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Uncertainty of stock market price behaviour and monetary policy: Evidence from Nigeria

Onanuga, Abayomi Toyin

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Abstract

This paper attempts to answer the question of how the uncertainty of stock price behaviour affected monetary policy decisions in Nigeria during the period 1991Q1-2015Q4. Although studies have been conducted on how the stock market responds to monetary policy decisions there is a paucity of analysis on how stock prices and the uncertainty of stock prices affect monetary policy, especially in Nigeria. Data was obtained from the Central Bank of Nigeria statistical database. Both Generalised Autoregressive Conditional Heteroskedasticity modelling and Generalised Method of Moments estimation were used for analysis. Findings from the regression analysis reveal that stock prices, as well as their unpredictable behaviour, significantly affect monetary policy decisions during the period under study. Another interesting finding is that the pair of the uncertainty of real output and inflation also significantly affected the monetary policy rate and that the monetary authority was more responsive to this pair than that of inflation and stock prices. The recommendation based on our findings is that the Central Bank of Nigeria should incorporate the uncertainty of stock prices into the monetary policy model when determining the policy rate.

Keywords:

Inflation, stock prices, monetary policy, share price index, uncertainty.

JEL classification:

E31, G10, E52, G30, D81

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Onanunga, A.T. ✉ Department of Accounting & Banking and Finance, Olabisi Onabanjo University, P. M. B. 2002 Ago-Iwoye, Ogun State, Nigeria.
✆ 2348033519370. E-mail: abonanuga@yahoo.com

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La incertidumbre del comportamiento del precio del mercado de valores y la política monetaria: **Una aplicación a Nigeria**

Onanuga, Abayomi Toyin

Resumen

Este artículo trata de encontrar respuestas a la cuestión relativa a cómo las decisiones de política monetaria se ven afectadas por la incertidumbre sobre los precios de las acciones en el caso nigeriano (1991-2015). Aunque se han llevado a cabo algunos estudios sobre cómo responde el precio de las acciones a las decisiones de política monetaria, son muy escasos aquellos centrados en cómo los precios de los valores, y la incertidumbre sobre los mismos, afecta a las decisiones política monetaria (especialmente en Nigeria). Para dar respuesta a la anterior cuestión, se utiliza la información proporcionada por el Banco Central de Nigeria para llevar a cabo la estimación de modelos de heteroscedasticidad condicional autorregresiva, realizándose tales estimaciones con el método generalizado de los momentos. Los resultados obtenidos ponen de manifiesto que los precios de las acciones, así como su comportamiento impredecible, influyen significativamente en las decisiones de política monetaria que se tomaron en el periodo objeto de estudio. Otro resultado interesante es que la dupla "incertidumbre en la producción real e inflación" también afectó significativamente a la tasa de política monetaria, de tal manera que las autoridades monetarias fueron más sensibles a la dupla anterior que al par "incertidumbre en inflación y precios de los activos". En base a las conclusiones obtenidas, se recomienda al Banco Central de Nigeria la inclusión de la incertidumbre en el precio de las acciones en su modelo de determinación de la tasa de política monetaria.

Palabras clave:

Inflación, precio de las acciones, política monetaria, índice de valores, incertidumbre.

1. Introduction

The heterogeneity of monetary transmission channels as documented by the literature shows that policymakers' actions taken in order to achieve macroeconomic objectives are not restricted to one channel but can occur through a number of established channels (e.g. interest rates or asset prices). In most countries, these actions affect the financial market (Gilchrist and Leahy, 2002). However, Mishkin (2007) and Liu and Zhang (2012) among others, noted that for advanced nations, asset prices, such as equity prices, bond prices and mortgage prices, respond to changes in monetary innovations. Furthermore, as pointed out in Gilchrist and Leahy (2002), since the substantial movements in asset prices in the USA and Japan in the last decade of the past century, which apparently coincide with large swings in growth rates, economists have been calling for policy makers to respond to asset price volatility.

Despite the fact that, according to Doh and Connolly (2013), the response of asset prices to policy guidance has weakened after the world financial crisis, the phenomenon is still worthy of empirical investigation. This paper investigates whether evidence supports this hypothesis in a developing country like Nigeria, by determining how monetary policy responds to the uncertainty of stock prices and the uncertainty of the pairs that can be formed from real output gap, inflation gap and stock prices (real output gap and inflation gap; real output gap and stock prices, and inflation gap and stock prices).

The relevance of each of these channels for monetary management in each country undoubtedly depends to a large extent on the level of development of the financial sector, (markets and institutions), the regulatory framework and the stage of economic development. However, the general opinion in monetary economics is that changes in asset prices have significant effects on aggregate output (Mishkin, 2001), and if stability of output is one of the key objectives of government, the monetary authority must take actions to correct such effects (Clarida *et al.*, 1998).

The standard loss function as specified by a central bank attempts to minimize a weighted average of the squared deviations of output from its potential level and inflation from its target level. In spite of this, for monetary policy to be optimal and for a central bank to sufficiently minimize its loss function, that policy has to accommodate changes in asset prices. The theoretical reasons for including asset prices in a central bank loss function were discussed by Bernanke and Gertler (1995). However, in a developing economy (like Nigeria) where the financial market is less developed than in advanced economies, how does monetary policy respond to changes in the stock market?

Investors' growing awareness and their desire to increase their financial wealth engenders the gradual move from the traditional investment pattern (bank deposits and savings), especially in developing nations, towards investment in stocks. In developing countries, this calls for the central bank's attention on assessing the response of the monetary policy rate to shocks from the capital market, as central banks have done in developed countries.

The empirical literature reveals a range of views on this issue. For example, Jovanovic, (2011) investigated how monetary policy affects the stock market in the United States, using monthly closing prices of V IX to represent stock market price uncertainty, and found significant evidence to support the fact that monetary policy Granger-causes stock market prices.

Haugh (2008) conducted a study on asset price shocks and monetary policy under uncertainty. He simulated the study data in order to determine the appropriate threshold which determines the parameters related with the asset price bubble in the capital market. The simulation first included then excluded asset prices in a monetary policy rule, so as to compare the performance of the objective function for the two situations. He found that completely excluding asset prices from the monetary policy model may not be desirable when it comes to determining the optimal monetary policy rate. He therefore suggested that it is better to adopt a high-threshold rule when the policymaker intends to include asset prices in monetary policy models, rather than completely ignoring the variable.

Bernanke and Kuttner (2005) examined the United States' stock market response to the federal funds rate (FFR) by comparing the pre-1994 and post-1994 period. They found evidence to suggest that monetary policy actions account for only a small portion of the overall variation in stock prices.

Gilchrist and Leahy (2002) investigated the effect of asset prices shocks on monetary policy by experimenting with the Real Business Cycle (RBC) model, a Keynesian Sticky-Price (KSP) model and a third model which adds a financial propagation mechanism on top of the new KSP model, as in Bernanke *et al.* (1999). After conducting a comprehensive sensitivity analysis, they concluded that asset prices and the economy as a whole can exhibit large fluctuations in response to shocks whose initial impact is on growth expectations and the net worth of firms. They did not, however, find any robust evidence that justifies the inclusion of asset prices in monetary policy models.

Empirical analysis of the response of equity prices to monetary policy has been undertaken by some scholars in Nigeria. Abaenewa and Ndugbu (2012) studied this phenomenon in the period 1985-2010; they found that monetary policy has a weak influence on equity prices. Aliyu (2011) also investigated the same phenomenon and determined the response of stock returns to monetary policy during the global financial crisis. He found that unexpected aspects of money supply and interest rate disturbances significantly affect stock returns.

Using a fairly similar analytical approach, Babajide *et al.* (2016) focused on the response of stock prices to economic growth and the interest rate. They found, as observed in the earlier studies, that stock prices respond not only to the interest rate but also to economic output. Olulu-Briggs and Ogbulu (2015) used money supply as a proxy for monetary policy instead of interest rate in order to determine the response of stock prices to monetary policy innovations. In line with other prior studies, they found that stock prices respond to the money supply. Ekong and Onye (2016) obtained similar results in spite of using a different methodology.

The main novelty in this paper is that it is determined the response of monetary policy to changes in stock market prices as well as to the uncertainty of the prices in a forward-looking model. This approach is selected based on the fact that investors are generally forward-looking and they normally incorporate their future expectations into their investment decisions while considering movements in stock prices.

The rest of the paper is structured as follows. Section two reviews the theoretical background on which this paper relies. Section three deals with the methodology, section four presents the main findings and section five concludes and makes a number of recommendations.

2. Theoretical review

In terms of transmission mechanisms, the asset price channel is comprised of routes such as equity prices, real estate prices, exchange rates, and credit to household and firms. The effect of changes made by the monetary authority on stock prices is central to some theoretical models such as Keynesian theory. Keynes (1935) argued that an increase in the supply of money by the monetary authority causes the deposit money banks (commercial banks) to decrease their interest rate on both deposits and loans. In specific terms, the reduction in the deposit rate drives small investors to invest in shares with the hope of benefiting from both capital appreciation and income receipts in form of dividends. Tobin (1969), as cited in Gantnerova (2004), also posited that asset prices such as equity respond to changes in the monetary policy rate when the policymaker pursues an expansionary policy (a reduction in the interest rate). Such a response causes a rise in equity prices on the stock market when policymakers reduce the interest rate. Mishkin (2001) stated that the reduction in the interest rate by the monetary authority leads to a reduction in the demand for bonds, whereas demand for equity rises. The action of the monetary authority encourages businesses to increase their shareholding based on Tobin's "q" investment theory, and thus take advantage of the opportunity to put their capital goods to productive use(s).

A similar argument about the reaction of stock prices to changes made by the monetary authority was advanced in the life cycle hypothesis by Modigliani (1971). He asserted that another significant source of consumers' lifetime means of satisfying consumption needs could be the financial assets they own. If such financial assets are held in equity form, an expansionary monetary policy can increase the stock value and consequently the household financial wealth.

According to Bernanke and Gertler (1995), another monetary transmission route through which policymakers' actions can affect the capital market is the borrower's balance sheet channel. As explained above, an expansionary monetary policy increases the prices of equities in the capital market and thus their net worth. Firms' increased net worth encourages banks to lend to them due to the reduction in adverse selection and moral hazard difficulties.

In consideration of the theoretical review above, it is clear that the monetary transmission route is not limited to the interest rate channels but can also pass through a number of other channels such as the asset prices channel, in which, for example, stock prices and real estate prices are prominent. However, the discussion on whether or not to include asset price in monetary rules is still ongoing. According to Gilchrist and Leahy (2002), interest rates could provide information on why there is distortion in the financial market and asset prices can also be used to carry out such a task, but Cogley (1999) stated that the flow of asset prices is not easy to track, therefore it may not be directly related to economic activity. Earlier, Brainard (1967) opined that, for the sake of caution, it would be better for policymakers to include asset price in policy models, even if only for information purposes, rather than excluding them entirely. This issue is therefore very important for aiding monetary policy modelling in a developing country like Nigeria. As such, there is a need to examine the empirical relationship between these variables so as to determine how the activities of the capital market, such as the unpredictable nature of the movements in stock prices, affect monetary policy decisions.

3. Methodology

3.1 Data and Methods

This paper employed quarterly data obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin (2015 edition) and the National Bureau of Statistics 2015 Report.

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The period of study covers 1991Q1-2015Q4. The variables considered in this paper are the following:

- The Treasury bill rate, which is used as the proxy for the monetary policy rate due to its flexibility and because it can reflect changes in the money market conditions when compared to the monetary policy rate inertia. This approach has been widely used in the literature; for example, Naraidoo and Raputsoane (2013) used it for South Africa.

- The all-share index (rate of change) of the Nigerian Stock Exchange is used as a proxy for equity prices. This serves as a composite measure of changes in stock prices as opposed to considering changes in the prices of individual stocks.

- The real economic output used in this paper has been adjusted for inflation at 2010 constant prices (CBN, 2013). The real output gap was obtained from the real output data after filtering the data using the Hodrick-Prescott (HP) filter. Using the HP filter to decompose the data into the trend and the cyclical component is a common approach in the literature; for instance, see Lumo (2015), Redebusch *et al.* (2015) and Chamberlin (2015). The inflation rate used in this paper is the consumer price index and the target inflation data used is as prescribed by the CBN since 1991. Uncertainty estimates of equity prices, real output gap and inflation are derived based on Generalised Autoregressive Conditional Heteroskedasticity (GARCH) modelling, and the Generalised Method of Moments (GMM) was used in regression analysis. All the data used in this paper were seasonally adjusted in order to avoid the effect of the cyclical recurring movements from the series and to bring out the main trend components embedded in the series.

3.2 Rationale for the empirical model

The empirical model used in this paper augments the interest rate rule (Taylor, 1993) with equity prices and the generated uncertainty of equity prices, real output and inflation resulting from the GARCH approach. Since the paper attempts to determine how the conditional variance of the explanatory variables changes over time, the GARCH variance series obtained provides a means of measuring the uncertain behaviour of the stock prices, real output and inflation variables as well as revealing any evidence of volatility clustering in the series.

According to Gujarati (2014), GARCH (p, q) can be used to capture such information, while Bollerslev (1986) showed that a simple GARCH (1, 1) model provides a marginally better fit compared to ARCH models with a relatively long lag. Engle (2001) was of the view that, in some cases, it is necessary to use GARCH (p, q), models with more than one lag to derive good conditional variance estimates. In view of the fact that the aim of this paper is not to estimate the uncertain behaviour of the study series based on infinite unconditional variance using the Integrated GARCH (IGARCH) (Hamilton, 1994), GARCH (p, q) specifications have been used to derive the uncertainty estimates of equity prices, real output gap and inflation.

In an observable situation, the monetary authority can specify the period social loss function in the Svensson (1999) sense as follows:

$$L_t = E_t\left[\sum_{j=t}^{\infty}\beta^{j-t}(\pi_j^2 + \lambda_j y_j^2)\right] , \tag{3.1}$$

where L_t denotes the "period" loss function and E_t indicates expectation conditional on information available in period t, and λ_j is the central bank's preference weight for stabilizing real aggregate output gap (y_j) relative to inflation π_j . However, in a forward-looking situation, King (2000) posited the macroeconomic model representing the aggregate demand of the "IS" curve and the Phillips curve as stated in equations (3.2) and (3.3).

$$y_t = E_t y_{t+1} - \gamma\left[r_t - r^*\right] + x_{dt} , \tag{3.2}$$

$$\pi_t = \beta E_t \pi_{t+1} + \phi\left(y_t - y_t^*\right) + x_{\pi t} , \tag{3.3}$$

where y_t stands for the current real output, which depends on its expected future value $E_t y_{t+1}$, as stated in equation (3.2). Furthermore, the real interest rate is denoted by r_t, with r^* being the rate of return prevailing in the absence of demand shock. Finally, x_{dt} is the aggregate demand shock. The parameter γ determines the effect of real interest rate on real aggregate output. In the expectational Phillips curve in equation (3.3), π_t is the current inflation rate, and the expected future inflation $E_t\pi_{t+1}$ serves as a determinant of current inflation; β a-priori satisfies $0 \leq \beta \leq 1$ and $\varphi > 0$ governs how inflation responds to deviations of output from its capacity level y_t^*.

Interest rate smoothing theory, in the view of Rudebusch (2002), deals with the policymaker's inertia in the adjustment of the monetary policy rate, and the functional form of such a policy adjustment can be stated as:

$$i_t = \rho_1 i_{t-1} + (1-\rho_1) i_t^* , \tag{3.4}$$

where i_t is the nominal interest rate and i_t^* defines what the Taylor rule represents, as indicated in equation (3.5). According to Woodford (2001), the Taylor rule implies that monetary policy can stabilize inflation if the policy rate is adjusted by more than the change in inflation. The baseline model of the Taylor rule is as stated in equation (3.5).

$$i_t = \alpha_\pi \pi_t + \alpha_y y_t + \varepsilon_t \quad , \tag{3.5}$$

where y_t is the percentage deviation of real output from its potential level, π_t is the inflation gap, α_π and α_y are coefficients and ε_t is the uncorrelated stochastic shocks that follow a white noise process.

3.3 Empirical model

The empirical model specified in this paper relies on New Keynesian economics and the augmented Taylor rule that includes the smoothing parameter, as discussed in Rudebusch (2002). Based on the rational expectations model, in which both the investor and the inflation-targeting posture of the central bank are basically forward-looking, the share prices equation is as stated in equation (3.6) and the variance, which, in light of both simple and partial autocorrelation functions, follows a GARCH (1, 2) process, is represented in equation (3.7)

$$s_{t+1} = \delta_1 s_t + \delta_2 \pi_t + \vartheta_t \tag{3.6}$$

$$\sigma^2_{st} = \gamma_1 + \gamma_2 \vartheta^2_{t-1} + \gamma_3 \vartheta^2_{t-2} + \gamma_4 \sigma^2_{st-1} \tag{3.7}$$

where s is the equity prices, π represents inflation and ϑ_t is the error term that follows a Gaussian white noise process.

The real output and inflation equations that represent the functional relationship between the aggregate demand and supply based on a forward-looking approach are as stated in equations (3.8) and (3.10), while the variance, which according to both the simple and partial autocorrelation functions follows a GARCH (1, 1) process, is defined in equations (3.9) and (3.11):

$$y_t = \phi_0 + \phi_1 y_{t+1} - \phi_2 i_{t-1} + \mu_t \tag{3.8}$$

$$\sigma^2_{yt} = \theta_1 + \theta_2 \mu^2_{t-1} + \theta_3 \sigma^2_{yt-1} \tag{3.9}$$

$$\pi_t = \alpha_1 \pi_{t+1} + \alpha_2 y_{t-1} + \varepsilon_t \tag{3.10}$$

$$\sigma^2_{\pi t} = \beta_1 + \beta_2 \varepsilon^2_{t-1} + \beta_3 \sigma^2_{\pi t-1} \tag{3.11}$$

where y_t is the output variable, i is the nominal rate of interest, π is inflation, and μ_t and ε_t are the disturbance terms in equations (3.8) and (3.10) which generate an infinite sequence that is i.i.d. N(0, σ^2). σ^2_{st}, σ^2_{yt} and $\sigma^2_{\pi t}$ are measures of uncertainty for stock prices, output and inflation, respectively, which measure the ARCH and GARCH effects. $\delta_i(i=1,2)$, $\gamma_i(i=1,2,3,4)$, $\varphi_i(i=0,1,2)$), $\theta_i(i=1,2,3)$, $\alpha_i(i=1,2)$ and $\beta_i\ (i=1,2,3)$ are model coefficients, while ϑ_t, μ_t and ε_t are error terms that follow a Gaussian white noise process.

Adapting the work of Naraidoo and Raputsoane (2013), equation (3.12) includes a smoothing parameter under certainty equivalence where the policymaker observes the macroeconomic variables. Therefore, combining equations (3.4) and (3.5), the function of the monetary policy rate can be expressed under certainty as follows:

$$i_t = \rho_0 + \rho_1 i_{t-1} + (1-\rho_i) + \alpha_\pi (E_t \pi_{t+1} - \pi^*) + \alpha_y y_t + \varepsilon_t \qquad (3.12)$$

where i_t is the monetary policy rate, π_t is the inflation rate, π^* is the target inflation, y_t is the output gap, ρ_0, ρ_i, α_π, α_y, are parameter estimates and ε_t is the error term assumed to be orthogonal to the explanatory variables.

Equation (3.12) is augmented with the all-share index as the proxy for equity prices, as indicated in equation (3.13), which represents the certainty equivalence situation in a forward-looking model.

$$i_t = \rho_0 + \rho_1 i_{t-1} + \alpha_\pi (E_t \pi_{t+1} - \pi^*) + \alpha_y y_{t+1} + \alpha_s s_{t+1} + \upsilon_t \qquad (3.13)$$

where the notations are as previously explained in equation (3.12) and s_t is the equity price, ρ_0, ρ_1, α_π, α_y and α_s are the model parameters and ν_t is the error term, which follows a Gaussian white noise process.

In order to determine whether the monetary policy rate responds to uncertainty of equity prices as well as to real output and inflation, the GARCH estimates of the three variables are included in equation (3.14) as stated below.

$$i_t = \rho_0 + \rho_1 i_{t-1} + \rho_y^* \sigma_{yt}^2 + \rho_\pi^* \sigma_{\pi t}^2 + \rho_s^* \sigma_{st}^2 + \rho_{yt} y_{t+1} + \rho_{\pi t} \pi_{t+1} + \rho_{st} s_{t+1} + \xi_t \qquad (3.14)$$

where i_t is the monetary policy rate at time t and σ_{yt}^2, $\sigma_{\pi t}^2$, σ_{st}^2 represent uncertainty (variability) of real output, inflation and stock prices, respectively. y_{t+1}, π_{t+1}, s_{t+1} are forward-looking variables of real output, inflation and stock prices, respectively, while ρ_0, ρ_1, ρ_y^*, ρ_π^*, ρ_s^*, ρ_{yt}, $\rho_{\pi t}$, ρ_{st} are the model parameters of the baseline model in equation (3.14) and ξ_t is the error term, which is Gaussian white noise.

The uncertainty variables in equation (3.14) are paired into three "uncertainty pairs" (real output gap-inflation gap; real output gap-stock prices and inflation gap-stock prices), as indicated in equation (3.15), in order to determine the response of the monetary policy rate to the "uncertainty pairs" in Nigeria.

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$$i_t = \rho_0 + \rho_1 i_{t-1} + \alpha_1(\sigma^2_{yt}\sigma^2_{\pi t}) + \alpha_2(\sigma^2_{yt}\sigma^2_{st}) + \alpha_3(\sigma^2_{\pi t}\sigma^2_{st}) + \eta_t \quad (3.15)$$

In equation (3.15), are model parameters ρ_0, ρ_1, α_1, α_2, α_3 and η_t is the disturbance term, which is Gaussian white noise. Equations 3.7, 3.9, 3.11, 3.14 and 3.15 are estimated for analysis[1], and the discussion of our findings is presented in the next section.

4. Discussion of results

In Table 1, the results of the unit root test based on the Augmented Dickey Fuller (ADF) approach indicate that all the generated GARCH series are stationary at level while the main series (monetary policy rate, all-share index (ASI), real GDP and inflation data) are stationary at the first difference.

Table 1. **Results of the ADF Unit Root Test**

Name of variables	ADF test	Order of integration
T-bill	-8.83*	1(1)
Equity prices	-7.32*	1(1)
Real output gap	-9.98*	1(1)
Inflation rate gap	-10.01*	1(1)
Uncertainty of equity prices	-4.41*	1(1)
Uncertainty of real output gap	-3.75*	1(1)
Uncertainty of inflation rate gap	-3.01**	1(0)

ADF Critical Values: 1% -3.4992 @ [I(1)]*
*5%** -2.8922 @ [I(0)]*

Table 2 reports the measurement of the level of uncertainty of stock prices proxied by ASI as well as that of the economic output and the level of inflation, which are proxied by the real gross domestic product (RGDP) and the consumer price index (CPI), respectively. The volatility of RGDP and inflation variables based on GARCH (1, 1) sum up to 1.40 and 1.17, respectively, thus indicating volatility persistence which may not die out quickly. The results for ASI indicate that both the ARCH and the GARCH terms are significant, with coefficient values of 0.62 and –0.27, respectively.

The findings based on the GARCH analysis in Table 2 suggest that the variables under study show some uncertainty in their respective behaviour. Tables 3-5 contain the results of the ARCH effect test after estimating the level of uncertainty of the variables listed in Table 2.

[1] The econometric software used in this paper for estimating the empirical models (GARCH and GMM) is the EViews 9.5 edition.

Table 2. Results of GARCH estimation

Coefficient	Estimate
All-share index	
γ_2	0.62*(0.1999)
γ_4	-0.27* (0.0715)
Real output	
θ_2	1.00*(0.3322)
θ_3	0.40* (0.1423)
Inflation	
β_2	0.95* (0.2237)
β_3	0.22*** (0.1234)

Standard error in parentheses
(*) (**) and (***) indicate significant at the 1%; 5% and 10% significance level, respectively

The results show that the null hypothesis is not rejected in any of the three cases, which indicates the absence of autoregressive conditional heteroskedasticity in the series at the 1% level of significance.

Table 3. Results of ARCH effect test for all-share index

F - statistic	0.001917	Prob. F(1,96)	0.9652*
Obs* *R* Squared	0.001957	Prob. Chi-Squared	0.9647*

(*) failure to reject the Null Hypothesis at 1% level of significance

Table 4. Results of ARCH effect test for real output

F - statistic	0.332214	Prob. F(1,96)	0.5657*
Obs* *R* Squared	0.338026	Prob. Chi-Squared	0.5610*

(*) failure to reject the Null Hypothesis at the 1% level of significance

Table 5. Results of ARCH effect test for real output

F - statistic	0.975376	Prob. F(1,96)	0.3258*
Obs* *R* Squared	0.985681	Prob. Chi-Squared	0.3208*

(*) failure to reject the Null Hypothesis at the 1% level of significance

GMM estimates

As can be observed in Table 6, the coefficient estimates of the certainty equivalence model indicate a relatively high level of inertia in the management of the monetary policy rate during the period of study. Aside from inflation, which is not statistically significant, real output and stock market price significantly affect the monetary policy rate at the 5% level of significance.

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Table 6. **Results of ARCH effect test for inflation**

Coefficient	Estimate
ρ_0	7.3409**(2.3609)
ρ_1	0.8824*(15.9932)
$\rho_{\pi t}$	0.0029 (0.7704)
ρ_{yt}	0.6461**(2.3303)
ρ_{st}	−0.6281**(-2.0449)
R-Squared 0.794	
Adj- *R* squared 0.786	
J. statistic 6.739	
Prob. (J-statistic) 0.46	
Prob. $\chi^2_{0.05}$ 14.1	
Instrument rank 12	
t-statistic in parentheses	

(*), (**) and (***) indicate significant at the 1%, 5% and 10% significance level respectively

The estimates listed in Table 6 suggest that real output has a positive relationship with the monetary policy rate, while the stock price has a negative relationship with it. This implies that a one-percent increase in real output causes an increase of 0.6461 percentage points in the monetary policy rate, while a one-percent increase in the stock price leads to a decrease of 0.6281 percentage points in said rate. These findings on the relationship between stock price and monetary policy rate are in line with the theoretical propositions of Modigliani (1971), Tobin (1969), Bernanke and Gertler, (1995) and Mishkin (2001), whose various theoretical models all hold that expansionary monetary policy has an inverse relationship with stock price.

Table 7 shows the GMM estimation results for the uncertainty variables along with the certainty equivalence variables. As can be seen, following the inclusion of uncertainty variables, the parameter (ρ_1) dropped from 0.8824 to 0.6787. This is also an indication that the current monetary policy rate depends on the prior rate but the uncertainty perceived by the policymakers has led to the decline of the response rate.

The uncertainty variables for the stock prices, real output and inflation significantly influence the policy rate at the 5% level of significance for stock prices and at the 1% level of significance for the other two variables (real output and inflation). The estimates for the uncertainty of stock prices and real output are $\rho_s^* < 0$ and $\rho_y^* < 0$, while that of inflation is $\rho_\pi^* > 0$. This implies that monetary policymakers in Nigeria are more responsive to inflation uncertainty than to uncertainty in real output and stock prices. In addition, it is of note that stock prices also affect the determination of the policy rate negatively, as is the case with the certainty equivalence model. The consistency in the results for both the certainty equivalence model and the uncertainty model suggest that the stock price is an important factor to be considered in monetary policy modelling in Nigeria.

Table 7. Uncertainty model – GMM estimation results

Coefficient	Estimate
ρ_0	14.1521*(3.6343)
ρ_1	0.6787*(12.5531)
$\rho_{\pi t}$	0.0054 (1.2480)
ρ_{yt}	0.8658 (1.6583)
ρ_{st}	–1.6128*(-5.5143)
ρ_{π}^{*}	0.3875*(2.8948)
ρ_{y}^{*}	–0.7136*(-8.3044)
ρ_{s}^{*}	–32.3668**(-2.1212)
R-Squared 0.7852	
Adj- *R* squared 0.768	
J. statistic 10.55	
Prob. (J-statistic) 0.72	
Prob. $\chi^2_{0.05}$ 23.70	
Instrument rank 22	

t-statistic in parentheses
(*), (**) and (***) indicate significant at the 1%, 5% and 10% significance level respectively

From the results listed in Table 8, it can be concluded that the "uncertainty pairs" (real output and inflation; real output gap and stock prices, and inflation and stock prices) significantly affect the monetary policy rate (at the 1% level of significance). However, the parameter ρ_1 increased to about 0.86 due to the effects of pairing the uncertainty estimates of the study variables. The response rate parameter is still slightly lower than that of the certainty equivalence model (decreases by 0.02). The lesson to be drawn from the response rate estimates is that the CBN should be more conservative when setting the policy rate.

Table 8. Uncertainty pair interaction model – GMM estimation results

Coefficient	Estimate
ρ_0	2.1501* (5.2839)
ρ_1	0.8594* (31.0312)
$\rho_{y}^{*}{}^{*}\rho_{\pi}^{*}$	0.0542*(2.8401)
$\rho_{y}^{*}{}^{*}\rho_{s}^{*}$	-49.1939*(-4.2998)
$\rho_{\pi}^{*}{}^{*}\rho_{s}^{*}$	–2.2863*(-5.4563)
R-Squared 0.8039	
Adj- *R* squared 0.7952	
J. statistic 14.98	
Prob. (J-statistic) 0.5971	
Prob. $\chi^2_{0.05}$ 27.6	

t-statistic in parentheses
(*) indicates significant at the 1% level of significance

Table 8 also shows that $\rho_y^* \rho_s^* < 0$ and $\rho_\pi^* \rho_s^* < 0$, while $\rho_y^* \rho_\pi^* > 0$, which implies that the monetary policy authority is less responsive to the "uncertainty pairs" real output gap-stock prices and inflation gap-stock prices than to the "uncertainty pair" real output gap-inflation gap. The implication of this finding is that, as with the uncertainty case, the monetary policymaker is less responsive to the uncertainty of stock prices in spite of the fact that it significantly affects monetary policy.

Results from the diagnostic tests

It is of note that in Tables 6, 7 and 8, the value of the Sargan-Hansen *J*-statistic is lower than that of Prob. $\chi^2_{0.05}$. This indicates that the models specified and analysed are not misspecified. According to the value of Prob. (*J*-statistic) in each of the three Tables (6, 7 and 8), the null hypothesis cannot be rejected, which suggests that over-identification restrictions are satisfied.

Table 9 lists the value of the Cragg-Donald (1993) statistic to test whether the instruments used for analysis are weak, in spite of the fact that over-identification restrictions are satisfied. Given that the Cragg-Donald *F*-statistic is greater than the critical values at the 10% level of significance for the certainty equivalence model, and at the 5% level of significance for both the uncertainty model and the uncertainty pair interaction mode, the null hypothesis can be rejected, which indicates that the instruments employed in the regression analysis are strong despite the fact that the model parameters are over-identified. Thus, the post estimation tests suggest that our findings are sufficiently reliable and robust to inform policy.

Table 9. **Uncertainty pair interaction model – GMM estimation results**

Type of model	Cragg-Donald *F*-statistic	Critical values (relative bias)
Certainty equivalence	11.81	5%-18.30: 10%-10.43: 20%-6.22
Uncertainty	18.01	5%-16.10: 10%-9.37: 20%-4.46
Interaction	59.24	5%-19.56: 10%-10.60: 20%-5.93

5. Conclusion and recommendations

The main aim of this paper is to find answers to the question of how the uncertainty of stock prices affected the path of monetary policy in Nigeria in the period 1991Q1-2015Q4. For this purpose, the GARCH-GMM approach was used. GARCH modelling is used for estimating the measure of uncertainty of the study variables and GMM is used for regression analysis of the study's empirical models. The results obtained reveal that both the stock prices and the uncertainty of stock prices significantly affected the monetary policy rate in the period of study. The empirical analysis suggests that, when modelling the monetary policy, monetary policymakers in Nigeria are more responsive to inflation uncertainty than to the uncertainty of real output and stock prices. In addition to this, the interaction model also suggests that monetary policy is more responsive to the "uncertainty pair" of output gap and inflation gap, while it is less responsive to that of inflation gap and stock prices. In view of these findings, it can be concluded that in spite of the significant effect of uncertainty of stock prices on monetary policy, this fact is not taken into account by the monetary authority when fixing the monetary policy rate. Therefore, it is highly recommended that monetary policymakers in Nigeria endeavour to consider the uncertainty of stock prices when modelling the policy rate.

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