

Time Varying Correlation of Stock Returns Relative to Exchange Rate and Inflation Rate and also Their Volatilities: Evidence from Nigeria

C.G Amaefula¹ and B.K Asare²

¹Department of Mathematics and Statistics Federal Polytechnic Kaura Namoda, Zamfara State, Nigeria

²Department of Mathematics Usmanu Danfodiyo University Sokoto Sokoto State, Nigeria

Abstract: This paper investigates the time varying correlation of stock returns relative to exchange rate and inflation rate and their volatilities in Nigeria. The data sets on monthly All Shares Index prices of the NSE market, monthly official exchange rate of naira per unit of one US dollar and consumer price index cover the period of 1985M1-2010M12. The Diagonal BEKK (1, 1) model was adopted to capture time varying correlation and regression model was used to test the significant of time trend and global financial crises on the correlations. The results reveal that the correlation of stock market returns relative to exchange rate and inflation rate seems to be constant over time while the correlation of stock returns volatility relative to volatility of exchange rate and inflation vary over time and the trends exhibit a downward slope. This implies that the magnitude of their interdependence have decreased over time. The global financial crises have significant negative effect on the correlation between stock returns and exchange rate and between stock returns volatility and inflation volatility. This implies that external shocks are likely to reduce the degree of interdependence between stock returns and exchange rate and between stock returns volatility and inflation volatility.

Keywords: Correlation, Diagonal BEKK, Stock Returns, Exchange Rate, Inflation

I. Introduction

In the past two decades now researchers have devoted much time and interest studying the impacts of macroeconomic indicators on stock market returns and volatility. No study seemed to have examined the structure of interdependence between stock market returns and macroeconomic variables. Correlation between stock returns and each of these macroeconomic variables under investigation gives us an idea concerning how they move over time in relation with each other and the lower the correlation, the lesser the level of dependence between the variables.

The recent global financial crises which brought setbacks in financial stability as volatility increased and risk appetite declined have re-awakened the need for more intensive research to restore financial and economic stability across the globe. According to [1], Nigerian economy faltered and the banking system experienced a crisis in 2009, triggered by global events. The stock market collapsed by 70% in 2008-2009 and many Nigerian banks had to be rescued. This development has spurred the need for the dimension of this research for better macroeconomic policy that engenders economic and financial stability via empirical findings across the globe.

[2] is one of the earliest studies that investigated the structure of correlations and covariances between national stock market indices. Her result showed that the correlation matrix over four equal 46 months sub-periods is more stable than the counterpart covariance matrix using both the Jenrich and Box tests. The instability in the covariance matrix is attributed to the non-stationarity of a few variances which cause a structural change in the level of the covariances. [3],[4], [5] are earlier studies that have only shown that correlation between national stock market indices tends to vary over phases of business cycle. These earlier studies investigated the structure of correlations between national stock market indices and no study seemed to have examined the time varying correlation between stock market returns and macroeconomic variables.

This paper is the first of its kind and it is unique in the following sense; firstly, it examines the structure of correlation of stock returns relative to exchange rate and inflation rate. Secondly, it also investigates whether there exist time varying correlation between the volatility of stock returns and the volatility of these macroeconomic variables under investigation. Thirdly, it examines the dimension of the time trend of the correlations and finally, it investigates the effect of the global financial crises on these correlations. This study however, widens the scope of existing literature on the subject matter.

The rest of this paper is arranged as follows; section 2 deals with the material and methodology, section 3 deals with data analysis and results and section 4 is the conclusion and implications.

II. Material And Methodology

The data sets in this research consist of monthly All Shares Index prices of the NSE market, monthly official exchange rate of naira per unit of one US dollar and consumer price index (CPI) were all obtained through transcription from the published CBN Statistical Bulletins (2010) and the data sets cover the period of 1985 M1-2010 M12.

The compounded monthly index returns, exchange rate and inflation were calculated as the first difference of the natural logarithm of current and previous months of observations multiplied by 100. And they are constructed as follows; The stock returns is given as $sr_t = 100 \times (\log SPI_t - \log SPI_{t-1})$, the exchange rate is given as $er_t = 100 \times (\log EXR_t - \log EXR_{t-1})$ and the inflation rate is given as $ifr_t = 100 \times (\log INFR_t - \log INFR_{t-1})$.

2.1 Measuring Volatility of the Variables

Simple generalized autoregressive conditional heteroscedasticity (GARCH(1, 1)) model introduced by [6] was adopted to measure the volatility of stock returns, exchange rate and inflation with a fat-tailed distribution. The mean and the conditional variance equations are given below;

$$\begin{cases} r_t = \mu + \varepsilon_t \\ \sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \end{cases} \quad (1)$$

where $\varepsilon_t \rightarrow \text{GED}(\nu, 0, \sigma_t^2)$ and the tail parameter $\nu > 0$. The GED is a normal distribution if $\nu = 2$ and fat-tailed if $\nu < 2$. According to the property of GARCH model $0 \leq \alpha, \beta \leq 1$ and $(\alpha + \beta) < 1$ shows that the model is covariance stationary. Again, a large ε_{t-1}^2 or σ_{t-1}^2 , gives rise to a large σ_t^2 . This means that a large ε_{t-1}^2 tends to be followed by another large ε_t^2 , generating again, the well-known behavior of volatility clustering in financial time series.

2.2 The Diagonal BEKK Specification for Capturing Time Varying Correlation

The Diagonal BEKK parameterization of the multivariate GARCH(1, 1) model was adopted to capture the time varying correlation where it exist. This procedure can also be adopted to study the nature of correlation between their volatilities. Are the higher correlation structures associated with financial crises? The model is of the form;

$$Y_t = C + \varepsilon_t \quad (2)$$

where $Y_t = [y_{1t}, \dots, y_{nt}]$ is an $n \times 1$ vector of response variables. C is the vector of constants, $\varepsilon_t = [\varepsilon_{1t}, \dots, \varepsilon_{nt}]$ is an $n \times 1$ error vector such that $\varepsilon_t \sim N(0, H_{it})$, where H_{it} is the time varying variance-covariance matrix condition on information available at time $t-1$. The error vector in (2) is given as $\varepsilon_t = H_t^{1/2}(\theta)Z_t$. Where $H_t^{1/2}(\theta)$ is a $N \times N$ positive definite matrix. Also, we assume the $N \times 1$ random vector Z_t such that, $Z_t \sim N(0, I_N)$ where, I_N is an identity matrix of order N .

$$H_t = C + \sum_{i=1}^q A_i \varepsilon_{t-i} \varepsilon_{t-i}' A_i' + \sum_{i=1}^p B_i H_{t-1} B_i' \quad (3)$$

Where A_i and B_i are $(N \times N)$ diagonal parameter matrix respectively and C is defined as an $(N \times N)$ positive definite matrix of parameters. Hence, equation (3) becomes

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{12,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1} \varepsilon_{2,t-1} \\ \varepsilon_{1,t-1} \varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix} \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{12,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix} \quad (4)$$

And allowing the correlation to vary over time, the conditional correlation is given as

$$\rho_{ij,t} = (h_{ij,t}) \times (h_{ii,t} h_{jj,t})^{-\frac{1}{2}} \tag{5}$$

where $h_{ij,t}$ is the time varying conditional covariance and $h_{ii,t}$ and $h_{jj,t}$ are time varying conditional variances.

2.3 Regression Model of Time Varying Correlation

The method of regression model was used to test the hypotheses that the time trend in the time-varying correlations is not significant. Also, we examined the impact of the global financial crises on the correlation (degree of relationship) between stock market returns and each of the macroeconomic variables and their volatilities. The model is used to regress the time-varying correlations against a constant, time trend and a dummy variable for the period of global financial crises. The model is of the form;

$$\rho_{ij,t} = \beta_0 + \beta_1 t + \beta_2 D_t + e_{it} \tag{6}$$

Where, β_0 , β_1 , and β_2 are regression coefficients. $\rho_{ij,t}$ is the time varying correlation between stock returns and each of the macroeconomic factors respectively, t is the time trend, D_t is the dummy variable for the period of global financial crises and e_{it} is the error term and it assumed to be normally distributed. The dummy variable takes the value zero (0) before the global financial crises and the value one (1) during the global financial crises. If the p-value for the β_1 is significant, then the null hypothesis of constant correlation between stock returns and the macroeconomic factor under consideration is rejected.

III. Data Analysis And Results

An examination of the summary statistics in Table 1 below clearly shows that the average monthly returns are positive. And from the monthly standard deviation, it is apparent that er_t is most volatile, followed by sr_t . The ifr_t is the least volatile. The statistics show excess kurtosis since the kurtosis of all the variables exceed the normal value of 3, and the skewness are all positive except stock returns that is skewed to the left (negatively skewed). These show fat tails and sharper peaks than the normal distribution. This leptokurtic behaviour is not captured by an ARCH process with a normal distribution. The Jarque-Bera normality test confirms the non-normality of the distributions of all the variables. Therefore the GARCH model with generalized error distribution can be employed to address the excess kurtosis.

Table 1. Summary Statistics

Variables	sr_t	er_t	ifr_t
Mean	0.017380	0.016760	0.016605
Std.Dev	0.062041	0.290582	0.043727
Skewness	-0.596348	0.567930	4.115697
Kurtosis	11.38503	114.2834	25.53489
Jarque-Bera	929.5176	160492.5	7458.520
Prob	0.000000	0.000000	0.000000
Sum Sq. Dev	1.193206	26.17583	0.592733
Observation	312	312	312

Table 2. Unit Root Test using Elliot Rothenberg, and Stock Point Optimal (ERS)

Variable	Deterministic Terms	Lags	Test value	critical values			Result
				1%	5%	10 %	
sr_t	C	4	0.440351	1.954400	3.219950	4.413250	Stationary
	C, t	1	0.828020	4.000050	5.637800	6.876650	Stationary
er_t	C	1	0.122351	1.954400	3.219950	4.413250	stationary
	C,t	1	0.449949	4.000050	5.637800	6.876650	stationary
ifr_t	C	2	0.870402	1.954400	3.219950	4.413250	Stationary
	C,t	2	2.966176	4.000050	5.637800	6.876650	Stationary

The results of the [7] unit root test in Table 2 above shows that all the variables are stationary at 1%, 5% and 10% respectively. The lag order used in the Elliot Rothenberg, and Stock Point Optimal (ERS) Test were suggested by the model selection criteria.

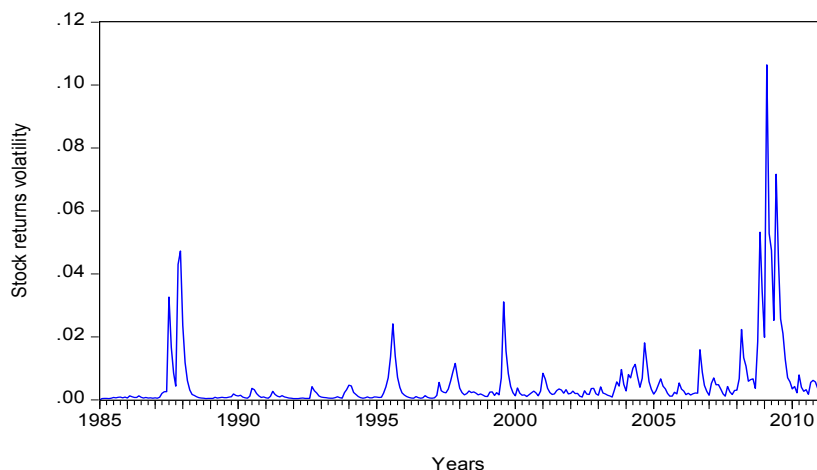


Figure1. Plot of stock returns volatility using the conditional variance from GARCH(1, 1) model

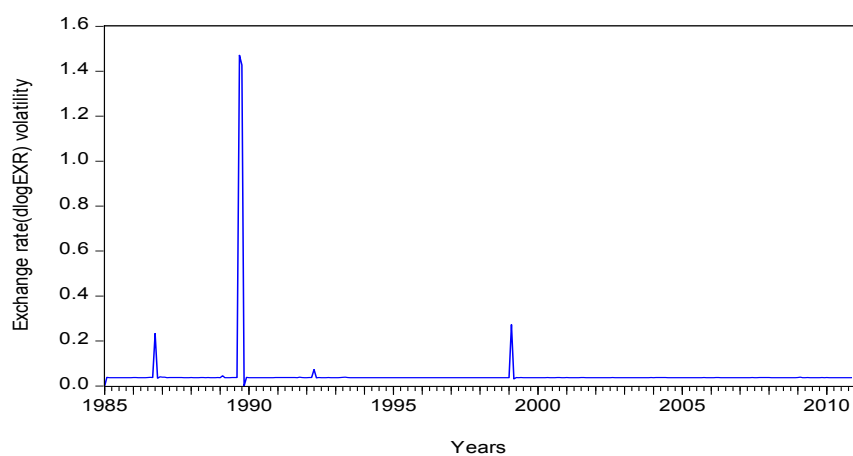


Figure 2. Plot of exchange rate volatility using the conditional variance from GARCH(1, 1) model.

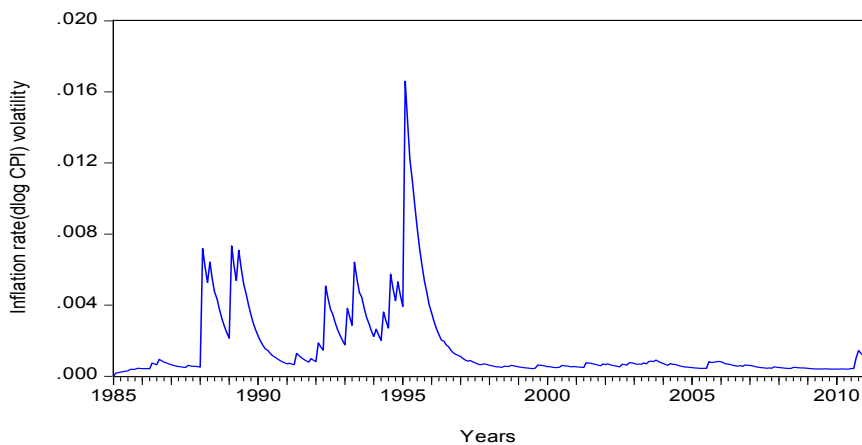


Figure 3. Plot of inflation volatility using the conditional variance from GARCH(1, 1) model.

Table 3. Estimates of Diagonal BEKK (1, 1) model for stock returns and exchange rate

Parameter	Series 1 (stock returns) Series 2 (exchange rate)			Remarks
	Coefficients	t-value	p-value	
Cst 1	2.1587	7.312*	0.0000	Significant at 1%
Cst 2	-0.0000	-0.0016	0.9987	
C ₁₁	2.7804	4.797*	0.0000	Significant at 1%
C ₁₂	-0.0000	-0.0059	0.9953	
C ₂₂	0.0000	0.0074	0.9941	
A ₁₁	0.2638	2.453**	0.0147	Significant at 5%

A ₂₂	0.9109	12.45*	0.0000	Significant at 1%
B ₁₁	0.9282	47.36*	0.0000	Significant at 1%
B ₂₂	0.3846	4.388*	0.0000	Significant at 1%
Log likelihood	-913.845			
Q-statistics Series 1 Series 2	Q(50)=6.7937 Q(10)=0.2095		1.0000 1.0000	No serial correlation in the squared residuals up to 50 th and 10 th lags for Series 1 and series 2 respectively

The symbol (*) and (**) denote significant at 1% and 5% respectively.

Table 4. Estimates of Diagonal BEKK (1, 1) model for stock returns and inflation rate

Parameter	Series 1 (stock returns) Series 2 (inflation rate)			Remarks
	Coefficients	t-value	p-value	
Cst 1	1.9955	6.208*	0.0000	Significant at 1%
Cst 2	0.7013	6.366*	0.0000	Significant at 1%
C ₁₁	3.6426	1.562	0.1194	
C ₁₂	-0.3728	-0.8395	0.4019	
C ₂₂	0.6181	1.899***	0.0585	Significant at 10%
A ₁₁	0.8230	4.345*	0.0000	Significant at 1%
A ₂₂	0.1799	2.173**	0.0306	Significant at 5%
B ₁₁	0.5680	1.243	0.2150	
B ₂₂	-0.9395	-37.25*	0.0000	Significant at 1%
Log likelihood	-1661.174			
Q-statistics Series 1 Series 2	Q(50)=50.0307 Q(10)=11.0124		0.47281. 0.3566	No serial correlation in the squared residuals up to 50 th and 10 th lags for Series 1 and series 2 respectively

The symbol (*), (**), and (***) denote significant at 1%, 5% and 10% respectively

The summary of diagonal BEKK (1, 1) models estimates in Table3 and Table4 were used to capture the time varying correlations between stock returns and exchange rate and also between stock returns and inflation rate respectively. The parameters are well specified and based on the Q-statistics, the models are adequate.

Table 5. Regression estimates of time-varying correlations of stock returns relative to exchange rate and inflation rate against a constant, time trend, a dummy variable for the period global financial crises

Variables	Regression Model			Time varying Correlation mean	R ²
	$\rho_{ij,t} = \beta_0 + \beta_1 t + \beta_2 D_t + e_{it}$				
	Coefficients				
	β_0	β_1	β_2		
er_t	-0.0253599 [-1.35] (0.1782)	4.68220e-005 [0.383] (0.7023)	-0.0612292 [-2.02] (0.0440)**	-0.0274661	0.0172
ifr_t	-0.0505626 [-4.51] (0.0000)*	-2.63975e-006 [-0.0361] (0.9712)	-0.00541481 [-0.300] (0.7647)	-0.0518168	0.0006

The symbols [], (), * and ** denote t-value, p-value, significant at 1% and 5% respectively.

The summary result of table 5 shows that the trend value is not significant for correlation of stock market returns relative to exchange rate and inflation rate. This indicates that the null hypothesis of constant correlation of stock market returns relative to exchange rate and inflation rate respectively, cannot be rejected. The result shows that the mean value of the correlations are all negative, R² is the coefficient of determination, which gives the ratio of explained variation to total variation. And the global financial crises has negative impact on the correlation of stock market returns relative to exchange rate and inflation rate, but, it is significant relative to exchange rate at 5% levels and insignificant relative to inflation rate. This implies that the global financial crises have caused a sharp drop in the magnitude of interdependence between stock market returns and exchange rate. These results are more visible considering Figure 4 and 5 below.

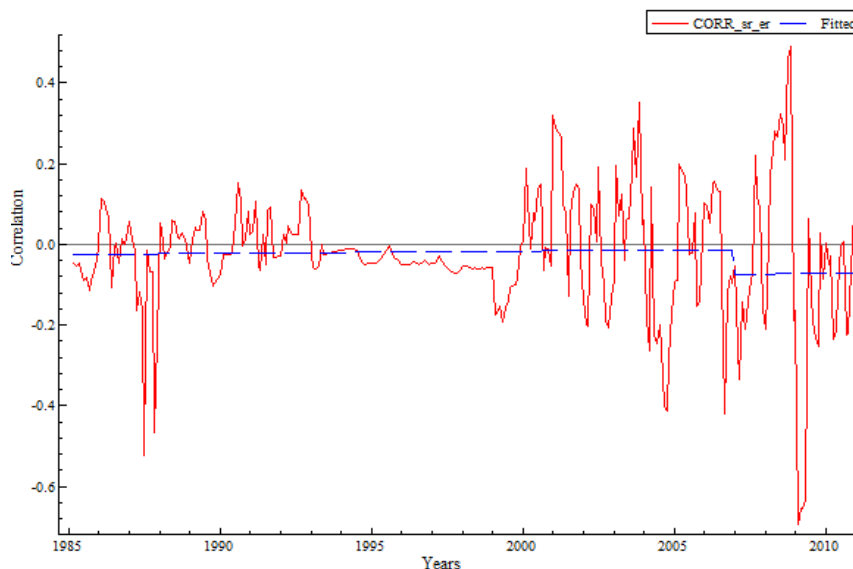


Figure 4. Fitted trend lines for time varying correlation between stock returns and exchange rate.

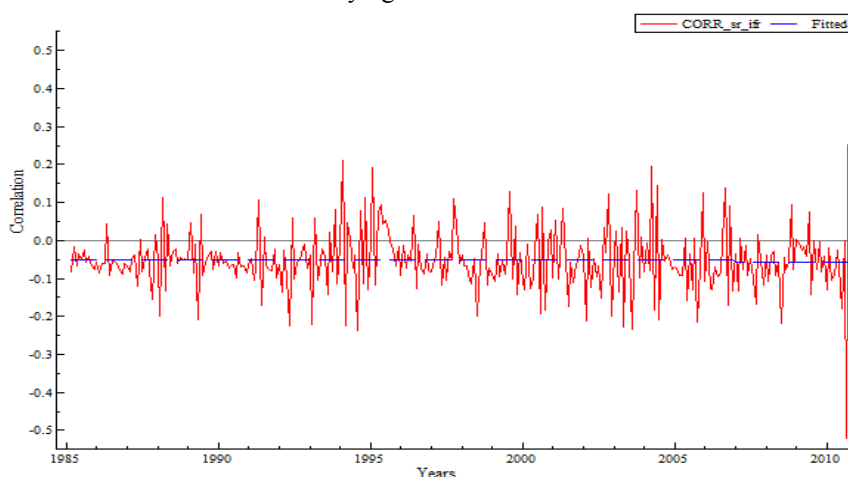


Figure 5. Time varying correlation between stock returns (sr) and inflation rate (ifr) with a fitted trend line.

Table 6. Estimates of Diagonal BEKK(1, 1) specification of stock returns volatility and exchange rate volatility

Parameter	Series 1 (stock returns volatility) Series 2 (exchange rate volatility)			Remarks
	Coefficients	t-value	p-value	
Cst 1	0.0010	0.6340	0.5265	
Cst 2	0.0459	6.535	0.0000*	Significant at 1%
C ₁₁	0.0020	1.929	0.0546***	Significant at 10%
C ₁₂	-0.0020	-0.3552	0.7227	
C ₂₂	0.0832	2.115	0.0352**	Significant at 5%
A ₁₁	0.8506	1.709	0.0885***	Significant at 10%
A ₂₂	0.5390	2.796	0.0055*	Significant at 1%
B ₁₁	0.5257	2.658	0.0083*	Significant at 1%
B ₂₂	0.0015	0.3708	0.7111	
Log likelihood	1565.352			
Q-statistics				No serial correlation in the squared residuals up to 50 th and 50 th lags for Series 1 and series 2 respectively
Series 1	Q(50)=1.5801		1.0000	
Series 2	Q(50)=0.3223		1.0000	

The symbol (*) and (***) denote significant at 1% and 10% respectively.

Table 7. Estimates of Diagonal BEKK(1, 1) specification for stock returns volatility and inflation rate volatility

Parameter	Series 1 (stock returns volatility) Series 2 (inflation rate volatility)			Remarks
	Coefficients	t-value	p-value	
Cst 1	0.0003	0.4450	0.6567	Significant at 1%
Cst 2	0.0006	10.31*	0.0000	
C ₁₁	0.0015	1.901***	0.0583	Significant at 10%
C ₁₂	0.0001	1.162	0.2462	
C ₂₂	0.0004	6.368*	0.0000	Significant at 1%
A ₁₁	0.8703	4.443*	0.0000	Significant at 1%
A ₂₂	0.7852	4.908*	0.0000	Significant at 1%
B ₁₁	0.4925	2.867*	0.0044	Significant at 1%
B ₂₂	0.6193	4.138*	0.0000	Significant at 1%
Log likelihood	3000.405			
Q-statistics				No serial correlation in the squared residuals up to 50 th and 50 th lags for Series 1 and series 2 respectively
Series 1	Q(50)=15.9881		1.0000	
Series 2	Q(50)=2.2978		1.0000	

The symbol (*)and (***) denote significant at 1% and 10% respectively.

The summary of diagonal BEKK (1, 1) models estimates in Table 6 and Table 7 were used to capture the time varying correlations between stock returns volatility and exchange rate volatility and also between stock returns volatility and inflation rate volatility respectively. The parameters are well specified and based on Q-statistics, the models are adequate.

Table 8. Regression estimates of time-varying correlations of stock returns volatility relative to the volatility of exchange rate and inflation rate against a constant, time trend, a dummy variable for the period global financial crises

variables	Regression Model			Time varying Correlation Mean	R ²
	$\rho_{ij,t} = \beta_0 + \beta_1 t + \beta_2 D_t + e_{it}$				
	Coefficients				
	β_0	β_1	β_2		
$\sigma_{er,t}^2$	-0.0181 [-5.23] (0.0000)*	-8.776e-005 [-3.90] (0.0001)*	-0.0008 [-0.144] (0.8855)	-0.0319	0.0778
$\sigma_{ifr,t}^2$	0.3451 [11.8] (0.0000)*	-0.0005 [-2.82] (0.0051)*	-0.3170 [-6.66] (0.0000)*	0.2122	0.2872

The symbols [], (), * and ** denote t-value, p-value, significant at 1% and 5% respectively.

The result in Table 8 shows that mean value of the correlation is negative relative to the volatility of exchange rate and positive relative to the volatility of inflation rate. The result also shows that the trend parameters are negative and significant at 1% level respectively. This result indicates that the null hypothesis of constant correlation is rejected in favour of the alternative. The result also shows that the correlation of stock market returns volatility relative to the volatility of exchange rate and inflation rate exhibits a downward trend over time. These results are more visible in Figure 6, and 7 below. The result also shows that the global financial crises exert significant negative effect on the time varying correlation between stock returns volatility and inflation volatility. But relative to exchange rate volatility, correlation is negative and insignificant.

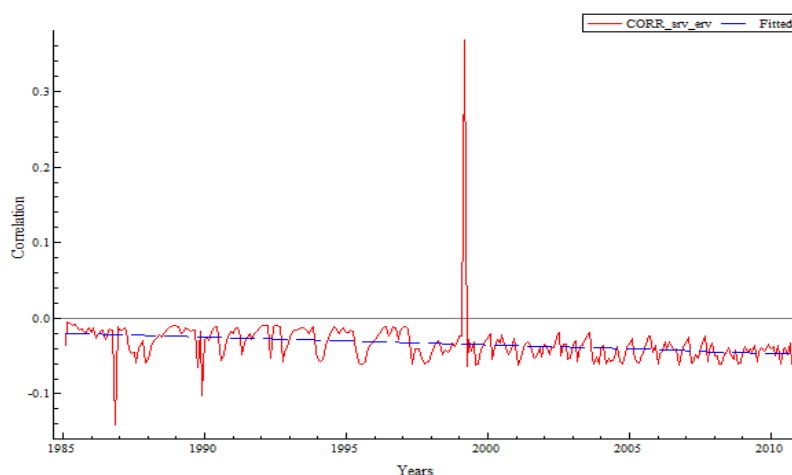


Figure 6. Fitted trend line for time varying correlation between stock returns volatility and exchange rate volatility.

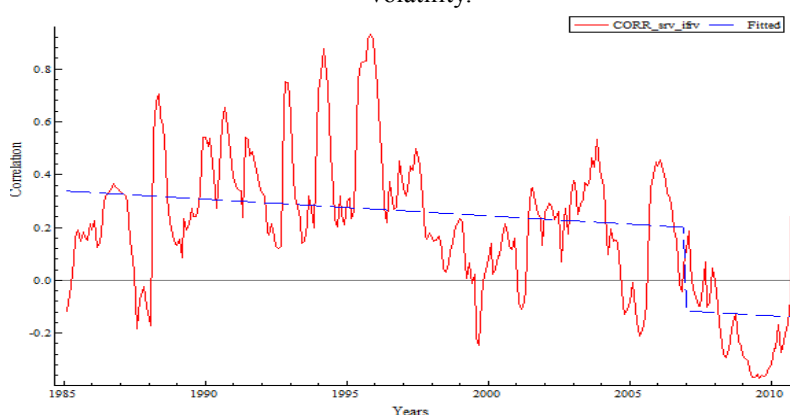


Figure 7. Fitted trend line for time varying correlation between stock returns volatility and inflation rate volatility.

IV. Conclusion And Implications

The paper examines the time varying correlation of stock returns relative to exchange rate and inflation rate and volatility in Nigeria. And GARCH(1, 1) was employed to measure the volatility of the variables. The Diagonal BEKK parameterization of the multivariate GARCH(1, 1) model was adopted to capture the time varying correlation where it exist and the regression model was used to test the significant of the time trend and the global financial crises on the correlations.

The results reveals that the correlation of stock market returns relative to exchange rate and inflation rate seems to be constant over time while the correlation of stock returns volatility relative to exchange rate volatility and inflation volatility vary over time and the trends exhibit a downward slope. This implies that the magnitude of their interdependence have decreased over time. And if the trend between these volatilities continues as the empirical results have shown, then, one can say that the NSE market may not consider the volatility of exchange rate and inflation as a threat. The result also shows that the global financial crises have significant negative effect on the correlation between stock returns and exchange rate and between stock returns volatility and inflation volatility. This implies that external shocks are likely to reduce the degree of interdependence between stock returns and exchange rate and between stock returns volatility and inflation volatility. However, the findings of this study may not only serve as an eye opener for policy makers in developing macroeconomic policies that could serve as a hedge against external shocks, but also as a basis for further research.

References

- [1]. Bollerslev, T., Generalized Autoregressive Conditional Heteroscedasticity. *Journal of Econometrics*, 31, 1986, 307-327.
- [2]. Central Bank Nigerian Statistical Bulletin, website: www.cbn.gov.ng.2010.
- [3]. Elliott, G., Rothenberg, T. J., and Stock, J. H., Efficient Test for an Autoregressive Unit Root, *Econometrica*, 64, 1996, 813-836.
- [4]. Erb, C., Harvey, C. and Viskanta, T., Forecasting International Equity Correlations, *Financial Analysts Journal*, 1994, 50, 32-45.
- [5]. Kaplanis, E., Stability and Forecasting of the Co-movement Measures of International Stock Market Return, *Journal of International Money and Finance*, 8, 1988, 63-75.

- [6]. Longin, F and Solnik, B., Is the Correlation in International Equity Returns Constant: 1960-1990? *Journal of International Money and Finance*, 1995, 14, 3-26.
- [7]. Raganathan, V., Faff, R and Brooks, R., Correlations, Business Cycles and Integration, *MIMEO*, Royal Melbourne Institute of Technology. 1997
- [8]. Sanusi, L. S., The Nigerian Banking Industry: what went wrong and the way forward. A Convocation Lecture delivered at the Bayero University, Kano, Nigeria. 2010,