Uncertainty of Output Gap and Monetary Policy-Making in Nigeria

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Abstract: This paper investigates the effect of output gap uncertainty on monetary policy rate in Nigeria-1991Q1-2014Q4. A major challenge of monetary policy is the attainment of sustainable output level but in setting the optimal monetary policy rate information about output gap and how uncertainty of the gap affects the path of the monetary policy rate is crucial for policy use. Empirical evidence on this phenomenon in Nigeria has been concerned with how monetary policy affects output while evidence on the response of monetary policy to uncertainty of real output is not indepth. Analythical approach in this paper adopts the Generalised Method of Moments econometric technique. Evidence from the study suggest that real output gap and inflation uncertainty are statistically significant with estimated values of $p_y^y \sigma_{yt}^2 < 0 \; and \; p_\pi^\pi \sigma_{\pi t}^2 < 0$ respectively. The coefficient of the real output variable is significant with a coefficient estimate of $p_{yt} > 0$ while we found no strong evidence to support the effect of inflation on monetary policy rate. The inference from our findings is that monetary policy is less responsive to uncertainty of real output gap and inflation. Thus our recommendation is that the Central Bank of Nigeria should consider uncertainty of both output and inflation variables when setting the policy rate.

Keywords: inflation rate; monetary policy rate; real output potential; generalized method of moments

JEL Classification: E31; E52; E01; C13

1. Introduction

A major challenge of monetary policy in different countries among others is the attainment of sustainable output that is very close to the natural or the potential level of output. The effort of monetary policymakers in archiving this objective requires that the monetary policy rate set by a central bank be optimal in order to encourage investment which contributes to aggregate output in real time. The

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complexity of the available methods and availability of reliable data that estimates the likely natural level of output and the determination of the gap between the potential and the actual output *ex ante* is very essential for monetary management in any nation. Predicting the output gap by monetary policymakers has not been quite easy because the variable is not observable and there is no single approach for the determination of this phenomenon. This has been noted in the literature by Orphanides and van Norden (2002) in Flamini and Martin (2011) who express the view that reliable measure of the output gap is subject to debate. In spite of this, monetary policy must be perceived to be achieving output stability along with other macro objectives for it to be recognised as a welfare seeking policy by the people.

The need to study how macroeconomic uncertainty affects the monetary policy rate has been growing in monetary economics since the scholarly contribution of Brainard (1967). On USA, Smets (1998) conducted a study on how output gap uncertainty measurement error affects efficient monetary policy rules. He used multi equation analysis and found that output gap uncertainty has significant effect on the efficient response coefficient in a restricted instrument rule like that of the Taylor rule. Unlike Smets, Jorda and Salyer (2003) conducted a study on uncertainty and maturity of bonds. They found that uncertainty has significant effects on bonds and it in fact, reduces the yield on short-term and long-term bonds. Martin and Milas (2005) considered how uncertainty affects the Federal Fund Rate (FFR) and found that when uncertainty of inflation is greater, the policy makers respond more to changes in output when adjusting the policy rate. Cogley et al. (2011) in a study focus on how monetary policy could be conducted when confronted with multiple sources of uncertainty. The study considered models which include forward and backward looking representations and found that the Taylor rule type accounts for model and parameter uncertainty. In the study of Mayers and Montagoli (2011) they focused on how uncertainty affects monetary policy using the minutes of decision-making of monetary authority of three European countries (United Kingdom, Czech and Sweden). Their aim was to test whether information about uncertainty as recorded in the minutes of the central bank board meeting of individual country will help in explaining the interest rate setting of the banks. They found that the policy rate of these countries respond to uncertainty of output gap and inflation although the response rate varies across samples.

In Nigeria, the concern about uncertain economic environment by the CBN (2014) monetary policy committee who expressed the notion that knowledge of the behaviour of output and inflation has been imprecise when fixing the policy rate calls for empirical effort on this issue. Incidentally, studies on how the policy rate affects some macroeconomic variables like output and inflation in Nigeria are replete in the literature. Some of such studies include: Kromtit (2015) who found that monetary policy has insignificant positive impact on inflation while ThankGod and Tamarauntari (2014) found that monetary policy variables do have quick impact on output. Mordi and Amoo (2014) provide evidence to support the view that monetary policy is a major macroeconomic measure used by policymakers to influence the outcome of macroeconomic variables. While findings by Adigwe et al. (2015) suggest that monetary policy exerts positive impact on the GDP and negative impact on inflation. These recent studies did not consider the effects of uncertainty of output on the path of the policy rate in Nigeria.

In this paper, unlike the earlier studies, we employ a non-linear model to investigate the effect of uncertainty of output gap on the path of the monetary policy rate in Nigeria by modelling the current, forward and backward looking situations. The study found that monetary policy is less responsive to uncertainty of output. The rest of the paper is organised as follows. Section two explains the theoretical framework while section three is on methodology. Section four discusses our findings and section five concludes the paper with recommendations.

2. Theoretical Framework

The macroeconomic model on which this paper relies is the New Keynesian "IS" curve propounded by Clarida, Gali and Getler (1999) and the Taylor Rule by Taylor (1993). The macroeconomic model by Clarida et al. (1999) expresses the fact that: real output gap depends on the difference between the log of real actual output and the potential real output. Second, the current real output gap is a function of future output gap and interest rate. Finally the theory posits the Phillips curve which expresses the functional relationship between inflation and real output gap. The equations which express these relationships according to Clarida *et al*. are stated in equations (2.1-2.3)

$$x_t \equiv y_t - z_t \quad \ldots \quad (2.1)$$

Where x_t real output gap, z_t is the derived value of the actual real output filtered by Hodrick-Prescott approach.

$$x_t = -\emptyset[i_t - E_t\pi_{t+1}] + E_t x_{t+1} + \varepsilon_t \quad . \; . \; . \quad (2.2)$$

Where i_t is the interest rate, $E_t\pi_{t+1}$, is expected inflation rate in the next period and $E_t x_{t+1,}$ is the expected real output gap in the next period. $\emptyset$ is a parameter estimate and ε_t is the error term.

$$\pi_t = \gamma x_t + \beta E_t\pi_{t+1} + \vartheta_t \quad . \; . \; . \quad (2.3)$$

Where π_t is the inflation rate x_t real output gap $E_t\pi_{t+1}$ is the expected inflation rate. Taylor (1993) propounded an interest rate rule in which a central bank set its bank rate (policy rate) which responds to real output gap and deviations of inflation rate from its target. The Taylor (1993) the rule can be expressed in the form:

$$i_t = \delta_\pi \pi_t + \delta_y y_t + \delta_0 \quad . \quad . \quad . \qquad (2.4)$$

Where i_t represent the short term monetary policy rate, π_t stand for the deviation of inflation from its target and y_t is the real output gap while $\delta_{\pi,} \delta_y, \, and \, \delta_0$ are parameters estimates of the variables and the error term.

Brainard (1967) posits that uncertainty affects monetary policy as such the central bank can either use a target instrument to address a target objective or use multiple instruments for many objectives. A static liner equation expressed by Brainard (1967) describes that a target variable depends on a policy instrument. This is expressed as follows:

$$\gamma = \alpha P + \varepsilon \quad . \quad . \quad . \qquad (2.5)$$

Where γ is the target variable, which is real output, P is the policy instrument that is the monetary policy rate. α and ε are parameter estimate and error term respectively.

Equation (2.5) describes the possible uncertainty facing the policymaker. For example Brainard (1967) postulated that the *ex-ante* monetary policy rate P may respond to an estimate $\overline{\alpha}$ that is substantially different from its expected value due to uncertainty. Similarly, the policy maker is unable to determine the *ex-ante* monetary policy rate that will accommodate the effects of uncertainty due to ε the exogenous factors. In the face of such uncertainty, Brainard (1967) suggest that the central bank should be cautious in fixing the monetary policy rate. This has been variously referred to as the attenuation principle or conservatism theory in the literature.

3. Methodology

3.1 Data Sources and Description

Data were obtained from the Central Bank of Nigeria Statistical (CBN) Bulletin 2014 edition and the statistical data base of the bank. It covers a quarterly period of 1991:Q1-2014:Q4 for the following types of time series data. Real Gross domestic Product (RGDP) is the proxy for the real economic output. Inflation Rate (IR) represents the headline inflation quarter on quarter change for the period of the study. The Nominal Effective Exchange Rate (NEER) is the proxy for exchange rate and Monetary Policy Rate (MPR) is the proxy for monetary policy instrument. The study period started from 1991 because Inflation Target (IT) data was provided in the CBN statistical bulletin commencing from that date and the real output gap estimate was transformed by Hodrick-Prescott (HP) Filter.

3.2 Empirical Model

The empirical model for this paper relies on the theoretical proposition of Clarida et al. (1999) and the Taylor rule (1993). In respect of the empirical model we adapt the empirical work of Martin and Milas (2005) who have used a similar approach for United States of America (USA). The output gap equation for this study is stated in equation (3.1) and the uncertainty estimates based on GARCH (1, 1) analysis was obtained from the residual variances of equation (3.1) as expressed in equation (3.2)

$$y_t = \varphi_0 + \varphi_1 y_{t-1} - \varphi_2 i_{t-1} + \varepsilon_t \quad . \; . \; . \quad (3.1)$$

$$\sigma^2_{yt} = \emptyset_1 + \emptyset_2 \varepsilon^2_{t-1} + \emptyset_3 \sigma^2_{yt-1} \quad . \; . \; . \quad (3.2)$$

The inflation equation for this paper is as stated in equation (3.3) and the uncertainty estimates based on GARCH (1, 1) analysis was also obtained from the residual variances of equation (3.3) as expressed in equation (3.4)

$$\pi_t = \alpha_1 \pi_{t-1} + \alpha_2 y_{t-1} + \mu_t \quad . \; . \; . \quad (3.3)$$

$$\sigma^2_{\pi t} = \beta_1 + \beta_2 \mu^2_{t-1} + \beta_3 \sigma^2_{\pi t-1} \quad . \; . \; . \quad (3.4)$$

Where y_t and π_t stand for real output gap and inflation variable at time t, i_t is the interest rate, $\varphi_0, \varphi_1, \varphi_2$ are parameter estimates for real output gap in equation (3.1), α_1, α_2 are parameter estimates for inflation variable in equation (3.3) while $\varepsilon_t, and\ \mu_t$ are their respective error term that follow a white noise process. The variance equations of the real output and inflation variables in equation (3.2) and (3.4) have a-prior coefficient estimate that is expected to be $\emptyset_1 > 0, \emptyset_2 \geq 0\ and\ \emptyset_3 \geq 0$ for real output and $\beta_1 > 0, \beta_2 \geq 0\ and\ \beta_3 \geq 0$ respectively. The parameter estimates of $\emptyset_2\ and\ \emptyset_3$ and that of $\beta_2 and\ \beta_3$ are the coefficient values of GARCH (1, 1) for the real output and inflation variables.

The smoothing parameter of the monetary policy rate Clarida *et al.* (2000) in equation (3.5) is a functional relationship in which the current monetary policy rate depends on the weighted average of the previous monetary policy rate.

$$i_t = p_1 i_{t-1} + (1 - p_1) \quad . \; . \; . \quad (3.5)$$

In other to determine the response of monetary policy rate to uncertainty of real output the paper develops a model which considers three equations that include current, backward and forward looking methods based on augmented Taylor rule and an interest rate smoothing parameter in equation (3.5). The baseline models in this paper are expressed in equations (3.6-3.8)

$$i_t = p_1 + p_{2it-1} + p^y_y \sigma^2_{yt} + p^\pi_\pi \sigma^2_{\pi t} + p_{yt} y_t + p_{\pi t} \pi_t + \vartheta_t \quad \ldots \quad (3.6)$$

$$i_t = p_1 + p_{2it-1} + p_y^y \sigma_{yt}^2 + p_\pi^\pi \sigma_{\pi t}^2 + p_{yt} y_{t-1} + p_{\pi t} \pi_{t-1} + \epsilon_t \quad \dots \qquad (3.7)$$

$$i_t = p_1 + p_{2it-1} + p_y^y \sigma_{yt}^2 + p_\pi^\pi \sigma_{\pi t}^2 + p_{yt} y_{t+1} + p_{\pi t} \pi_{t+1} + \varphi_t \quad \dots \qquad (3.8)$$

Where i_{t-1} is the weighted average of the previous monetary policy rate. σ_{yt}^2 and $\sigma_{\pi t}^2$ are measures of uncertainty of real output gap and inflation, p_1, p_2, p_{yt}, $p_{\pi t}$,, p_y^y and p_π^π are parameter estimates while ϑ_{t}, ϵ_t $and \varphi_t$ are error terms. All other notations are as previously defined. Our empirical model for this paper are equations 3.2, 3.4and 3.6-3.8.

4. Discussion of Results

4.1 Results of Unit Root Test

The results of the unit root test considered both the ADF and KPSS because ADF statistic has limitations of lower power as it tends to reject the null hypothesis of unit roots (Sheefeni and Mabakeng, 2014).The results in Table 1 reveals that all variables for the study are stationary at level except uncertainty of inflation gap which is stationary at first difference.

Table 1. Unit Root Test Results

Variable	ADF Test	KPSS Test	Level of Integration
p_{it}	-2.70	0.099*	1(0)
p_{yt}	-3.62	0.038*	1(0)
$p_{\pi t}$	-6.88	0.103*	1(0)
p_y^y	-4.36	0.068*	1(0)
p_π^π	-8.52*	0.130*	1(1)

Critical Values: ADF - (1%* -4.06) @ [1(1)]

Critical Values: KPSS – (1%* 0.739) @ [1(0)] & (1%* 0.216) @ [1(1)]

Source: Authors (2016)

4.2. Garch Results

The GARCH (1, 1) results in Table 2 show that the real output gap overshoots while the inflation variable is persisting. The persistence of volatility of real output gap is not likely to die out slowly while that of inflation variable may die off slowly. The inference from the results is that the behaviour of real output gap is more uncertain than that of inflation variable.

Table 2. GARCH (1, 1) Results

Variable	Coefficient
Real output gap	
$\emptyset_2$	0.8823* (0.3023)
$\emptyset_3$	0.5739* (0.0769)
inflation gap	
β_2	0.3029** (0.1265)
β_3	0.6613* (0.0996)

The numbers in parenthesis are the standard error

(*) and [**] indicate 1% and 5% level of significance

Source: Authors (2016)

In Tables 3 the post estimation test of heterosskedasticity for GARCH (1, 1) for real output gap shows that there is no autoregressive conditional heteroskedasticity. Similarly in Table 4 the ARCH effect test also indicate failure to reject the null hypothesis. These test results suggest that the study can rely on the uncertainty estimates for further use.

Table 3. Heteroskedasticity Test: Breusch-Pagan-Godfrey (real output gap)

F- statistic	1.7124	Prob. F (3, 91)	0.1700*
Obs* R-squared	5.0765	Prob. Chi Square (3)	0.1663*

{*} failure to reject the Null Hypothesis at 1% level of significance

Source: Authors (2016)

Table 4. ARCH Effect Test Result (real output gap)

F-statistic	1.2613	Prob. F(1,92)	0.2643*
Obs*R-squared	1.2713	Prob. Chi-Square(1)	0.2595*

{*} failure to reject the Null Hypothesis at 1% level of significance

Source: Authors (2016)

In respect of inflation variable, similar post estimation test results in Tables 5 and 6 also suggest that that there is no autoregressive conditional heteroskedasticity. The ARCH effect test also indicates failure to reject the null hypothesis. These results also affirm the reliability of uncertainty estimate for inflation variable.

Table 5. Heteroskedasticity Test: Breusch-Pagan-Godfrey (Inflation)

F- statistic	0.2310	Prob. F (3, 90)	0.8746*
Obs* R-squared	0.7182	Prob. Chi Square (3)	0.8689*

{*} failure to reject the Null Hypothesis at 1% level of significance

Source: Authors (2016)

Table 6. ARCH Effect Test Result (Inflation)

F-statistic	0.4707	Prob. F(1,91)	0.4944*
Obs*R-squared	0.4786	Prob. Chi-Square(1)	0.4891*

{*} failure to reject the Null Hypothesis at 1% level of significance

Source: Authors (2016)

4.3. Gmm Results

Table 7 contains the regression results of the GMM estimator. The response parameter in the Table among others suggests that the monetary policy rate adjusts slowly based on the previous rate. The coefficient estimate of the current model at 0.8366 and backward model at 0.9576 conforms to the smoothing parameter theory. This infers that the Central Bank of Nigeria does not change the policy rate arbitrarily and substantially from one period to the next. In all the three options the previous policy rate has significant effect on the current policy rate except the forward model result that overshoots.

Table 7. Results of Model Estimates based on GMM Analysis

Variable	Current Model	Backward Model	Forward Model
p_1	3.6799 (1.7300)	1.1354 (0.9230)	- 0.9803 (0.7729)
p_{it-1}	0.8366* (0.0558)	0.9576* (0.0316)	1.0378* (0.0304)
$p_y^y \sigma_{yt}^2$	-0.7295* (0.2118)	-0.1533** (0.0634)	- 0.0738** (0.0342)
$\Delta\, p_\pi^\pi \sigma_{\pi t}^2$	-2.3731* (0.8429)	-0.9492** (0.4183)	- 1.2800* (0.4148)
p_{yt}	1.0144* (0.2007)	0.4064***(0.2242)	0.3544* (0.1223)
$p_{\pi t}$	0.0093 (0.0303)	-0.0481*** (0.0261)	0.0210 (0.0145)
Adj R Sq	0.7908	0.7483	0.7921
J. Statistic	4.8015	5.4525	9.0447
Prob $\chi^2_{0.050}$	14.1	12.6	16.9
Prob of J Statistic	0.6842	0.4872	0.4332

The numbers in parenthesis are the standard error

(*) and [**] {***} indicate 1%, 5% and 10% level of significance

Source: Author (2016)

Uncertainty of real output gap and inflation variables are statistically significant as they affected the policy rate negatively in all the model options. The coefficient estimate in the three model options for real output gap and inflation variable are $p_y^y \sigma_y^2 < 0 \; and \; p_\pi^\pi \sigma_\pi^2 < 0$. This implies that monetary policy is less responsive to uncertainty of real output gap and inflation in Nigeria. Our result is similar to what was found in some empirical literature as in Mayers and Montagoli (2011), Naraidoo and Raputsoane (2013) also found for South Africa that inflation and output gap uncertainty significantly affects monetary policy while Martin and Milas (2004) on United Kingdom, found that uncertainty of inflation affects monetary policy but no evidence for such effects was found for real output gap. Table 7 shows that the real output gap variable is statistically significant in the three options. In the current model, in response to a unit per cent increase in real output gap in excess of the equilibrium real output, monetary policy rate will increase by about 1.01 percentage points. In respect of the backward and forward looking models, monetary policy rate will increase by 0.41 and 0.35 percentage points respectively. The effect of inflation is weakly significant in the backward model but we found no evidence of its effects on the monetary policy rate in the current and forward looking models. The inference from these findings is that since the real output variable is significant in explaining the response of the policy rate, monetary authority in Nigeria can use a nonlinear model that include real output gap variable to stabilize output and inflation.

4.4. Diagnostic Test Results

The J statistic and the probability of $\chi^2_{0.050}$ under Table 7 are provided for each of the models. The results show that for each of the models, the estimates of the J statistic are less than the probability of $\chi^2_{0.050}$ we therefore fail to reject our models and conclude that the models of the study is not mis-specified. Furthermore, on the case of over-identifying restrictions for GMM analysis, the estimated value of the J statistic for all the models support that this paper fails to reject the null hypothesis that over identifying restrictions are satisfied.

The results of the diagnostic test in Table 8 are meant to confirm or reject whether the instruments used in each of the models are weak or strong. Since the Cragg-Donald F-statistic is greater than the critical values, this suggests that we accept the alternative hypothesis which states that the instruments are strong even though the parameters are over identified.

Table 8. Diagnostic Test: Weak Instrument Test

Type of Model	Cragg-Donald F. statistic	Critical values (Relative Bias)
current period	31.1219	5%-20.25: 10%-11.39: 20% - 6.69
Backward	47.5789	5%-18.37: 10%-10.83: 20% - 6.77
Forward	22.2714	5%-20.90: 10%- 11.51: 20% - 6.56

Source: Author (2016)

5. Conclusion and Recommendations

In this paper we made attempt to analyse and determine the effect of real output gap uncertainty on monetary policy rate. The GARCH results suggest evidence of uncertainty in the pattern of behaviour of real output gap and inflation variables. The results from the GMM regression analysis show that uncertainty of real output gap and inflation significantly affect monetary. However, we fail to reject the null hypothesis that inflation affects monetary policy while the real output gap variable positively affect monetary policy.

The implication of our findings is that monetary policy is less responsive to uncertainty of real output gap and inflation while it is responsive to real output gap variable. In view of the fact that the real output gap and uncertainty of real output gap are statistically significant in all the models we conclude that this uni-variate variable if included in a rule based model along with some other macroeconomic variables like inflation and exchange rate can be used to determine the optimal policy rate that can stabilize output and inflation in Nigeria. We therefore recommend that it is plausible for the Central Bank of Nigeria to consider the inclusion of real output gap and uncertainty of real output gap in monetary policy models. Due to the paucity of empirical evidence on this issue in emerging and developing economies compared to the developed nations, studies can be conducted in this area for such countries so as to enhance the decisions of the monetary policymakers.

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