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Modeling The Nigerian Stock Exchange Data Characterized with Heteroscedasticity Disturbances Using Bayesian Approach

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Abstract

The stock exchange plays a crucial role in influencing the development of a country's economy and growth.. This paper examines the Nigerian Stock Exchange data in the presence of heteroscedasticity disturbances parameters of Nigerian Stock Exchange using a wide range of variables. The results indicate that Bayesian estimation is reliable since the parameter estimates are consistent. Finally, Bayesian estimation when heteroscedasticity structure is present performs better than the homoscedasticity counterpart.

Keywords: *Bayesian estimation, heteroscedasticity, homoscedasticity, prior, posterior distribution.*

1 Introduction

The Nigerian Stock Exchange (NSE) was established and named as the Lagos stock exchange in 1960. The name existed till November 1977 when it was renamed in December 1977 and known as the Nigerian Stock Exchange (NSE) with its head office situated in Lagos State south western Nigeria. The Nigerian Stock Exchange (NSE) in 1988 recorded 5.1 billion naira in annual market capitalization and has continued to increase until 1997 when it dropped to 276.3 billion naira from 279.8 billion naira in 1996 and reduced further by 19.5 billion naira in 1998. It has since been following an upward trend that got to its peak of 10301 billion naira in 2007 and later crumbled to 3343.5 billion naira in 2008 (CBN, Bulletin, 2008).

The stock exchange plays a crucial role in influencing the development of a country's economy. As a result of this crucial role, this has also drawn much attention from both the statisticians and economists on theoretical and empirical analysis. Several studies have been carried out on stock exchange and others macroeconomic variables. Prominent amongst is the work of Maghyereh (2004) that investigated the linkages between crude oil price and stock market return in twenty-two emerging countries and found that oil shocks have no significant impact on stock index return.

Sadorsky (1999) showed that changes in oil price significantly affects stock returns using an unrestricted vector autoregressive (VAR) model with Generalized Autoregressive Conditional Heteroscedasticity models on US monthly data. Adjasi and Biekpe (2005) in their work investigated the relationship between stock market returns exchange rate movements in seven African Countries. Co-integration test showed that in the long-run exchange rate depreciation leads to increase in stock market prices in some of the countries and in the short-run, exchange rate depreciation reduces stock market return.

Solnik (2006) opines that there is a negative correlation between stock market and local currency. Golub (1983) and Krugman (1983) asserted in their work that both revealed that a country exporting oil may face exchange rate appreciation when oil price rises, and exchange rate depreciates, if otherwise. Osabuohien-Irabor (2016) investigated Volatility, Spillover Effects among Foreign Exchange Rates, Oil Price Fluctuation and the Nigerian using A Multivariate VAR-EGARCH-CC Analysis and suggests the existence of leverage effect in the currency market and in crude oil market.

A stock market is a complex market place, where stocks and shares are the traded commodity. Arnold (2004) defines stock markets as where government and industry can raise long-term capital and investors can purchase and sell securities. In addition, very few stock exchanges around the world still possess a physical location where buyers and sellers meet to trade. Johnson (1983) opines that: "*The stock markets are a complex of institutions and mechanisms through which funds for purposes longer than one year are pooled and made available to business, government, individuals and through which instruments already outstanding are transferred. The stock markets are well organized and are local, regional, national, and world-wide in scope.*"

Curry and Winfield (1994) offered a brief definition of the stock exchange as: "….. *an institution where quoted investments (stocks and shares) may be exchanged between buyers and sellers.*" Fabozzi et al. (2002) classified three types of stock market role namely as the interactions of buyers and sellers in a stock market determine the price of the traded asset, stock markets provide a mechanism for investors to sell a stock asset and finally, the economic function of a stock market is that it reduces the cost of transacting.

The effects of heteroscedasticity cannot be ignored as noted in the works of Geary (1966), White (1980), Pasha (1982), Hadri and Guermat (1999) amongst others. Classical approach to its detection, estimation and remediation are widely discussed in the econometric literature. Estimation of parameters using Bayesian approach in its presence is a major gap in the existing stock of knowledge. This approach combines out-of-sample information with observed data.

Mishra et al (2010) examined the stock market for dealing in long term financial instruments. Operational efficiency of the stock markets in emerging economies are adversely affected by the issue of information asymmetry where borrowers are believed to have more information than the lenders about the riskiness of the project funds are sought for. To achieve the status of a developed economy, the problem of information asymmetry in stock markets of emerging economies must be dealt with. Osakwe and Ananwude (2017) argue that the positive influence of stock market on economic growth has dominated empirical findings from across the world relative to independence of economic growth on stock market as well as no connection between stock market and economic growth.

The growth rates of the economy have positive relationship with development in the stock market as cited in Okonkwo et al (2015). The higher the growth rate of the economy, other things being equal, the more favourable it is for the stock market as equity prices may rise to the potential for higher profits from a healthy business climate. Theories explaining the connection between development of the stock market and economic growth have divergence postulations. Basically, there are two major views on the alleged linkage between stock market and economic growth. One school of thought known as the finance led economic growth model or the supply leading theory/hypothesis argues that stock market development is necessary for the achievement of growth and development of the economy. The theory states that economic growth requires huge long term resources which are only obtainable from stock market. This is on the premise that huge resources can be effectively and efficiently mobilized by the mechanism of the stock market. This theory was traced to the pioneering work of Schumpeter in 1912.

However, it became more popular following the study of Mackinnon and Shaw in 1973. From that time till date, most scholars have validated the positive influence of stock market activity on economic growth across the globe. The opposing view to the finance led growth theory contended that it is the level of development in the economy that determines the depth of development in the stock market. They argue that creation of more credit than required in the economy would retard long term growth of the economy.

Empirical investigations regarding development of stock market and the growth of the economy are mixed. The role of stock market in economic growth of Nigeria was ascertained by Adam and Sanni (2005) using granger causality test and regression analysis. The study reported a one-way causality between GDP growth and market capitalization and a two-way causality between GDP growth and market turnover. The causal linkage between stock market and economic growth in Nigeria during the period 1970 to 2008 was assessed by Afees and Kazeem (2010). Market capitalization ratio, total value traded ratio and turnover ratio were used as the indicators of stock market, while economic growth was proxies with trend in gross domestic product. The result of the granger causality test provided the existence of bidirectional causality between turnover ratio and economic growth, a unidirectional causality from market capitalization to economic growth and no causal linkage between total values traded. In all, economic growth in Nigeria was said to be propelled by stock market.

Josiah et al (2012) studied the developmental role of the Nigerian stock market and Kolapo and Adaramola (2012) from 1990 to 2010 determined the impact of the Nigerian capital market on economic growth. Gross domestic product reflected the growth of the economy, whereas market capitalization, total new issues, value of transactions, and total listed equities and government stocks summarized stock market development indices. Estimation using

Johansen co-integration and Granger causality showed that Nigerian capital market and economic growth are related in the long run. Causality analysis evidences bidirectional causation between economic growth and value of transactions and a unidirectional causation between market capitalizations to economic growth.

Furthermore, there was independence "no causation" between economic growth and total new issues as well as economic growth listed securities in the market. Oke and Adeusi (2012) assessed the contribution of stock market operation in Nigeria towards the development of the oil and gas sector which provides over 90% of Nigeria's foreign exchange. Model estimation with co-integration and error correction model indicated the presence of a long run relationship between stock market operation and oil and gas development. Similarly, Oke and Adeusi (2012) evaluated stock market reforms influence on economic growth between 1981 and 2012. The results of application of different econometric tools revealed that stock market reforms have contributed positively to economic growth of Nigeria.

The objective of the study is to estimate the parameters of the model when the heteroscedasticity is present with Nigerian Stock Exchange data for empirical illustration using Bayesian approach. The present study would complement the existing literature. The rest of the paper has been structured as follows. Section 2 focuses the Bayesian paradigm. Section 3 describes the materials and method. Section 4 explains the empirical results and discusses the findings while concluding remarks are given in section 5.

2 The Bayesian Paradigm

The theoretical framework is a linear regression model of the form

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + U \qquad (1)$$

The model of (1) can be rewritten in matrix form as

$$y = X\beta + U; \qquad U \sim N(0_n, h^{-1}\Sigma) \qquad (2)$$

where $y(n \times k)$ is the vector of observations on the dependent variable, $X(n \times k)$ are matrices of non-random regressors, $U(n \times 1)$ is a random vector of unobservable disturbances, $\beta(n \times (k+1))$ are unknown parameters vectors, h is the precision and $\Sigma(n \times n)$ positive definite covariance matrix.

2.1 The Likelihood

With the heteroscedasticity structure and using the properties of multivariate normal, the likelihood function of (2) can be written as:

$$p(y \mid \beta, h, \Sigma) = \frac{h^{\frac{n}{2}}}{(2\pi)^{\frac{n}{2}}} |\Sigma|^{-\frac{1}{2}} \left\{ \exp\left[-\frac{h}{2}(y - X\beta)^1 \Sigma^{-1}(y - X\beta) \right] \right\} \qquad (3)$$

The likelihood function in (3) can be rewritten in more slightly form after algebraic manipulations as

$$p(y\,|\,\beta,h,\Sigma)=\frac{1}{(2\pi)^{\frac{n}{2}}}\left\{h^{\frac{1}{2}}\exp\left[-\frac{h}{2}(\beta-\hat{\beta}(\Sigma))^{1}X^{1}\Sigma^{-1}X(\beta-\hat{\beta}(\Sigma))\right]\right\}\times$$

$$\left\{h^{\frac{v}{2}}\exp\left[-\frac{hv}{2s(\Sigma)^{-2}}\right]\right\} \qquad (4)$$

The result in (4) simply suggests a Normal-Gamma prior for the likelihood function. The $\hat{\beta}$ is the Generalized Least Squares (GLS) of the frequentist by the estimator

$$\hat{\beta}(\Sigma)=(X^{1}\Sigma^{-1}X)^{-1}X^{1}\Sigma^{-1}y \qquad (5)$$

$$s^{2}(\Sigma)=\frac{(y-X\hat{\beta}(\Sigma))^{1}\Sigma^{-1}(y-X\hat{\beta}(\Sigma))}{n-k} \qquad (6)$$

2.2 The Need for a Prior distribution

Prior represent an expectation or a prior belief about what a parameter value looks like. Prior act as a means to include additional information about the parameter values in the model. Specification of prior distribution is the first issue about which novice Bayesian analysts become agitated is their responsibility to select a prior. The selection is supposed to be subjective, so in principle, no one should be able to complain about one’s choice for a prior, but even seasoned analysts may often be anxious about these selections. Although proponents of the Bayesian approach often argue that data will overwhelm and obviate the choice of the prior Jaynes (2000). Basically, there are two types of prior in Bayesian analysis informative and noninformative.

Box and Tiao (1973) define a noninformative prior as one that provides little information relative to the experiment. In this study, we used noninformative prior. The reason for the choice of noninformative prior is to ensure that the data provides much information about the values of the model parameters and this is a popular approach. From the likelihood function in (4), the Normal-Gamma prior has the following distribution:

Prior for β condition on h is of the form:

$$p(\underline{\beta}\,|\,h)=\frac{h^{\frac{k}{2}}}{(2\pi)^{\frac{k}{2}}\,|\,\underline{\Sigma}\,|^{\frac{1}{2}}}\left\{\exp\left[-\frac{1}{2}(\beta-\underline{\beta})^{1}(\underline{\Sigma})^{-1}(\beta-\underline{\beta})\right]\right\} \qquad (7)$$

and prior for h is of the form

$$p(h)=\frac{1}{\Gamma(\frac{\underline{v}}{2})\left[\frac{2\underline{s}^{-2}}{\underline{v}}\right]^{\frac{\underline{v}}{2}}}\left\{h^{\frac{\underline{v}}{2}-1}\exp\left[\frac{h\underline{v}}{2\underline{s}^{-2}}\right]\right\} \tag{8}$$

Where, $\underline{\beta}$ and $\frac{1}{\Gamma(\frac{\underline{v}}{2})\left[\frac{2\underline{s}^{-2}}{\underline{v}}\right]^{\frac{\underline{v}}{2}}}$ in (7) and (8) are the priors for β and integrating constant respectively. So that the joint prior for β and h then becomes

$$p(\beta,h)=\frac{h^{\frac{\underline{v}+k}{2}-1}}{(2\pi)^{\frac{k}{2}}|\underline{\Sigma}|^{\frac{1}{2}}\Gamma(\frac{\underline{v}}{2})\left[\frac{2\underline{s}^{-2}}{\underline{v}}\right]^{\frac{\underline{v}}{2}}}\left\{\exp-\frac{1}{2}\left[(\beta-\underline{\beta})^{1}(\underline{\Sigma})^{-1}(\beta-\underline{\beta})+\frac{\underline{v}}{\underline{s}^{-2}}\right]\right\} \tag{9}$$

And we finally specify non-informative uniform prior for Σ, that is, $p(\underline{\Sigma})\propto 1.$

2.3 The Posterior distribution

The joint posterior density is obtained simply by multiplying the likelihood in (4) by the priors. According to Box and Tiao (1973, the lack of information integrated in the prior is then combine with the data during the estimation process, and the combination of these two pieces of information are then used to produce the posterior distribution, which can be summarized by a measure of central tendency that represents the final parameter estimates. Hence, the posterior distribution is then defined by

$$p(\beta,h,\Sigma\,|\,y)\ \propto\ \frac{1}{(2\pi)^{\frac{n}{2}}}\left\{h^{\frac{k}{2}}\exp\left[-\frac{h}{2}(\beta-\hat{\beta})^{1}X^{1}\Sigma^{-1}X(\beta-\hat{\beta})\right]\right\}\left\{h^{\frac{\underline{v}}{2}}\exp\left[-\frac{h\underline{v}}{2\underline{s}^{-2}}\right]\right\}$$
$$\times\frac{h^{\frac{\underline{v}+k}{2}-1}}{(2\pi)^{\frac{n}{2}}|\underline{\Sigma}|^{\frac{1}{2}}\Gamma(\frac{\underline{v}}{2})\left[\frac{2\underline{s}^{-2}}{\underline{v}}\right]^{\frac{\underline{v}}{2}}}\left\{\exp-\frac{h}{2}\left[(\beta-\underline{\beta})^{1}\underline{\Sigma}^{-1}(\beta-\underline{\beta})+\frac{\underline{v}}{\underline{s}^{-2}}\right]\right\},\ \sin ce\ k=n+v \tag{10}$$

From the joint posterior distributions in (10), the following three conditional densities were obtained.

(i) The conditional posterior density of β is;

$$P(\beta \mid h, \Sigma, y) \ = N(\bar{\beta}, \bar{\Sigma}) \quad (11)$$

where

$$\bar{\beta} = \bar{\Sigma}[\underline{\Sigma}^{-1}\underline{\beta} + hX^{1}\underline{\Sigma}^{-1}X\hat{\beta}_{GLS}]$$

$$\bar{\Sigma} = [\underline{\Sigma}^{-1} + hX^{1}\underline{\Sigma}^{-1}X]^{-1}$$

(ii) The conditional posterior density of h is;

$$p(h \mid \beta, \Sigma, y) = G[\underline{s}^{-2}, \bar{v}] \quad (12)$$

where

$$\bar{s}^{-2} = \frac{\bar{v}}{(y - X\beta)^{'}\Sigma^{-1}(y - X\beta) + \underline{v}\underline{s}^{2}}; \qquad \bar{\mathrm{v}} = n + \underline{v}$$

$$p(\Sigma \mid \beta, h, y) \propto p(\alpha) \mid \Sigma \mid^{-\frac{1}{2}} \left\{ -\frac{h}{2}\left[(y - X\beta)^{1}\Sigma^{-1}(y - X\beta)\right]\right\} \quad (13)$$

Which is the conditional posterior density of heteroscedasticity structure which does not take any easily recognized form of distribution and the full estimates is obtained using Metropolis-Hasting algorithm.

3 Materials and Method

The data used for empirical application is a daily operation of the Nigerian Stock Exchange market and comprises: Nigerian Stock Exchange All Share Index (NSEASI), Earning per Share (EPS), Return on Equity (ROE), Return on Asset (ROA) and Earnings before Interest Taxes and Management. The dependent variable is NSEASI for 545 days operation.

The dependent variable is Nigerian stock exchange all share index Y and explanatory variables are earning per share (X_1), return on equity (X_2), return on asset (X_3) and earnings before interest taxes and management (X_4). The MCMC estimation procedure requires proper prior distributions for the parameters in the model. In the empirical application the hyper-parameters will be set to be nearly noninformative. The standard deviation of the prior will be chosen to have a range of variability of the prior which is greater than the range of variability in the data. This assumption of prior selection allows us to have a flat prior in the regions of the parameter space where the likelihood have high values.

More specifically, for the scale parameter priors, the hyper-parameter priors values $\beta_0 = 2, \beta_1 = 4, \beta_2 = 8, \beta_3 = 8, \beta_4 = 10.$

For hyper-parameters we set $\underline{s}^2 = 4 \times 10^{-8}, \underline{v} = 5$ *and*

$$\underline{\Sigma} = \begin{bmatrix} 2.40 & 0 & 0 & 0 & 0 \\ 0 & 6.0 \times 10^{-7} & 0 & 0 & 0 \\ 0 & 0 & 0.15 & 0 & 0 \\ 0 & 0 & 0 & 0.6 & 0 \\ 0 & 0 & 0 & 0 & 0.6 \end{bmatrix}$$

In this study, the form of heteroscedasticity structure by Harvey's (1976) is considered, that is when variance is treated as an exponential function of exogenous variables and we use hyper-parameters above proposed by Oseni, et al (2019.) This variance as an exponential function is a very flexible, general model that includes most of the useful formulations as special cases. The general formulation is, $w_i = h(\exp(z_i^{'}, \alpha)),$ where $z_i^{'}$ and α are $z_i = (z_{i1}, z_{i2}, \cdots, z_{ip})$ is a $p \times 1$ vector of observations on a set of exogenous variables related to the regressors and $\alpha = (\alpha_1, \alpha_2, \cdots, \alpha_p)$ is a $p \times 1$ vector of parameters respectively.

The specification of the linear model is the same model in (1), with $E(U) = 0$

and

$$E(UU^1) = w_i = \begin{bmatrix} \exp(z_1^1, \alpha)^2 & 0 & \cdots & 0 \\ 0 & \exp(z_2^1, \alpha)^2 & & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & & \exp(z_n^1, \alpha)^2 \end{bmatrix}$$

where $h(.)$ is a positive function which depends on parameters α and explanatory variables, z_i. The structures described above were substituted into the likelihood to obtain the likelihood function in (4).

4 Empirical Results

Table1. Posterior means for β h, and Std. Dev. Nigerian Stock Exchange Data (Homoscedasticity version i.e. constant variance)

			95% HPDI	
Parameters	Means	Std. Dev.	2.5%	97.5%
β_0	22423.49	559.1550	(21524.31	23332.55)
β_1	-0.35961	0.099980	(-0.52451	-0.19573)
β_2	-4108.37	316.0074	(-4632.94	-3591.60)
β_3	23361.13	1849.283	(20330.88	26421.50)
β_4	440.8911	63.66790	(338.9290	541.9600)
h	$1.668e^{-11}$	$2.638e^{-09}$	(0.000000	0.000000)

Table 2. Posterior means for β, h, Std. Dev.and α Nigerian Stock Exchange Data (Heteroscedasticity version i.e.when variance is treated as an Exponential function of exogenous variables)

			95% HPDI	
Parameters	Means	Std. Dev.	2.5%	97.5%
β_0	22422.47	1.544900	(22419.93	22424.99)
β_1	-0.35960	0.003179	(-0.36480	-0.35400)
β_2	-4108.37	0. 384000	(-4109.01	-4107.02)
β_3	23352.80	0.771700	(23351.52	23354.06)
β_4	441.0598	0.771200	(439.7951	442.3318)
h	0.000000	$1.88e^{-25}$	(0.000000	0.00000)
α_1	0.000000	1.000000	(0.000000	0.00000)
α_2	0.000000	1.000000	(0.000000	0.00000)
α_3	0.000000	1.000000	(0.000000	0.00000)
α_4	0.000000	1.000000	(0.000000	0.00000)

Discussion of Results

Table 1 and 2 presented empirical results for Nigerian Stock Exchange data daily operation operations. Table 1 contains results for homoscedasticity (constant variance) version. Table 2 presented the results when variance is treated as an exponential function of exogenous variables. We noticed that the results obtained were similar and identical to the results of homoscedasticity version in table 1. This shows that the incorporation of the structures of heteroscedasticity as an exponential function has not had an enormous effect on results relating to mean posterior densities and standard deviation. The precision (h) values tend to zero as expected and the estimated parameters approximately 95% draws fall within each of the corresponding credible interval.

5. Conclusion

In this paper, we have shown that Bayesian estimation can be used as an alternative method to frequentist of estimation by specifying priors for all the parameters and hyper-parameters in the model. More specifically, this paper has attempted to do three things amongst others. First, we have used the mechanism of Bayesian estimation error disturbance as an exponential function of exogenous variables and obtained the posterior means, standard deviation and 95% highest posterior density intervals (HPDI's) for all the estimated model parameters. Second, we have also used the mechanism of Bayesian estimation homoscedasticity version and obtained the posterior means, standard deviation and 95% HPDI's Third, and we applied the Bayesian theory to the Nigerian Stock Exchange data and estimated the model parameters.

Heteroscedasticity is an easy thing to handle in Bayesian approach with little added computational effort, once we decide on the weight and specified the priors. The Bayesian estimation allows us to fit a parametric model for unequal variance not well identified, thus allowing us to use information in the weight in a more general and flexible setting than weighted least squares (WLS) in frequentist approach. Finally, Bayesian estimation when heteroscedasticity structure is present performs better than the homoscedasticity version having minimum standard deviation. Our result shows that assets, exchange before interest taxes and management has a positive significant influence on stock market on economic growth. The result obtained is not with the work of Osakwe and Ananwude (2017) that reveals that there is no connection between stock market and economic growth.

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