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## Inflation, Output Growth and their Uncertainties: A Multivariate GARCH-M Modeling Evidence for Nigeria

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# Inflation, Output Growth and their Uncertainties: A Multivariate GARCH-M Modeling Evidence for Nigeria

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## Abstract

The study applies a BEKK GARCH-M model to examine the effect of uncertainty on the levels of inflation and output growth in Nigeria. The results suggest a significant positive effect of inflation uncertainty on the level of inflation, supporting the Cukierman and Meltzer (1986) hypothesis. In addition, uncertainty about inflation is found to be detrimental to output growth, supporting the Friedman's (1977) hypothesis of a negative effect of inflation uncertainty on output growth. Uncertainty about growth does not have a significant effect on both the levels of inflation and output growth. The evidence in this study suggests that Nigeria should put in place policies minimizing inflation uncertainty to avoid its adverse effects on the economy. In addition, the independence relationship between output growth and its uncertainty in Nigeria suggest that they can be treated separately as suggested by business cycle models.

*JEL Classifications*: C22, E0.

*Keywords*: Inflation, Inflation Uncertainty, Output, Output Uncertainty, BEKK GARCH-M

## 1. Introduction

Monetary Policy stance in Nigeria has always been contractionary in a bit to combat rising inflation and ensure sustainable output growth as the economy is exposed to global commodity price shock due to undiversified economic activities. This has called for concern from stakeholders on the need for policy stance to support real sector growth especially in a low growth era but the monetary authority always argue that the Nigerian case is a paradox where output growth is low and dwindling amidst rising inflation and alarming unemployment rate. It is therefore imperative for empirical study to gauge the dynamic linkages inflation and output growth and as well their uncertainties in Nigeria to provide evidence for policy makers. This is the focus of this study and to the best of our knowledge there is dearth of such studies in Nigeria.

Interestingly, the dynamic linkages between inflation and output growth and their uncertainties have been controversial both theoretical and empirically (Bhar and Malik, 2010). While there is plethora of studies on these connections, the consensus in the literature is unclear and the evidence is mixed (Narayan and Narayan, 2013). Theoretically, Friedman (1977) and Black (1992) showed that rising inflation causes nominal uncertainty which invariably become a drag to output growth due to price distortion effect causing inefficient resource allocation but Pourgarani and Markus (1987) opined for a negative effect while Cukier and Meltzer (1986) and Holland (1995) provided support for the reverse causality running from nominal uncertainty to inflation as policy makers creates surprise inflation to spur growth. Black and Blackburn (1999) and Dotsey and Sarti (2000) opined for a positive effect of nominal uncertainty on output growth arguing that increasing nominal uncertainty results in precautionary savings that later boast investment and thereby growth, Pindyck (1991) and Ramsey and Ramsey (1991) however, pointed to a negative impact due to risk in returns. While Taylor (1981) and Fulier (1997) suggested a trade-off between nominal uncertainty and real uncertainty due to stabilization objective of the policy maker, Logue and Sweeney (1981) and Devereux (1989) insinuated a positive link from real uncertainty to nominal uncertainty. Black (1987) and Ramsey and Ramsey (1991) on the effect of real uncertainty on output growth supported a positive effect, Devereux (1989) supported a positive effect of real uncertainty on inflation. On Inflation-Growth nexus, Bruno and Easterday (1989) provided support for a positive effect, while Jones and Manuelli (1995), De Gregorio (1993), De Gregorio and Barro (1996) supported a negative link.

From the empirical literature, Grier and Perry (1998), Bhar and Malik (2010), Mehrara and Tavakolian (2010), Hasanor and Omay (2011), Karahan (2012), Narayan and Narayan (2013) showed that rising inflation leads to inflationary uncertainty. On the other hand, Karanasos et al. (2004), Narayan and Narayan (2013), Ndoricimpa (2015) showed that inflation uncertainty raises inflation while Grier et al. (2004) found otherwise. Fountas (2001) and Fountas et al. (2002) found evidence of a drag on growth from inflation uncertainty, Ndoricimpa (2015) found a spurring effect on growth.

Caporale and Mckiernan (1998), Grier and Perry (2000) and Narayan and Narayan (2013) found a positive effect of real uncertainty on growth but Henry and Olekains (2002) and Ndoricimpa (2015) found a negative correlation while Fountas et al. (2002) found no evidence. Logue and Sweeney (1981) found nominal uncertainty to spur real uncertainty, Karanasos and Kim (2005) found no evidence.

This study contributes to the literature on the connection between nominal uncertainty and real uncertainty and their effects on inflation and output growth for Nigeria as we use the Grier et al. (2004) asymmetric multivariate GARCH-M modeling approach for generating uncertainty as also used by Ndoricimpa (2015) for the South Africa case. This is at variance with previous studies in Nigeria that used the one-step approach in GARCH-in-Mean model (Olayinka, Hassan, 2010). The choice of the Grier et al. (2004) asymmetric multivariate GARCH-M approach is not farfetched as it allows one to jointly generate the uncertainty measures of inflation and output growth and analyzed their effects simultaneously while overcoming the misspecification problem arising from imposing diagonal and symmetric restrictions on the variance-covariance matric of output growth and inflation. The rest of the paper is organized thus. Section 2 highlights the Grier et al. (2004) methodology used, section 3 presents the empirical analysis while section 4 concludes the paper.

## 2. Methodology

To examine the effects of uncertainty on the levels of inflation and output growth in Nigeria, this study follows Grier et al. (2004) and applies a BEKK[1]GARCH-M model in which the conditional means of inflation ($\pi_t$) and output growth $(y_t)$ are in form of VARMA (Vector Autoregressive Moving Average) GARCH-M model, where the conditional standard deviations of output growth and inflation are included as explanatory variables in each conditional mean equation. The methodology was also applied by Ndoricimpa (2015) for the case of South Africa. The specification of the conditional means of inflation ($\pi_t$) and output growth $(y_t)$ is as follows:

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_{\mathrm{i}} Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_{\mathrm{j}}\, \varepsilon_{t-j} + \varepsilon_t \tag{1}$$

with $\varepsilon_t|\Omega_t \sim N(0, H_t)$, where$\Omega_t$represents the information set available at time t.. In addition, $(\varepsilon_{y,t}^2) = h_{y,t}$ , $(\varepsilon_{\pi,t}^2) = h_{\pi,t}$ , $E(\varepsilon_{y,t}\varepsilon_{\pi,t}) = h_{y\pi,t}$.

[1] BEKK model is a multivariate GARCH model developed by Engle and Kroner (1995) and was named after Baba, Engle, Kraft and Kroner. BEKK model is preferred in this study because it ensures the positive definiteness of the conditional variance-covariance matrix unlike the other variants of multivariate GARCH models.

$$H_t = \begin{bmatrix} h_{y,t} & h_{y\pi,t} \\ h_{\pi y,t} & h_{\pi,t} \end{bmatrix}$$

$$Y_t = \begin{bmatrix} y_t \\ \pi_t \end{bmatrix}; \varepsilon_t = \begin{bmatrix} \varepsilon_{y,t} \\ \varepsilon_{\pi,t} \end{bmatrix}; \sqrt{h_t} = \begin{bmatrix} \sqrt{h_{y,t}} \\ \sqrt{h_{\pi,t}} \end{bmatrix}; \mu = \begin{bmatrix} \mu_y \\ \mu_\pi \end{bmatrix}; \Gamma_i = \begin{bmatrix} \Gamma_{yy}^{(i)} & \Gamma_{y\pi}^{(i)} \\ \Gamma_{\pi y}^{(i)} & \Gamma_{\pi\pi}^{(i)} \end{bmatrix};,$$

$$\Psi = \begin{bmatrix} \psi_{yy} & \psi_{y\pi} \\ \psi_{\pi y} & \psi_{\pi\pi} \end{bmatrix}; \Theta_j = \begin{bmatrix} \theta_{yy}^{(j)} & \theta_{y\pi}^{(j)} \\ \theta_{\pi y}^{(j)} & \theta_{\pi\pi}^{(j)} \end{bmatrix}$$

where, $H_t$ is the conditional variance-covariance matrix, $h_{y,t}$ is the conditional variance of output growth, $h_{\pi,t}$ is the conditional variance of inflation, $h_{y\pi,t}$ & $h_{\pi y,t}$ are the conditional covariances between inflation and output growth, $\varepsilon_t$ is the vector of error terms, $\mu$ is the matrix of constant terms, $\Gamma_i$ is the matrix of Autoregressive coefficients, $\Psi$ is the matrix of in-mean coefficients and $\Theta_j$ is the matrix of Moving Average coefficients. Important to note is that in GARCH models, uncertainty (volatility) is captured by the conditional variance which is simply the variance of the one step ahead forecasting error.

To avoid the problem of misspecification, we first consider an asymmetric BEKK model where the conditional variance-covariance matrix is written as:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B + D'\omega_{t-1}\omega_{t-1}'D \qquad (2),$$

where $C = \begin{bmatrix} c_{yy} & 0 \\ c_{\pi y} & c_{\pi\pi} \end{bmatrix}; A = \begin{bmatrix} \alpha_{yy} & \alpha_{y\pi} \\ \alpha_{\pi y} & \alpha_{\pi\pi} \end{bmatrix}; B = \begin{bmatrix} \beta_{yy} & \beta_{y\pi} \\ \beta_{\pi y} & \beta_{\pi\pi} \end{bmatrix}; D = \begin{bmatrix} \delta_{yy} & \delta_{y\pi} \\ \delta_{\pi y} & \delta_{\pi\pi} \end{bmatrix}; \omega = \begin{bmatrix} \omega_{y,t} \\ \omega_{\pi,t} \end{bmatrix}$

In equation (2), C is a lower triangular matrix of constant terms, A is a matrix of ARCH coefficients which captures the ARCH effects and B is a matrix of GARCH coefficients capturing the GARCH effects. The diagonal elements in matrix A show the impact of own past shocks on the current conditional variance, the diagonal elements in Matrix B represent the impact of own past volatility on the current conditional variance, while the off-diagonal elements in matrices A and B represent the volatility spillovers' effects (Xu, Sun, 2010). Asymmetry in the conditional variance-covariance matrix is captured by the matrix D which is the matrix of asymmetric coefficients. The BEKK model becomes symmetric if asymmetric coefficients are statistically jointly equal to 0, i.e. $\delta_{ij} = 0$, for all $i, j = y, \pi$.

Equation (2) can also be written as follows:

$$h_{y,t} = c_{yy}^2 + c_{\pi y}^2 + \alpha_{yy}^2\varepsilon_{y,t-1}^2 + 2\alpha_{yy}\alpha_{y\pi}\varepsilon_{y,t-1}\varepsilon_{\pi,t-1} + \alpha_{y\pi}^2\varepsilon_{\pi,t-1}^2 + \beta_{yy}^2 h_{y,t-1} + 2\beta_{yy}\beta_{y\pi}h_{y\pi,t-1} + \beta_{\pi y}^2 h_{\pi,t-1} + \delta_{yy}^2\omega_{y,t-1}^2 + 2\delta_{yy}\delta_{y\pi}\omega_{y,t-1}\omega_{\pi,t-1} + \delta_{y\pi}^2\omega_{\pi,t-1}^2 \qquad (3.a)$$

$$h_{y\pi,t} = c_{\pi y}\left(c_{yy} + c_{\pi\pi}\right) + \alpha_{y\pi}\alpha_{yy}\varepsilon_{y,t-1}^2 + (\alpha_{yy}\alpha_{\pi\pi} + \alpha_{y\pi}\alpha_{\pi y})\varepsilon_{y,t-1}\varepsilon_{\pi,t-1} + \alpha_{\pi y}\alpha_{\pi\pi}\varepsilon_{\pi,t-1}^2 + \beta_{yy}\beta_{y\pi}h_{y,t-1} + (\beta_{yy}\beta_{\pi\pi} + \beta_{y\pi}\beta_{\pi y})h_{y\pi,t-1} + \beta_{\pi y}\beta_{\pi\pi}h_{\pi,t-1} + \delta_{y\pi}\delta_{yy}\omega_{y,t-1}^2 + (\delta_{yy}\delta_{\pi\pi} + \delta_{y\pi}\delta_{\pi y})\omega_{y,t-1}\omega_{\pi,t-1} + \delta_{\pi y}\delta_{\pi\pi}\omega_{\pi,t-1}^2 \qquad (3.b)$$

$$h_{\pi,t} = c_{\pi\pi}^2 + c_{\pi y}^2 + \alpha_{y\pi}^2\varepsilon_{y,t-1}^2 + 2\alpha_{y\pi}\alpha_{\pi\pi}\varepsilon_{y,t-1}\varepsilon_{\pi,t-1} + \alpha_{\pi\pi}^2\varepsilon_{\pi,t-1}^2 + \beta_{y\pi}^2 h_{y,t-1} + 2\beta_{y\pi}\beta_{\pi\pi}h_{y\pi,t-1} + \beta_{\pi\pi}^2 h_{\pi,t-1} + \delta_{y\pi}^2\omega_{y,t-1}^2 + 2\delta_{y\pi}\delta_{\pi\pi}\omega_{y,t-1}\omega_{\pi,t-1} + \delta_{\pi\pi}^2\omega_{\pi,t-1}^2 \qquad (3.c)$$

From equation 1 (the conditional mean equations), the effect of uncertainty on the level of inflation and output growth can be examined. The effect of output growth uncertainty and inflation uncertainty on output growth can be assessed by respectively testing the null hypotheses that $\psi_{yy} = 0$ and $\psi_{y\pi} = 0$. A positive and significant $\psi_{yy}$ would mean a positive effect of output growth uncertainty on output growth (Black hypothesis), while a negative and significant $\psi_{yy}$ would imply a negative effect of output growth uncertainty on output growth, supporting the views of Pindyck (1991) and Ramey and Ramey (1991). A positive and significant $\psi_{y\pi}$ would mean a positive effect of inflation uncertainty on output growth (Dotsey-Sarte hypothesis), while a negative and significant $\psi_{y\pi}$ would mean a negative effect of inflation uncertainty on output growth [Friedman (1977) hypothesis].

Similarly, testing the effect of uncertainty, nominal and real, on the level of inflation is conducted by respectively testing whether $\psi_{\pi y} = 0$ and $\psi_{\pi\pi} = 0$. A positive and significant $\psi_{\pi y}$ would imply positive effects of output growth uncertainty on inflation (the Devereux hypothesis) while a negative and significant $\psi_{\pi y}$ would imply a negative effect of output growth uncertainty on inflation. On the other hand, a positive and significant $\psi_{\pi\pi}$ would mean a positive effect of inflation uncertainty on inflation (Cukierman-Meltzer hypothesis), while a negative and significant $\psi_{\pi\pi}$ would mean a negative effect of inflation uncertainty on inflation [the stabilization hypothesis of Holland (1995)].

## 3. Empirical Results and Discussion

Quarterly data on inflation and output growth for Nigeria are used for the period 1986:1 to 2017:4. Data were obtained from the Central Bank of Nigeria. Summary statistics in panel A of Table 1 show that inflation, $\pi$ is positively skewed while output growth, $y$ is negatively skewed. However both variables display leptokurtic behavior. Non-normality of the two variables is confirmed by Jarque-Bera (1987) test. A look at the variance shows that inflation is more volatile than output growth.

**Table 1. Preliminary Tests Results**

**Panel A. Summary Statistics**

| | **Mean** | **Variance** | **Skewness** | **Excess Kurtosis** | **J-B Test** |
|---|---|---|---|---|---|
| $\pi$ | 20.374 | 381.508 | 1.650 [0.000] | 1.812 [0.000] | 75.645 [0.000] |
| $y$ | 3.593 | 17.541 | -1.203 [0.000] | 2.401 [0.000] | 61.691 [0.000] |

**Panel B. Unit Root and ARCH Tests**

| | **DF-GLS Test** | **ARCH (2)** | **ARCH (4)** | **ARCH (6)** | **ARCH (8)** |
|---|---|---|---|---|---|
| $\pi$ | -2.372 (-2.079) | 179.89 [0.000] | 181.67 [0.000] | 187.40 [0.000] | 180.85 [0.000] |
| $y$ | -5.108 (-2.079) | 136.27 [0.000] | 141.11 [0.000] | 160.94 [0.000] | 160.00 [0.000] |

**Notes:** The optimal lag used for GF-GLS test is one (1) chosen by Schwarz information criterion. Between (.) are the critical values at 5% level, and between [.] are the p-values.

We conduct preliminary tests before any further analysis, including unit root test and ARCH test. Unit root test is conducted to assess the order of integration of the series, while ARCH test helps checking for the evidence of conditional heteroscedasticity in the data, that is, whether the variances of the series are time-varying. As Grier and Perry (1998) points out, one should be able to reject the null hypothesis of constant variance before estimating a GARCH model and generate uncertainty measures. DF-GLS test of Elliott-Rothenberg-Stock (1996)is used to test for unit root in the series, while testing for the presence of ARCH effects in the series is done using LM-ARCH test of Engle (1982). The results of the two tests are reported in Panel B of Table 1. DF-GLS test rejects the null hypothesis of a unit root in inflation and output growth series. Inflation and output growth series are hence stationary processes; there is no need therefore to difference them when estimating the Mean equations. ARCH test suggests that inflation and output growth series exhibit significant volatility clustering, implying that the variances of inflation and output growth are not constant but time-varying.

Since the presence of ARCH effects is confirmed, we proceed to estimate our asymmetric BEKK GARCH-M[2] model. The estimation results are in Table 2. To assess the adequacy of the GARCH model estimated, that is, to check whether the conditional mean and the conditional variance-covariance equations are well specified, we apply the usual diagnostic tests on GARCH models, Ljung-Box test and McLeod-Li test. The results in Panel C of Table 2 shows that at 5% level, Ljung-Box test indicates that there is no serial correlation of 5th and 10th order in the standardized residuals of the inflation mean equation. In contrast, the same test rejects the null hypothesis of no serial correlation of 5th and 10th order in the standardized residuals of the output growth mean equation, which can question the adequacy of the output growth mean equation, although the multivariate Q variant test seems to reject the null hypothesis of no serial correlation. Similarly, McLeod-Li test indicates that the squares of the standardized residuals of inflation and output growth equations are also serially independent at 5% level, implying that there are no remaining ARCH/GARCH effects.

**Table 2. Estimation Results of an Asymmetric BEKK GARCH-M Model for Nigeria**

**Panel A. Conditional Mean Equations**

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t, \text{ where } \varepsilon_t \sim N(0, H_t)$$

$$\mu = \begin{bmatrix} 4.5773 \\ (1.276) \\ 0.3867 \\ (0.286) \end{bmatrix}; \Gamma_1 = \begin{bmatrix} 0.6320 & -0.526 \\ (0.065) & (0.105) \\ 0.0103 & 0.8777 \\ (0.016) & (0.033) \end{bmatrix}; \Psi = \begin{bmatrix} 0.7113 & 0.7376 \\ (0.245) & (0.749) \\ 0.0383 & 0.2295 \\ (0.093) & (0.195) \end{bmatrix};$$

$$\Theta_1 = \begin{bmatrix} 0.2664 & 0.4862 \\ (0.087) & (0.497) \\ -0.022 & 0.4237 \\ (0.013) & (0.092) \end{bmatrix}; \Theta_2 = \begin{bmatrix} 0.3502 & 0.4304 \\ (0.108) & (0.181) \\ -0.020 & 0.2145 \\ (0.013) & (0.073) \end{bmatrix}$$

**Panel B. Conditional Variance-Covariance**

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B + D'\omega_{t-1}\omega_{t-1}'D$$

$$C = \begin{bmatrix} 0.2190 & \\ (0.131) & 0 \\ -0.429 & -0.000001 \\ (0.052) & (0.260) \end{bmatrix}; A = \begin{bmatrix} 0.4343 & 0.0161 \\ (0.141) & (0.020) \\ -0.055 & 0.9179 \\ (0.352) & (0.162) \end{bmatrix}; B = \begin{bmatrix} 0.9027 & -0.019 \\ (0.046) & (0.012) \\ 0.3534 & 0.1456 \\ (0.233) & (0.137) \end{bmatrix}; D = \begin{bmatrix} 0.0480 & -0.047 \\ (0.293) & (0.080) \\ -0.384 & 0.7305 \\ (0.207) & (0.369) \end{bmatrix}$$

$$Diagonal\ VARMA: \{H0: \Gamma^i_{\pi y} = \Gamma^i_{y\pi} = \theta^i_{\pi y} = \theta^i_{y\pi} = 0, i = 1,2;\ \chi^2(6) = 32.9263\ [0.000]\}$$

$$No\ GARCH: \{H0: \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0, \forall i, j = \pi, y; \chi^2(12) = 13120.0377\ [0.000]\}$$

$$No\ GARCH-M: \{H0: \psi_{ij} = 0, \forall i, j = \pi, y; \chi^2(4) = 21.8547\ [0.000]\}$$

$$No\ ASYMMETRY: \{H0: \delta_{ij} = 0, \forall i, j = \pi, y; \chi^2(4) = 5.4215\ [0.2467]\}$$

$$Diagonal\ GARCH: \{H0: \alpha_{\pi y} = \alpha_{y\pi} = \beta_{\pi y} = \beta_{y\pi} = \delta_{\pi y} = \delta_{y\pi} = 0; \chi^2(6) = 9.1824\ [0.1635]\}$$

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[2] In estimating the mean equation, we consider $p = q = 1$ and the diagnostic tests confirm that the mean equation is well specified with that lag order.

| Panel C. Diagnostic Tests | | | | | | |
|---|---|---|---|---|---|---|
| | **L-B Q(5)** | **McLeod-Li(5)** | **L-B Q(10)** | **McLeod-Li(10)** | **Multivariate Q Test** | |
| | | | | | **5 lags** | **10 lags** |
| $z_{y,t}$ | 18.74 [0.002] | 4.981 [0.418] | 27.806 [0.002] | 6.422 [0.478] | 24.81[0.21] | 48.09[0.17] |
| $z_{\pi,t}$ | 4.285 [0.509] | 2.493 [0.777] | 13.456 [0.199] | 10.384 [0.407] | | |

**Notes**: Results from our estimations using WinRATS 10.0 Between parentheses (.) are the standard errors and between brackets [.] are the p-values. $z_{j,t}$ is the standardized residual defined as $z_{j,t} = \varepsilon_{j,t}/\sqrt{h_{j,t}}$, where $j = y, \pi$. L-B stands for Ljung-Box.

In addition, we conduct some coefficient restriction tests in the Mean equation and conditional variance-covariance equations, to check whether some of the coefficients are not redundant (see table 2, panel B). In this regard, we test for the hypotheses of diagonal VARMA, no GARCH, no GARCH-M, no asymmetry and diagonal GARCH. The results show that all the hypotheses are rejected at 1% significance level, except for the hypotheses of no asymmetry and diagonal GARCH. Rejecting the hypothesis of no GARCH confirms that the conditional variance-covariance matrix is heteroscedastic, that is, the conditional variances of inflation and output growth are time-varying. Coefficient restriction tests confirm that the form of the mean equation adopted (Vector Autoregressive Moving average, VARMA plus the in-mean coefficients included) properly captures the dynamics of inflation and output growth, but that the form of the conditional variance-covariance matrix adopted (asymmetry and non-diagonality) does not adequately captures the dynamics of the conditional variance of inflation and output growth. The results points rather to a more simplified model where the conditional variance-covariance matrix is symmetric and diagonal. Consequently, we re-estimate the mean and conditional variance-covariance equations by considering symmetry and diagonality. The estimation results are in Table 3, and the diagnostic tests(see Panel C) indicate that the conditional mean and conditional variance-covariance equations are well specified.

**Table 3. Estimation Results of a Symmetric BEKK GARCH-M Model for Nigeria**

**Panel A. Conditional Mean Equations**

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \varepsilon_{t-j} + \varepsilon_t, \text{ where } \varepsilon_t \sim N(0, H_t)$$

$$\mu = \begin{bmatrix} \begin{matrix} 3.7517 \\ (1.155) \end{matrix} \\ \begin{matrix} 0.7297 \\ (0.059) \end{matrix} \end{bmatrix}; \Gamma_1 = \begin{bmatrix} \begin{matrix} 0.9784 \\ (0.105) \end{matrix} & \begin{matrix} 0.4512 \\ (0.616) \end{matrix} \\ \begin{matrix} -0.008 \\ (0.003) \end{matrix} & \begin{matrix} 1.5523 \\ (0.050) \end{matrix} \end{bmatrix}; \Gamma_2 = \begin{bmatrix} \begin{matrix} -0.348 \\ (0.098) \end{matrix} & \begin{matrix} -0.909 \\ (0.571) \end{matrix} \\ \begin{matrix} 0.0069 \\ (0.003) \end{matrix} & \begin{matrix} -0.636 \\ (0.047) \end{matrix} \end{bmatrix}; \Psi = \begin{bmatrix} \begin{matrix} 1.0437 \\ (0.207) \end{matrix} & \begin{matrix} 0.0930 \\ (0.318) \end{matrix} \\ \begin{matrix} -0.055 \\ (0.010) \end{matrix} & \begin{matrix} -0.027 \\ (0.030) \end{matrix} \end{bmatrix};$$

$$\Theta_1 = \begin{bmatrix} \begin{matrix} 0.0233 \\ (0.071) \end{matrix} & \begin{matrix} 1.1434 \\ (0.656) \end{matrix} \\ \begin{matrix} 0.0044 \\ (0.003) \end{matrix} & \begin{matrix} 0.2290 \\ (0.063) \end{matrix} \end{bmatrix}; \Theta_2 = \begin{bmatrix} \begin{matrix} 0.6351 \\ (0.077) \end{matrix} & \begin{matrix} 0.2250 \\ (0.252) \end{matrix} \\ \begin{matrix} -0.003 \\ (0.003) \end{matrix} & \begin{matrix} 0.0202 \\ (0.044) \end{matrix} \end{bmatrix}$$

**Panel B. Conditional Variance-Covariance**

$$\mathrm{H}_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B$$

$$C = \begin{bmatrix} \begin{matrix} 0.0225 \\ (0.125) \end{matrix} & 0 \\ \begin{matrix} -0.075 \\ (0.044) \end{matrix} & \begin{matrix} -0.000001 \\ (0.426) \end{matrix} \end{bmatrix}; A = \begin{bmatrix} \begin{matrix} 0.3318 \\ (0.067) \end{matrix} & 0 \\ 0 & \begin{matrix} 1.6800 \\ (0.189) \end{matrix} \end{bmatrix}; B = \begin{bmatrix} \begin{matrix} 0.9359 \\ (0.015) \end{matrix} & 0 \\ 0 & \begin{matrix} 0.1072 \\ (0.072) \end{matrix} \end{bmatrix}$$

**Panel C. Diagnostic Tests**

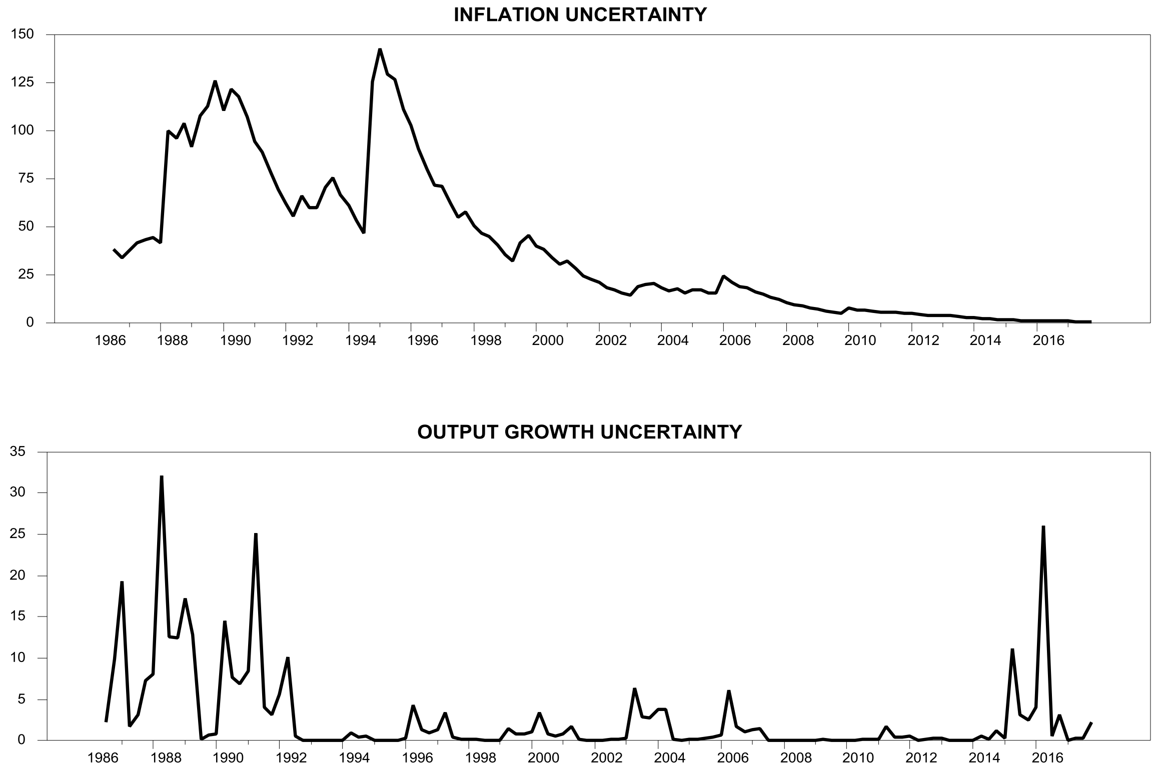
| | **Ljung-Box Q(5)** | **McLeod-Li(5)** | **Ljung-Box Q(10)** | **McLeod-Li(10)** |
|---|---|---|---|---|
| $z_{y,t}$ | 7.289[0.200] | 8.693 [0.121] | 10.880 [0.366] | 11.793 [0.299] |
| $z_{\pi,t}$ | 7.436 [0.190] | 0.322 [0.997] | 14.771 [0.140] | 3.110 [0.978] |

**Notes**: Results from our estimations using WinRATS 10.0 Between parentheses (.) are the standard errors and between brackets [.] are the p-values. $z_{j,t}$ is the standardized residual defined as $z_{j,t} = \varepsilon_{j,t}/\sqrt{h_{j,t}}$, where $j = y, \pi$.

The derived conditional standard deviations of inflation and output growth capturing inflation uncertainty and output growth uncertainty are in figure 1.

Figure 1 indicates that the greatest inflation uncertainty (volatility) was prevalent in the 1980s and 1990s, but it has been however declining since around 1995. The greatest output growth uncertainty is seen in the 1980s, early 1990s and recent years of 2010s. On average, inflation uncertainty seems to have been higher than output growth uncertainty. The uncertainty about inflation arise more in these periods as the economy was hit by unprecedented negative exogenous commodity price shock and lack of policy synergy to curtail the situation. The reason is not farfetched as Nigeria always treats positive oil price shock as permanent experience hence, in periods of negative price shock, it becomes difficult to ensure fiscal discipline leading to pro-cyclicality instead of counter-cyclicality of fiscal response.

**Figure 1: Inflation Uncertainty and Output Growth Uncertainty for Nigeria**




Next, we focus on the objective of the study which is to examine the effectof uncertainty, nominal and real, on the levels of inflation and output growth in Nigeria.

The estimation results in Table 3 (panel A) suggest a positive and significant effect of inflation uncertainty on the level of inflation (the null hypothesis that $\psi_{\pi\pi} = 0$ is rejected at 1% level), with an estimated coefficient of inflation uncertainty equal to $(\psi_{\pi\pi} = 1.043)$. This supports hence the Cukierman-Meltzer hypothesis. Indeed, Cukierman and Meltzer (1986) argue that an increase in inflation uncertainty leads to an increase in the level of inflation as policymakers create surprise inflation to stimulate output.Our findings on the relationship between the level of inflation and its uncertainty, contradict those of Bamanga et al. (2016) and Hegerty (2012) that supported the Friedman's hypothesis. We find however that output growth uncertainty does not significantly affect the level inflation (the null hypothesis that $\psi_{\pi y} = 0$ cannot be rejected even at 10% level).

Regarding the effect of uncertainty on output growth, the results indicate a robust significant effect of inflation uncertainty (the null hypothesis that $\psi_{y\pi} = 0$ is rejected at 1%).The coefficient of inflation uncertainty in the output growth mean equation, is negative, equal to $\psi_{y\pi} = -0.055$. This suggests a negative effect of inflation uncertainty on output growth in Nigeria, supporting the Friedman's (1977) hypothesis. Indeed, inflation uncertainty creates greater risk for savers and investors, distorting hence their decisions to save or to invest as well as reducing the efficiency of resource allocation (Holland, 1984; Rizvi, 2010).As Friedman (1977) points out, inflation uncertainty renders the market prices system less efficient for coordinating economic activity. And according to Fischer and Modigliani (1978), inflation uncertainty leads to the change in the pattern of asset accumulation and the shortening of contracts, reducing hence the rate of investment by firms. It should be noted that Idowu and Hassan (2010) reached the same conclusion for Nigeria, but Odim et al. (2015) concluded to a positive effect of inflation uncertainty on output growth.

On the effect of real uncertainty, the results suggest an insignificant effect of output growth uncertainty on output growth (the null hypothesis that $\psi_{yy} = 0$ fails to be rejected even at 10% level), supporting Friedman's (1968) hypothesis of an independence relationship between the two variables.

The analysis of elements in matrices A and B gives the following intuition. The diagonal elements in Matrix B, $\beta_{yy}$ and $\beta_{\pi\pi}$ are statistically significant ($\beta_{\pi\pi}$ is significant at 5% level, while $\beta_{yy}$ is significant at 10% level), implying that own past volatility (uncertainty) affect the conditional variances of inflation and output growth in Nigeria. In addition, the results show that $\alpha_{\pi\pi}$ in the diagonal elements in Matrix A is statistically significant at 10% level, suggesting that own past shocks affect the conditional variances of inflation

## 4. Concluding Remarks

The study sought to examine the effect of uncertainty on the levels of inflation and output growth in Nigeria using a BEKK GARCH-M model suggested by Grier et al. (2004). The results support the Cukierman and Meltzer (1986) hypothesis of a positive effect of inflation uncertainty on the level of inflation. In addition, uncertainty about inflation was found to be detrimental to output growth, supporting the Friedman's (1977) hypothesis of a negative impact of inflation uncertainty on output growth. However, uncertainty about growth does not have a significant effect on both the levels of inflation and output growth.

The evidence in this study suggests that Nigeria should put in place policies minimizing inflation uncertainty to avoid its adverse effects on the economy. In addition, the independence relationship between output growth and its uncertainty in Nigeria suggest that they can be treated separately as suggested by business cycle models. As a resource dependent economy, positive commodity price boom should not treated as permanent experience so that in periods of negative commodity price shocks, fiscal response can be effective in ensuring counter-cyclicality.

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