\sum_{i=0}^{h-1} \theta_{mn}^2 \sum_{i=1}^{h-1} \left(i_n' P \Phi_i i_m \right)^2 \tag{3.9}$$

Where i_s is the $t + h$ column of I_k in application, the contributions are often normalized relatively to the h-step ahead forecast-error variance of variable n:

$$\sum_{i=0}^{h-1} \theta_{.n}^2 \sum_{i=1}^{h-1} i_n' \Phi_i ' \Sigma \Phi_i i_n \tag{3.10}$$

Also, another test to be considered is the granger causality test. Predictive causality and feedback is an important aspect of applied time series and panel data analysis. Evidence to this, is the observation that procedures on testing for Granger causality using panel data models, are very well cited and widely available in standard econometric software.

In analyzing the causality test, it is necessary to eliminate the trends and make the variables stationary. Granger's concept of causality in reality is a VAR model with an appropriate lag length when the causality relation between two variables are examined, they are regressed with each other according to the constrained regression logic with appropriate lag lengths. For each estimated regression, the F-values are calculated using the error terms squares obtained and compared with the F- table value.

RESULTS

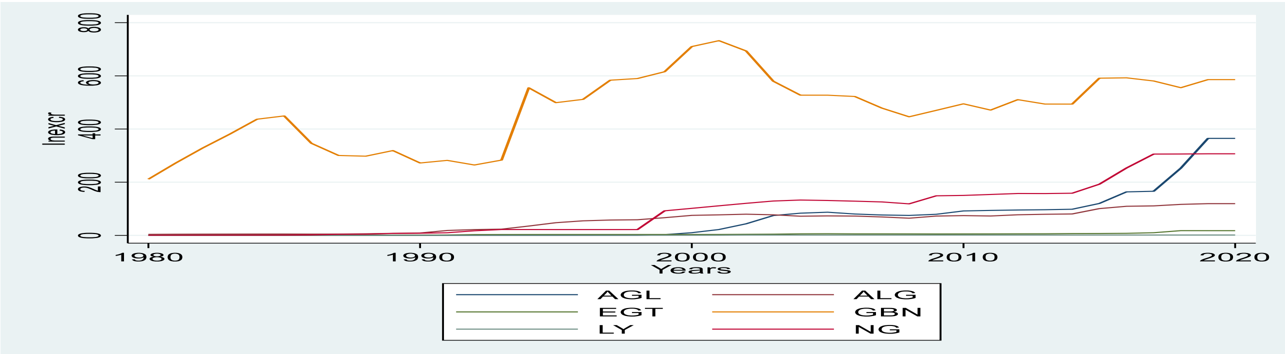


Figure 4.1: Time Plot on Logarithm transformed series on Exchange Rate (Inexchr) from the Six Selected Countries

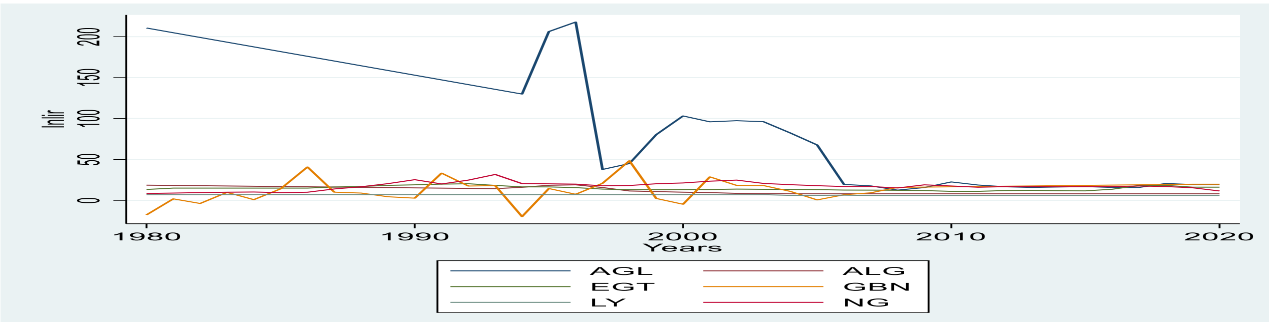


Figure 4.2: Time Plot on Logarithm transformed series on Lending (Inlir) from the Six

selected Countries

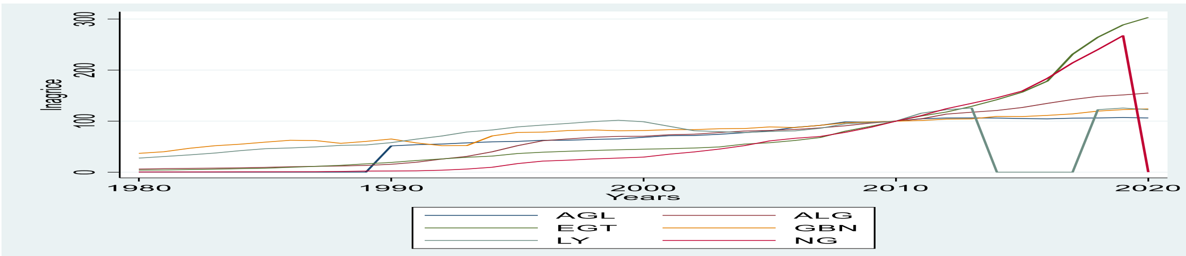


Figure 4.3: Time Plot on Logarithm transformed series on Agricultural Export Earnings (lnagric) from the Six Selected Countries

4.3 Descriptive Statistics Test

Table 4.1 is the result for the descriptive test for normality and this test statistic provides basic information about the variables and highlights potential relationship between them.

Table 4.1: Descriptive Statistics of the Study Variables

Variable		Mean	Std. Dev.	Min	Max	Observations
inexcr	overall	115.5822	181.7591	2.99e-08	732.3977	N = 246
	between		179.4583	.7973488	474.2437	n = 6
	within		78.03268	-147.3819	418.3547	T = 41
inlir	overall	26.66561	43.71558	-19.82	217.88	N = 246
	between		34.28068	6.598537	96.2639	n = 6
	within		30.45901	-57.06829	148.2817	T = 41
inagric	overall	69.40477	53.69048	.0482797	303.13	N = 246
	between		8.219774	58.45452	81.29463	n = 6
	within		53.1614	-2.614342	298.3865	T = 41

4.4 Unit Root Test

The unit root test using the Im, Persaran & Shim and Levin, Lin& Chu test and the results are shown in the table below

Table 4 2: Panel unit root tests results

Variables	Im, Persaran & Shim		Levin, Lin& Chu	
	Level	**First Difference**	**Level**	**First Difference**
Inexcr	2.245	-6.0610***	6.233	-7.0196***
Inlir	-1.794	-11.0231***	-1.465	-8.457***
Inagric	1.438***	-3.191***	4.908	-5.485***

*** *denotes significance at 1% level,* ** *denotes significance at 5% level, and* * *denotes significance at 10% level*

4.5 Differenced Series

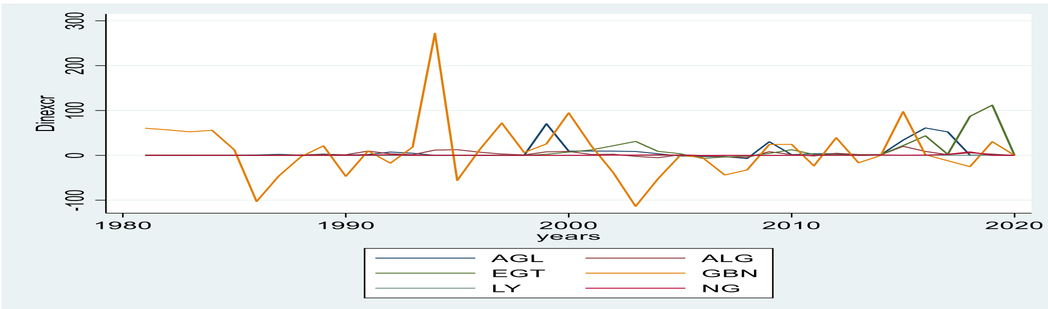


Figure 4.4: Time Plot on the Differenced Series of the logarithm transformed Exchange Rate(DInexchr) from the Six Selected Countries

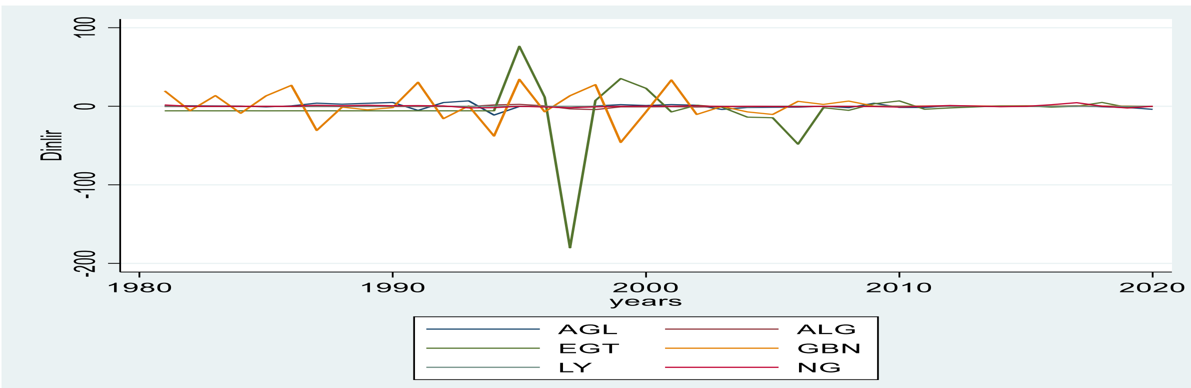


Figure 4.5: Time Plot on the Differenced Series of the logarithm transformed Lending Rate (Inlir) from the Six Selected Countries

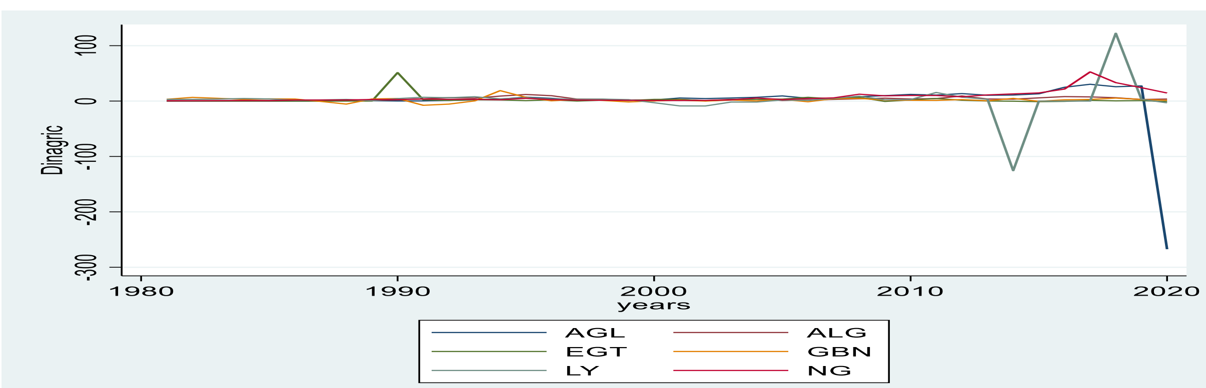


Figure 4.6: Time Plot on the Differenced Series of the logarithm transformed Agricultural Export Earnings (Dinagric) from the Six Selected Countries

4.6 Lag-Order Selection Statistics for Panel VAR Model Estimation

Table 4.3: Lag-Order Selection Statistics for Panel VAR Model Estimation

lag	CD	J	J pvalue	MBIC	MAIC	MQIC
1	.998922	29.96975	.3155149	-115.1628	-24.03025	-60.84801
2	.9992156	19.42326	.3662066	-77.33176	-16.57674	-41.12192
3	.9980377	6.071111	.7327807	-42.30639	-11.92889	-24.20148

Notes: *Pvarsoc* Stata the Command was used.

4.7 Co-integration Test

The result of the Kao of co-integration test to determine the presence of long-run relationship among the study variables is shown in table 4.4 below

Table 4.4: Results of Co-integration Test

```
Ho: No cointegration                          Number of panels      =      6
Ha: All panels are cointegrated               Number of periods     =     39

Cointegrating vector: Same
Panel means:          Included                Kernel:            Bartlett
Time trend:           Not included            Lags:              2.50 (Newey-West)
AR parameter:         Same                    Augmented lags:    1
```

	Statistic	p-value
Modified Dickey-Fuller t	-0.1438	0.4428
Dickey-Fuller t	0.6692	0.2517
Augmented Dickey-Fuller t	0.1590	0.4368
Unadjusted modified Dickey-Fuller t	0.0318	0.4873
Unadjusted Dickey-Fuller t	0.8014	0.2114

4.9 Post Estimation Test on the Vector Autoregressive (VAR) Model

The results of the post estimation test particularly the contemporary co-efficients of correlation, dynamic stability test, variance decomposition response, impulse response test and granger causality test are shown below. The panel data Vector Autoregressive (VAR) Model estimated in a generalized method of moments framework is used and the results are as shown below:

4.9.1 Contemporary Co-efficients of Correlation

This is done to determine the co-efficients of correlation between variables under investigations and the results are shown in Table 4.7 below.

Table 4.7: Contemporary Co-efficient of Correlation

Contemporary coefficients

	dinexcr	dinlir	dinagric
dinexcr	1	0	0
dinlir	-.08733602	1	0
dinagric	.03886895	.00061159	1

4.9.3 Dynamic Stability Test

The stability of the panel VAR requires the modulus of the eigen-values of the dynamic matrix to lie within the unit circle. The resulting table and graph of eigenvalues reported in table 4.8 and Figure 4.7 below

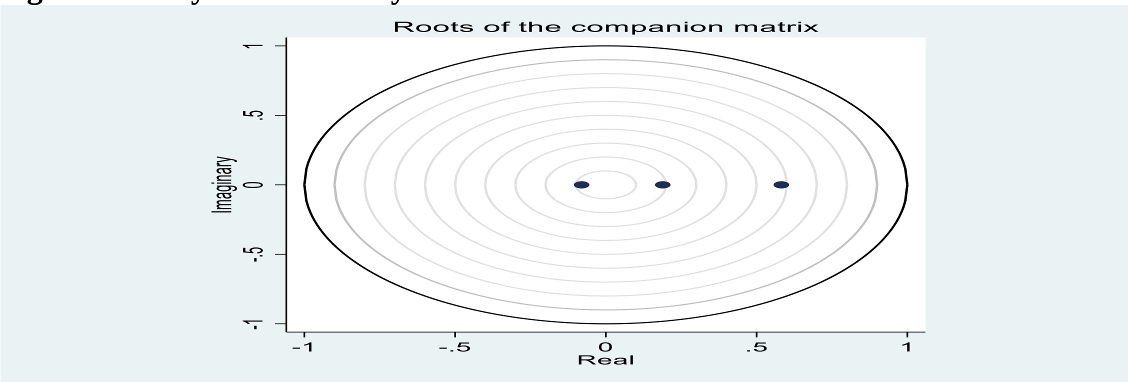
Table 4.8: Results of the Eigenvalue Stability Test

Eigenvalue stability condition

Eigenvalue Real	Eigenvalue Imaginary	Modulus
.5821204	0	.5821204
.1886826	0	.1886826
-.0805304	0	.0805304

All the eigenvalues lie inside the unit circle
pVAR satisfies stability condition.

Figure 4.7: Dynamic Stability Test



4.9.5 Impulse Response Test

Table 4.9: Impulse Response Test

Response of dinexcr to shock in dinexcr

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	27.70021	17.65549	35.80624	0	0	0
1	29.95963	16.70452	41.89941	1	1	1
2	27.52698	14.42189	39.40089	.999606	.9755985	.9999608
3	24.47144	11.77182	35.36101	.9962168	.9410521	.9987208
4	21.61042	8.506182	31.40194	.9868613	.8876312	.9952652
5	19.04541	6.022599	29.35369	.9713661	.8237661	.9892887
6	16.75795	3.565712	26.92999	.9507426	.7543531	.982491
7	14.71644	1.345878	24.21763	.9263442	.6758028	.9757278
8	12.89224	.1450219	21.73339	.8995237	.6020591	.9680925

Response of dinlir to shock in dinexcr

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	-2.419226	-4.365482	.5386953	0	0	0
1	-.0895688	-2.643073	3.038905	.027187	.000377	.1789146
2	-.1438767	-2.715402	2.618231	.0164154	.0022598	.13293
3	-.5107841	-2.973544	2.39416	.0127816	.0034164	.1373215
4	-.8424968	-3.082265	2.115445	.0114917	.0034274	.1517077
5	-1.074951	-3.309856	1.91889	.0116286	.0037805	.1671288
6	-1.217405	-3.298976	1.921423	.0126969	.0036353	.1825236
7	-1.288932	-3.135727	1.839019	.0143136	.0035331	.1959557
8	-1.306767	-2.911116	1.751411	.0161853	.0035321	.2065738

Response of dinagric to shock in dinexcr

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	1.076678	-.1241985	2.00824	0	0	0
1	2.112151	-.6429774	4.083453	.0022979	.0000234	.022342
2	1.738448	-1.489713	4.166872	.0052772	.0003656	.0538717
3	.9663697	-3.141779	3.480392	.0055184	.0004994	.0656829
4	.2191724	-4.05182	2.81314	.0047743	.0006304	.0671114
5	-.4100313	-4.709534	2.228286	.0040243	.0008199	.0611032
6	-.9187087	-5.449931	1.90666	.0035879	.0011176	.0559356
7	-1.322116	-6.034394	1.543078	.0035175	.0011441	.0562295
8	-1.636476	-6.677682	1.380298	.0037761	.001349	.0591727

Response of dinexcr to shock in dinlir

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	0	0	0	0	0	0
1	-.7446353	-5.554628	3.743225	0	0	0
2	-2.33203	-7.96277	3.629423	.0003329	3.78e-06	.0238198
3	-3.648587	-9.657682	4.032907	.0024644	.0001844	.052257
4	-4.626268	-10.86847	4.534632	.0063053	.0005127	.0819852
5	-5.310791	-11.51622	4.609942	.011335	.0007063	.1203829
6	-5.759117	-12.25038	4.494252	.0170122	.0006909	.1579174
7	-6.020037	-12.20159	4.326535	.0228848	.0007924	.1898035
8	-6.133443	-11.37074	4.15599	.028612	.0009803	.2143707

Response of dinlir to shock in dinlir

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	14.4714	7.020288	20.55341	0	0	0
1	11.8933	4.638195	18.30827	.972813	.8210854	.999623
2	10.15251	3.889725	16.23175	.9827741	.863341	.9964745
3	8.582907	2.519836	14.42309	.9865307	.85918	.9951311
4	7.279189	1.624951	12.76412	.9871227	.8427036	.994419
5	6.203365	.9756011	11.89589	.9853263	.8209605	.9927884
6	5.314853	.6293558	10.92978	.9816149	.7966254	.9901106
7	4.57838	.3504377	9.94571	.976387	.7718483	.9878465
8	3.965193	.1195267	8.80909	.9699988	.7400709	.9856751

Response of dinagric to shock in dinlir

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	.0088505	-.6883681	.9959707	0	0	0
1	.0171322	-1.889076	2.007897	1.55e-07	1.26e-07	.0021053
2	-.3646972	-2.840366	2.138059	3.49e-07	.0000133	.0072315
3	-.7197619	-3.473773	2.405642	.0000852	.0000327	.0134084
4	-.9699342	-3.750354	2.408511	.0003248	.0000401	.0249782
5	-1.119441	-4.076576	2.474788	.0006658	.0000608	.0359758
6	-1.188955	-4.173973	2.546115	.0010425	.0000823	.0446657
7	-1.198379	-4.006632	2.718908	.0014084	.0001097	.0568118
8	-1.164045	-3.732725	2.882181	.0017364	.0001203	.0663954

Response of dinexcr to shock in dinagric

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	0	0	0	0	0	0
1	-.3188705	-3.071591	1.709593	0	0	0
2	1.762286	-.9857795	5.355638	.000061	3.87e-07	.0058164
3	4.20881	1.059296	9.640213	.0013189	.0003863	.0186664
4	6.419069	2.124271	12.82653	.0068333	.0013261	.0579819
5	8.275918	3.220631	15.11119	.0172989	.0032003	.1166233
6	9.790393	3.91596	16.62645	.0322452	.0051378	.1780885
7	10.99765	4.478364	17.05269	.0507711	.0081065	.2407345
8	11.93409	4.712749	18.0839	.0718643	.0118421	.3039346

Response of dinlir to shock in dinagric

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	0	0	0	0	0	0
1	.5379024	-.8472095	1.528199	0	0	0
2	-.1646258	-2.027596	.8260797	.0008104	5.81e-06	.0097179
3	-.6512828	-2.752814	.3163824	.0006877	.0001611	.0112619
4	-1.026497	-3.261719	-.0494369	.0013856	.0002896	.0227226
5	-1.339065	-3.513325	-.1904508	.0030451	.0004253	.0405126
6	-1.605602	-3.639888	-.2776924	.0056882	.0006235	.0632691
7	-1.831178	-3.680161	-.4518395	.0092994	.0007825	.0880479
8	-2.018461	-3.516305	-.5103886	.0138159	.0010509	.1171923

Response of dinagric to shock in dinagric

step	IRF	Lower	Upper	FEVD	Lower	Upper
0	22.43483	8.076792	32.9437	0	0	0
1	23.5816	7.681732	34.40289	.9977019	.9748393	.999868
2	22.31485	8.051579	32.22842	.9947224	.9453174	.9992934
3	20.93457	6.778238	29.28019	.9943964	.9314859	.9989229
4	19.61509	5.961245	27.39796	.9949009	.9256633	.9983027
5	18.33865	4.988314	25.44135	.9953099	.921046	.9975648
6	17.09818	4.220118	23.87933	.9953696	.916836	.9970585
7	15.89607	3.639596	21.85204	.9950741	.9057879	.9968331
8	14.73669	2.875977	19.93445	.9944875	.9006552	.9964038

95% lower and upper bounds reported; percentile ci

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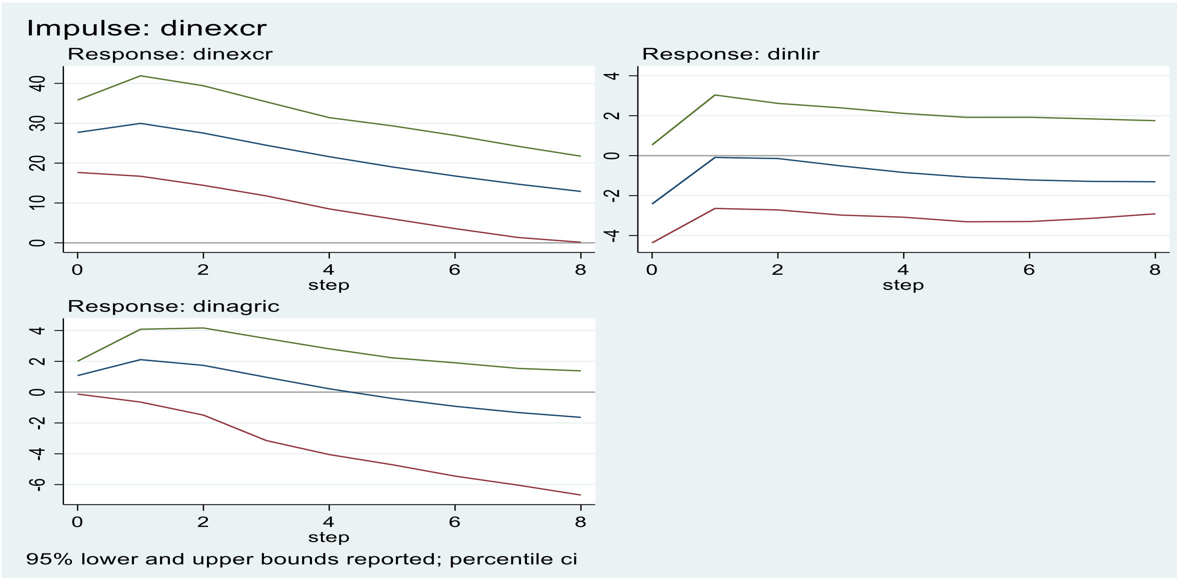

Figure 4.8: Impulse Response Function on Exchange Rate from the Six Selected Countries

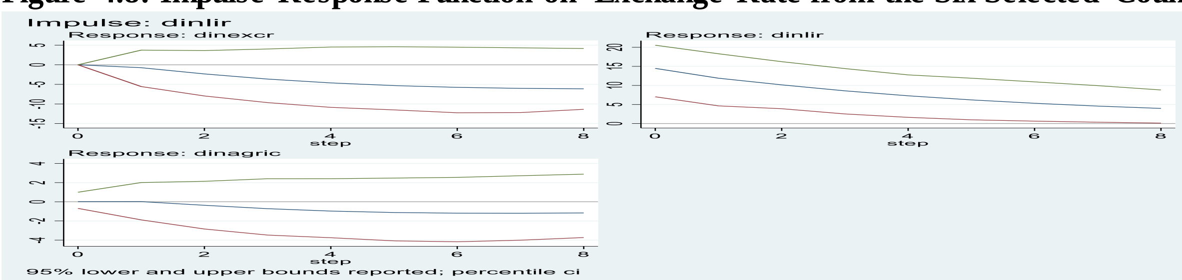

Figure 4.9: Impulse Response Function of Lending Interest Rate from the Six Selected Countries

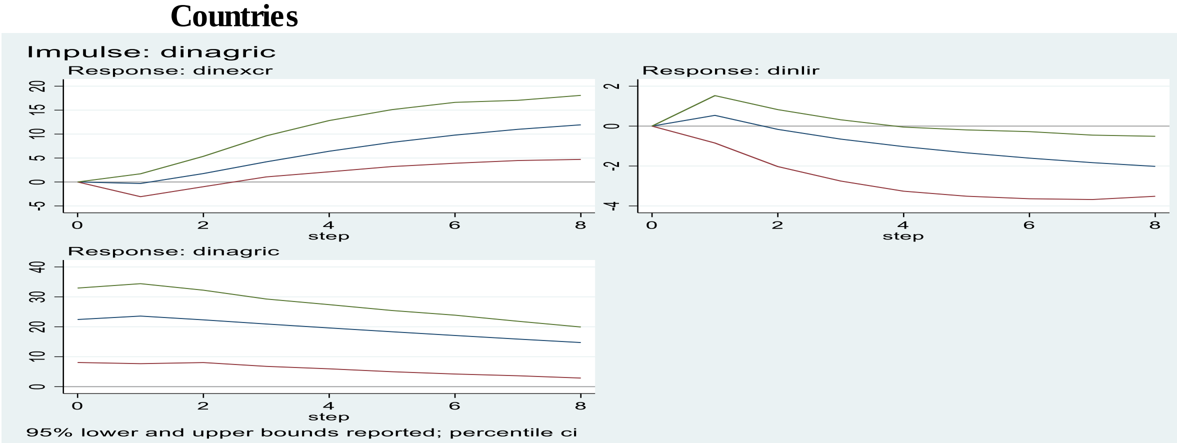

Figure 4.10: Impulse Response Function of Log Agricultural Earnings from the Six Selected Countries

4.9.2 Granger Causality Test

The results of the granger causality test to determine the causal effects among the variables are shown in table 4.10

Table 4.10: Granger Causality Test

panel VAR-Granger causality Wald test
Ho: Excluded variable does not Granger-cause Equation variable
Ha: Excluded variable Granger-causes Equation variable

Equation \ Excluded	chi2	df	Prob > chi2
dinexcr			
dinlir	1.655	1	0.198
dinagric	0.005	1	0.944
ALL	3.947	2	0.139
dinlir			
dinexcr	0.028	1	0.866
dinagric	0.020	1	0.888
ALL	0.128	2	0.938
dinagric			
dinexcr	0.062	1	0.803
dinlir	2.761	1	0.097
ALL	3.853	2	0.146

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4.9.4 Variance Decomposition Response

The results of the Variance Decomposition Response are shown in Table 4.11

Table 4.11: Results of Variance Decomposition Response Test

Forecast-error variance decomposition

Response variable and Forecast horizon	Impulse variable dinexcr	dinlir	dinagric
dinexcr			
0	0	0	0
1	1	0	0
2	.9976083	.0015185	.0008732
3	.9931267	.004906	.0019673
4	.9872927	.0098206	.0028867
5	.9805953	.0158634	.0035413
6	.973393	.0226535	.0039535
7	.9659587	.0298645	.0041768
8	.9584997	.037236	.0042644
9	.9511688	.0445716	.0042596
10	.9440742	.0517309	.0041949
dinlir			
0	0	0	0
1	.0214802	.9785197	0
2	.0334954	.9650124	.0014921
3	.0475057	.9490674	.0034269
4	.0632431	.9316463	.0051105
5	.0804756	.9131822	.0063422
6	.0989812	.8938914	.0071274
7	.1185403	.8739148	.0075449
8	.1389381	.8533747	.0076873
9	.1599682	.8323935	.0076382
10	.1814382	.8110975	.0074643
dinagric			
0	0	0	0
1	.001362	.0121477	.9864903
2	.0133398	.0391544	.9475059
3	.0352637	.0741212	.890615
4	.0646321	.1099209	.825447
5	.0982728	.1417221	.7600052
6	.1336352	.1675562	.6988086
7	.1690967	.1873547	.6435487
8	.203762	.201903	.5943351
9	.2371856	.2122047	.5506097
10	.2691699	.2191976	.5116324

Discussion of Findings

5.1 Time Plots

Figure 4.1, 4.2 and 4.3: Time Plot of the raw Series of log exchange rate(Inexchr), lending (Inlir) and Agricultural export earnings(Inagric) for the six selected countries

5.2 Descriptive Statistics Test

Table 4.1 contains the result for the descriptive test for normality and this test statistic provides basic information about the variables and highlights potential relationship between them. The results display descriptive statistics for the entire sample and the summary for each variable. It shows three different types of statistics and it include: overall, between and within. The 'overall' statistics is based on individual respective observations, the "between" statistics is calculated on the basis of summary statistics for the six countries (entities) regardless of their time(period) while "within" statistics is based on the summary statistics of time periods regardless of the country. The mean of exchange rate (inexchr) per country (in 246 observations) is 115.5822 with the range from 2.99e-08(Nigeria in 1980) to 737.3977(Egypt in 2020). Also, the mean of the lending interest rate(Inlir) per country (in 246 observations) is 26.666, with the range from -19.82(Nigeria in 1965) to 217.88(Egypt in 2020) and agricultural export earnings(Inagric) had a mean of 69.40477, with the range from 0.0427 (Nigeria in 1980) to 303.13(Egypt in 2020).

5.3 Unit Root Test

Table 4-2 contains panel unit root test results. This was done using the Im, Persaran & Shim, Levin, Lin, and Chu tests. According to Pesaran (2007), since there is cross-section dependence in the series, the 2nd generation of unit root tests and cross-sectionally augmented IPS (CIPS) tests were executed using the Im, Persaran & Shim, and Levin, Lin, and Chu tests. Series is I(1) and the CIPS test assumes cross-section dependence is in the form of a single unobserved common factor. In their first difference, all variables were stationary. Although, all the variables are stationary with and without trend and we can used the PVAR developed by Abrigo and Love (2016)

5.4 Differenced Series Time Plots

Figures 4.4, 4.5, and 4.6 show the time plot of the differenced series of log exchange rates (DInexchr), lending rates (DInlir) and agricultural export earnings (Dinagric) for the six selected countries. The series of the variables under investigation were changed to remove the trend and unit roots.

5.5 Lag-Order Selection Statistics for Panel VAR Model Estimation

Table 4.3 contains the VAR Lag Order Selection Criteria for the model. The lag order is selected using statistical information criteria. The overall coefficient of determination (CD), Hansen's J statistic (J), and its p-value (J p-value) were computed to determine the lag length of the model. Also, the MBIC, MAIC and MQIC were computed using the three model selection criteria by Andrews and Lu (2001) and were used to determine the maximum of four lags totaling 246 observations, 6 panels, and an average number of T of 41. Similarly, since MBIC and MQIC values are lower at one lag, a first-order PVAR was selected.

5.6 Co-integration Test

Table 4.4 contains co-integration results using the kao test for panel VAR model estimation. The result presented in Table 4.4, from the Kao test statistic indicates that the null hypothesis of no co-integrating relationship is accepted and the alternative hypothesis of co-integration is rejected. Therefore, the empirical properties of the variables examined require estimation of the VAR in first differences since no co-integration relationships exist between the (non-stationary) variables (in levels). According to Granger (1988), when a time series becomes stationary only after being differentiated once, it might have linear combinations that are stationary without differencing. These series are generally called co-integrated. If the integration of order one is implied, the next step is to use the co-integration analysis to determine whether there is a long-term relationship between the set of integrated variables. Panel cointegration tests are improved, aiming to analyze long-term relationships between panel series after advances in panel unit root tests.

5.7 Post Estimation Test on the Vector Autoregressive (VAR) Model

The post estimation tests, particularly the contemporary co-efficient of correlation, Granger causality test, stability test, variance decomposition response, and impulse response test were conducted on the Vector Autoregressive (VAR) Model and the results are as thus:

5.7.1 Contemporary Co-efficient of Correlation

Table 4.7 contains the results obtained from a contemporary coefficient of correlation analysis. It was found that the lending interest rate and the exchange rate are negatively associated with the co-efficient of correlation of (-0.0873). Also, it was found that there existed a positive association between the exchange rate and agricultural export earnings. Also, there is a positive association between lending interest rates and agricultural export earnings.

5.7.2 Dynamic Stability Test

The dynamic stability test was also conducted, and the result is presented in Figure 4.9. The graph shows that all roots lie inside the unit root circle and the detailed result shows that all moduli are less than one. The inverse roots of a characteristic polynomial satisfy the stability condition (of the diagnostic test) since no root lies outside the unit root circle. Therefore, the estimated VAR is stable.

5.7.3 Impulse Response Test

Table 4.9 contains the results of the impulse response test. It is well known that individual co-efficient estimated in panel data VAR models are usually difficult to interpret (Abrigo & Love, 2016 and Lutkepohl, 2005). Therefore, researchers mostly rely on the results of impulse response functions to determine or trace out the response of the dependent variable to shocks in the residual (error) terms in a panel VAR system. In this vein, the impulse response function (IRF) is seen as the center-piece of every Panel Data VAR model analysis.

However, the estimated panel data VAR model result is shown in the appendix to this paper. Figures 4.8, 4.9, and 4. 10 present impulse response functions of log exchange rates from the six selected countries. Each of these IRFs is generated by Monte Carlo simulations with 200 repetitions. Areas between the upper and lower lines have a 95% confidence interval for IRFs over the next 10 years. The three variables estimated using the XTVARs consist of the exchange rate, lending rate, and agricultural export earnings. The impulse response functions in Figure 4.8 show that exchange rate have negative effect on lending rate before the gradual decline with positive but low impact. Reaching its minimum level in the first period, the increase in growth level appears to be nearly 0.06 percent. There is a positive response to agricultural export earnings and it is statistical meaningfulness from the 4th period. However, increases in lending rates and exchange rates are likely to have a negative effect on agricultural export earnings. These results indicate that the economic impact of the exchange rate on agriculture might be positive but limited in the case of the six countries, whereas the exchange rate is likely to reduce the level of lending interest rates slightly.

Figure 4.9 shows the impulse response function of the log lending interest rate from the six selected countries. According to impulsive response functions obtained from the lending interest rate (Figure 4.9), the reaction of the exchange rate in response to an impulse given to lending interest is negative and significant during the entire period. However, after five periods, the economic effects of an increase in lending interest are likely to decrease. A plausible explanation is that in developing countries, high exchange rate may be due to borrowing rather than investing in the economy. The response of agricultural export earnings has been positive during the entire period. Figure 4.10 shows the impulse response function of log agricultural earnings from the six selected countries. The effect of a change in agricultural export earnings is different from the lending interest rate and exchange rate. An expansion in agricultural earnings have positive effect on lending interest rates and exchange rates. This finding indicates that increasing agricultural export earnings has a long-term effect on economic growth and poverty reduction. This leads to the inclusion of growth in selected counties. Therefore, higher rate of expenses accrued from lending interest rates and exchange rates will not have effect on incomes generated from agricultural export commodities.

5.7.4 Variance Decomposition Response

Table 4.11 shows the result of variance decomposition test for interest rate, maximum lending rate, prime lending rate and exchange rate. The percentage of the forecast error variance shows that in the short run, 100% forecast variance in exchange rate is self-explained lending rate, and agricultural earnings however, shows very weak influence in predicting interest rate, therefore they are strongly exogenous. As we move into the future exchange rate decreases while lending rate, and exchange rate increases but were not strongly exogenous as the percentage forecast variance of exchange rate was 94.40% in the long run while the percentage forecast variance of lending rate and agricultural earnings were 5.17%, and 0.419% respectively. Also, the percentage of the forecast error variance shows that in the short run, 97.85% forecast variance in lending rate is self-explained. Exchange rate and agricultural earnings, shows very weak influence in predicting lending rate and were strongly exogenous lending interest rate decreases while exchange rate and agricultural earnings increases as we move into the future but were not strongly exogenous as the percentage forecast variance of lending rate was 81.11% in the long run while the percentage forecast variance of exchange rate and agricultural earnings were 18.14% and 0.75% respectively. Similarly, the percentage of the forecast error variance show that in the short run, 98.65% forecast variance in the agricultural earnings was self-explained lending rate and exchange rate shows very weak influence on agricultural earnings and were strongly exogenous. Agricultural earnings decrease while lending rate and Exchange rate increases as we move into the future but were however not strongly exogenous because the percentage forecast variance of agricultural earnings in the long run was 51.16 % while the percentage forecast variance of lending rate and exchange rate were 21.91 % and 26.92% respectively.

5.8. Granger Causality

Table 4.10 contains the estimates of the granger causality test. The results revealed that the causality does not exist (or run) between any of the variables since their p-values of causalities are greater than the standard probability value of (0.005). Also, it was confirmed that there is no directional relationship that exist between the variables.

6.1 Conclusion

The study: exchange rate, interest rate and agricultural export earnings: an analysis using Panel VAR Model. The study uses vector Autoregressive model estimation results using PVAR Stata code developed by Abrigo and love (2015). The post estimation test on the Vector Autoregressive (VAR) Model shows a contemporary co-efficient of correlation analysis. It was found that lending interest rate and exchange rate are negatively associated with co-efficient of correlation of (-0.0873). Also, it was found that there exist a positive association between exchange rate and agricultural export earnings. Also, there is positive association between lending interest rate and agricultural export earnings. The Inverse roots of a characteristic polynomial of the estimated Panel VAR model satisfied the stability condition (of the diagnostic test) since no root lied outside the unit root circle. Therefore, the estimated VAR is stable. However, it was confirmed that there is no directional relationship that exist between the variables. The null hypothesis of no co-integrating relationship is accepted, while the alternative hypothesis of co-integration is rejected. Also, it was confirmed that there is no directional relationship that exist between the variables. Again, there is no bi-directional relationship between exchange rate, interest rate and agricultural export earnings from six African countries. These results indicated that the economic impact of exchange rate and lending rate on agriculture might be positive but limited in the case of the six countries whereas exchange rate is likely to reduce the level of lending interest rate slightly. The results of the granger causality test revealed that the causality does not exist (or run) between any of the variables since their p-values of causalities are greater than the standard probability value of (0.005). conclusively, the heterogeneities present in interdependencies in the dynamic interaction between exchange rate, interest rate and agricultural export earnings were perfectly captured in the PVAR developed by Abrigo and Love (2015) estimation. In PVAR estimation, it is assumed that the estimated errors are homoscedastic and serially uncorrelated and so the first –difference transformation is consistently estimated equation-by –equation by injecting lagged difference with difference and levels from earlier periods as suggested in Anderson and Hsiao (1982). The parameters of panel VAR model were well estimated. In the identification of the shock associated with their dynamic interactions, exchange rate was found to have negative effect on lending rate before the gradual decline with positive but low impact . Although, they are strongly exogenous.

6.2 Recommendations

The following recommendations were made based on the results obtained in the study and they include:

1. In modeling the dynamic interaction between exchange rate, interest rate and agricultural export earnings using Panel VAR Model of the six African countries, there is need for the inclusion of the lags of the response variable among the determinants (Agricultural export earnings, interest rate and exchange rate), particularly for multivariate models. The presence of lags measures the dynamic interaction as well capture heterogeneities in the series.
2. There is also the need for policies, which will stabilize exchange rate and lending interest rate so that their response to shock will significantly improve the economy of these six African Countries.
3. Having identified the fact that the economic impact of exchange rate and lending rate on

agricultural export earnings might be positive but limited in the case of the six countries, whereas exchange rate is likely to reduce the level of lending interest rate slightly, government of these countries need to invest more in the agricultural sector with a view to reduce the economic impact of exchange rate and lending rate.

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Appendix

Result of the Panel Data VAR Estimation

```
. xtvar dinexcr dinlir dinagric
. . . . . . . . . . . . . . . . . . . . . . . . .  100
. . . . . . . . . . . . . . . . . . . . . . . . .  200
.
Panel (LSDV) vector autoregression              Number of obs      =       234
Group variable: cid                             Number of groups   =         6

                                                Obs per group      =        39
```

Equation	Parms	RMSE	R-sq	F	P > F
dinexcr	12	27.7002	0.9785	254.725	0.0000
dinlir	12	14.6722	0.8799	117.6859	0.0000
dinagric	12	22.4607	0.8313	178.1515	0.0000

F statistic for F(6,222)

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
dinexcr						
l1_dinexcr	1.077626	.0666745	16.16	0.000	.9462304	1.209022
l1_dinlir	-.0514469	.1259833	-0.41	0.683	-.2997232	.1968293
l1_dinagric	-.0142132	.1383774	-0.10	0.918	-.2869145	.2584881
l2_dinexcr	-.1806816	.0679335	-2.66	0.008	-.3145587	-.0468044
l2_dinlir	-.0634664	.1228111	-0.52	0.606	-.3054912	.1785584
l2_dinagric	.1100411	.1521545	0.72	0.470	-.1898109	.409893
dinlir						
l1_dinexcr	.0676103	.0353161	1.91	0.057	-.0019874	.1372079
l1_dinlir	.821834	.0667307	12.32	0.000	.6903272	.9533408
l1_dinagric	.0239762	.0732956	0.33	0.744	-.120468	.1684204
l2_dinexcr	-.0729101	.035983	-2.03	0.044	-.143822	-.0019981
l2_dinlir	.0296156	.0650505	0.46	0.649	-.0985799	.1578111
l2_dinagric	-.0512833	.0805931	-0.64	0.525	-.2101086	.1075421
dinagric						
l1_dinexcr	.0354418	.0540628	0.66	0.513	-.0711002	.1419838
l1_dinlir	.000541	.1021533	0.01	0.996	-.2007732	.2018552
l1_dinagric	1.051116	.1122029	9.37	0.000	.8299966	1.272235
l2_dinexcr	-.0536389	.0550838	-0.97	0.331	-.1621929	.0549151
l2_dinlir	-.0249995	.0995811	-0.25	0.802	-.2212447	.1712458
l2_dinagric	-.1097016	.1233741	-0.89	0.375	-.3528358	.1334326