ASSESSING MONETARY POLICY EFFECTIVENESS AMID CLIMATE UNCERTAINTY: A BAYESIAN DSGE FRAMEWORK

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ABSTRACT

This study is driven by the urgent need to evaluate and strengthen the effectiveness of monetary policy in maintaining price stability, particularly in the context of increasing climate-related uncertainties and recurrent economic disruptions in Nigeria. To achieve this, the study employs a Bayesian Dynamic Stochastic General Equilibrium (BDSGE) framework, utilizing quarterly data from the first quarter of 2000 to the second quarter of 2024.Initial findings from the baseline model indicate that inflation exhibits a significant and positive response to adverse output or technology shocks, while showing a significant negative response to monetary policy interventions. However, when the model is extended to account for additional shocks specifically those arising from climate change, exchange rate volatility, and fluctuations in crude oil prices the inflationary impact of monetary and output shocks becomes even more pronounced. This heightened sensitivity suggests that climate-related uncertainty exacerbates the effects of economic shocks on inflation, thereby diminishing the overall effectiveness of traditional monetary policy tools. The findings highlight the critical need for monetary authorities to incorporate climate adaptation and mitigation considerations into the monetary policy framework. Doing so is essential to improving policy resilience and ensuring macroeconomic stability in the face of escalating environmental and economic challenges.

Keywords: *Climate Change, Inflation, Macroeconomic Stability, Monetary Policy, Output Gap,*

JEL Classification: *Q54, E31, E60, E52, O47*

1.0 Introduction

The escalating frequency and severity of climate-related shocks have profoundly impacted the macroeconomic landscape, compelling central banks to reconsider the role of monetary policy amid climate uncertainty. Physical risks, such as extreme weather events, and transition risks, arising from the shift to low-carbon economies, present significant challenges to economic stability. These climate-induced disruptions intersect with traditional monetary policy objectives, including price and financial stability, necessitating a re-evaluation of the tools and frameworks central banks employ to navigate this uncertain terrain.

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Two key challenges have attracted more concern on monetary policy effectiveness. Firstly, the effectiveness of monetary policy tools to fulfil the mandate of price stability may be impacted by climate change and its mitigating measures. Secondly, the ability of central banks to balance between playing a supporting role in mitigating climate change associated risks and staying within their mandate (Hansen, 2022; Drudi et al, 2021; Campiglio et al, 2018; Campiglio, 2016).

Hansen (2022) argues that expanding the mandate of monetary policy without appropriate modelling and empirical backing could jeopardise the credibility and independence of central banking. Central banks, therefore, need to employ appropriate tools to account for climate risks without deviating from their core objectives. Dynamic Stochastic General Equilibrium (DSGE) models have become central to understanding the interactions between monetary policy and climate uncertainty (Sapkota, 2024; Chan, 2020; Shobande & Shodipe, 2019; Nachane, 2017). Traditional DSGE models are often ill-equipped to incorporate the complexities of climate risks. However, advancements in Bayesian estimation techniques have enabled researchers to include climate-related variables, such as carbon taxes and renewable energy investments, within these frameworks (Tu & Wang, 2022; Argentiero et al., 2018; Lemoine & Rudik, 2017). These studies highlight the need for models that integrate physical and transition risks to provide robust policy insights.

Drudi et al (2021) assert that climate change amplifies economic and financial risks through two primary channels. Physical risks, manifested as more frequent natural disasters and gradual environmental degradation which could disrupt labour markets, supply chains, and capital stock. Additionally, transition risks, arising from the implementation of carbon taxes, green finance initiatives, and regulatory shifts which could lead to stranded assets, inflationary pressures, and structural adjustments in production and consumption patterns. These dynamics complicate the identification of monetary shocks, dampen the effect of natural rate of interest, and weaken the transmission mechanisms of monetary policy (Drudi et al, 2021; Claeys et al., 2018). Despite growing recognition of these challenges, the integration of climate risks into macroeconomic and monetary frameworks remains nascent. Hansen (2022) argues that uncertainties regarding the magnitude and timing of climate impacts complicate the identification of shocks, weakening the ability of traditional monetary tools to stabilize inflation and output. Similarly, Batten (2018) highlights that physical and transition risks can interact nonlinearly, amplifying their economic impact.

Other studies explore the intersection of monetary policy and climate change using Dynamic Stochastic General Equilibrium (DSGE) models. Economides and Xepapadeas (2018) incorporate a climate module into a New Keynesian DSGE model, finding significant implications for monetary policy conduct.

Svensson and Williams (2008) propose a Markov jump-linear-quadratic approach to optimize monetary policy under uncertainty. Thakoor and Kara (2023) model climate disasters as left-tail productivity shocks, suggesting a modified Taylor rule that equally weights inflation and output growth responses. Chen and Pan (2020) investigate the optimal mix of monetary and climate policies using an Environmental DSGE model, finding that monetary policy dynamics are influenced by climate policy regimes and environmental regulation enforcement. They also suggest that augmenting climate change mitigation into monetary policy targets can enhance welfare, though potential conflicts with traditional central bank mandates may arise. These studies collectively emphasize the growing importance of considering climate factors in monetary policy design and implementation.

Extant literature reveals that the implications of climate change on monetary policy are less explored, especially in developing and emerging economies like Nigeria, where vulnerabilities to climate shocks are more pronounced. Previous attempts at using Bayesian DSGE to measure the response of macroeconomic indicators on monetary policy shocks in Africa did not account for climate change (Obioma et al., 2022; Owusu-Afriyie et al., 2022; Sillah et al., 2022; Enisan & Tolulope, 2019; Alkader, 2018; Adebiyi & Modi, 2016; Adebiyi & Modi, 2011). Notable gaps include limited understanding of the impact of climate risks on the effectiveness of monetary policy. Furthermore, existing Dynamic Stochastic General Equilibrium (DSGE) models often fail to adequately account for climate-related uncertainties, underscoring the need for enhanced quantitative tools (Boneva et al, 2022; Hansen, 2022; Drudi et al, 2021).

This study seeks to employ a Bayesian DSGE approach to evaluate the effectiveness of monetary policy under climate uncertainty. By incorporating climate risks into a structured and probabilistic framework, this study not only advances the theoretical underpinnings of climate-aware monetary policy but also provides actionable insights for central banks. For instance, understanding the role of green quantitative easing or the potential for targeted refinancing operations can help policymakers navigate the dual objectives of mitigating climate risks and ensuring economic stability.

The study has profound policy implications. It will help in integrating climate considerations into monetary policy to enhance the central bank’s capacity to fulfil their mandate. We find that climate change shock could dampen the effectiveness of monetary policy, as interest rate respond negative and significantly to climate change shock. This finding could inform the design of resilient monetary strategies that support sustainable growth.

The reminder of the paper includes details of the Bayesian DSGE methodology in section 2. Highlights of the results on the dynamic interplay between monetary policy and climate risks in section 3 and conclusions as well as policy recommendations in section 4.

2.0 Methodology

This study adopts the Bayesian Dynamic Stochastic General Equilibrium (BDSGE) approach due to its strong foundation in economic theory and its widespread application in forecasting and analysing monetary policy globally (Del Negro et al., 2015). Building on theoretical principles, institutional insights, and empirical evidence, we examine the effects of monetary policy, productivity, demand, and climate shocks on monetary policy decisions, output, and inflation. The choice of the BDSGE approach is driven by its advantages over the maximum likelihood-based (BDSGE)method. Unlike the ML-based DSGE, the BDSGE framework is well-suited for handling medium to large-scale DSGE models, where parameter identification can be complex. Additionally, BDSGE's ability to incorporate prior information allows for leveraging existing evidence and addressing the limitations posed by small sample sizes, a challenge often encountered in ML-based DSGE models.

2.1 *Model Specification*

This study employs a Bayesian DSGE model based on Woodford (2003), incorporating equations that represent the behavior of households, firms, and central banks. The model is adapted to include external sector dynamics and climate change variables to analyze the effects of external and climatic shocks on a small open economy like Nigeria, which heavily relies on imports. Additionally, the model integrates forward-looking price-setting mechanisms and interest rate smoothing, reflecting the tendency of central banks to adjust policy rates gradually in a series of relatively small steps in the same direction (Nkang et al., 2023; Salisu et al., 2022)

The baseline Woodford (2003) nonlinear model is specified as follows:

$$\frac{1}{Y_t} = \beta E_t \left(\frac{1}{Y_{t+1}} \frac{R_t}{\Pi_{t+1}}\right) \quad (1)$$

Equation(1) is the household optimization;where β is the discount factor or the household's willingness to delay consumption. Equation (1) states that current output $y_t$is a function of expected output Y_{t+1}, expected inflation Π_{t+1} and current nominal interest rate (i.e., the monetary policy rate) R_t.

$$(\Pi_t - \Pi) + \frac{1}{\phi} = \phi \left(\frac{Y_t}{Z_t}\right) + \beta E_t \left(\Pi_{t+1} - \Pi\right) \quad (2)$$

 @A Publication of the Department of Economics, ADSU, Mubi. ISSN- Print: 2550- 7869; ISSN-Online: 3043-5323. Journal homepage: https://ajaefm.adsu.edu.ng

Equation (2) represent the firm optimization function, where ϕ is a parameter for the pricing decision of firms. Equation (2) presents the relationship between the ratio of actual output Y_t to the natural level of output $Z_t$and also the current deviation of inflation from its steady-state $(\Pi_t - \Pi)$to the expected value of the deviation of inflation from its steady-state in thefuture$E_t\ (\Pi_{t+1} - \Pi)$

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{1/\beta} U_t \tag{3}$$

Equation (3) is the Taylor rule that capture the behaviour of monetary authority, where R is the steady-state value of the interest rate and U_t is a state variable that captures all movements in the interest rate not driven by inflation. The central bank adjusts the interest rate in response to inflation and other factors not incorporated. The parameter 1⁄β is assumed to be always greater than 1 for model stability; hence, β must be greater than 0 and less than 1 (0<β <1).

We further rewrite Equations 1-3 in Equations 4-6 such that $X_t = Y_t/Z_t$ defines the output gap:

$$1 = \beta E_t\left(\frac{X_t}{X_{t+1}}\frac{1}{G_t}\frac{R_t}{\Pi_{t+1}}\right) \tag{4}$$

$$(\Pi_t - \Pi) + \frac{1}{\phi} = \phi X_t + \beta E_t\ (\Pi_{t+1} - \Pi) \tag{5}$$

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{1/\beta} U_t \tag{6}$$

Where $G_t = Z_{t+1}/Z_t$ is a state variable that captures Z_t.

The linearized model in equation (7) – (15) describes the external sector, forward-looking price setting behaviour of firms, interest rate smoothing, and financial friction.

Woodford (2003) presents a closed-economy framework, as it does not account for the external sector. However, no nation operates in complete isolation and thrives, underscoring the importance of incorporating the external sector to connect the economy with the global environment. The modified model employed in this study is based on the following linearized equations:

Baseline model

$$\pi_t = [\beta E_t(\pi_{t+1}) + \kappa x_t] \tag{7}$$

$$x_t = E_t(x_{t+1}) - \{r_t - E_t(\pi_{t+1}) - g_t\} \tag{8}$$

$$r_t = \frac{1}{\beta}\pi_t + u_t \tag{9}$$

$$u_{t+1} = \rho_u u_t + \epsilon_{t+1} \quad (10)$$

$$g_{t+1} = \rho_g g_t + \xi_{t+1} \quad (11)$$

In the baseline model, π_t *and* $r_t$denote the deviations of inflation and interest rates from their steady-state levels. Equation (7) represents the foundational New Keynesian Phillips Curve, which incorporates forward-looking price-setting dynamics, while equation (8) outlines an Euler equation that connects consumer behaviour to the output gap. This suggests that current pricing is influenced not only by the output gap but also by anticipated future price changes(π_{t+1}). Equation (9) serves as the standard Taylor rule, incorporating interest rate smoothing and highlighting how monetary policy decisions are shaped by both inflation and previous interest rates. Lastly, equations (10) and (11) depict the progression of shocks to monetary policy and productivity, with all external variables adhering to a first-order autoregressive process (AR(1)).

Model 2 with climate change and external sector variables

$$\pi_t = [\beta E_t(\pi_{t+1}) + \kappa x_t + \phi e_t + \Phi rpr] + \delta C_t \quad (12)$$

$$e_t = es_t \quad (13)$$

$$rpr_t = pr_t \quad (14)$$

$$C_t = ec_t \quad (15)$$

$$x_t = E_t(x_{t+1}) - \{r_t - E_t(\pi_{t+1}) - g_t\} - \psi C_t \quad (16)$$

$$r_t = \frac{1}{\beta}\pi_t + \partial C_t + u_t \quad (17)$$

$$u_{t+1} = \rho_u u_t + \epsilon_{t+1} \quad (18)$$

$$g_{t+1} = \rho_g g_t + \xi_{t+1} \quad (19)$$

$$es_{t+1} = \rho_{es} es_t + v_{t+1} \quad (20)$$

$$pr_{t+1} = \rho_{pr} pr_t + \lambda_{t+1} \quad (21)$$

$$ec_{t+1} = \rho_{ec} ec_t + \eta_{t+1} \quad (22)$$

In model 2, π_t *and* $r_t$represent deviations of inflation and interest rates from their steady states. Equation (12) modifies the New Keynesian Phillips Curve to account for exchange rate effects and climate change in a small open economy, incorporating forward-looking price-setting behavior. This suggests that current prices depend not only on the output gap and exchange rate but also on expected future price changes and climate factors $(\pi_{t+1}$ *and* $C_t)$

Equations (13) to (15) model the evolution of the exchange rate, crude oil price, and climate change, with Equation (16) representing Euler equation linking consumer behaviour to the output gap and climate change. Equation (17) adapts the Taylor rule to include interest rate smoothing and climate change, indicating that monetary policy decisions are influenced by inflation, prior interest rates, and climate dynamics. Finally, equations (18) to (22) describe the evolution of shocks to monetary policy, productivity, exchange rate, crude oil price, and climate change, with all exogenous variables following a first-order autoregressive (AR 1) process.

2.2 Estimation Procedure

The linear DSGE model, represented by equations (7)–(11) for the baseline and (12) – (22) for the second model with climate change, were estimated using the Bayesian approach, which combines prior information with maximum likelihood (ML) methods through Bayes' rule. The process began with specifying priors and defining the econometric model in ML format, followed by estimation using the Bayesian DSGE framework. The estimation employed the Metropolis-Hastings (MH) algorithm with Markov-chain Monte Carlo (MCMC) simulations.

Initially, the model was estimated without using a block option, with 30,000 MCMC iterations and a burn-in period of 5,000. However, this approach resulted in high autocorrelation. To address this, the model was re-estimated with a block option, increasing the MCMC simulations to 40,000 and the burn-in period to 6,000, totalling 46,000 iterations. This adjustment effectively resolved the autocorrelation issue, and the results from the block-option model were used for interpretation.

2.3 Prior Distributions of the Estimated Parameters

The Bayesian DSGE estimation process starts by identifying prior distributions, which represent available information before incorporating the data. In this study, priors were set using theoretical foundations, institutional insights, and empirical evidence. Specifically, the priors were drawn from the works of Woodford (2003), Adebiyi and Mordi (2017), Obioma et al., (2022) and Nkang et al., (2022).

Table 2.1: Priors for distributions

Parameters	Interpretation	Range	Density function	Para(1)	Para(2)
ψ	Coefficient of climate change the output gap	(0,1)	Beta	0.30	0.30
β	Discount factor and coefficient of inflation in the monetary policy rule	(0,1)	Beta	0.95	0.94
κ	Price adjustment parameter	(0,+∞)	Beta	0.60	0.63
ϕ	Coefficient of exchange rate	(0,+∞)	Beta	0.30	0.12
Φ	Coefficient of crude oil price	(0,1)	Beta	0.30	0.05
∂	Influence of climate on monetary policy rule	(0,1)	Beta	0.30	0.30
Δ	Influence of climate on inflation	(0,1)	Beta	0.50	0.40
ρ_u	AR(1) for the monetary policy shock	(-1,1)	Beta	0.50	0.47

ρ_g	AR(1) for the productivity shock	(-1,1)	Beta	0.75	0.81
ρ_{es}	AR(1) for the demand shock	(-1,1)	Beta	0.50	0.41
ρ_{pr}	AR(1) for the crude oil price shock	(-1,1)	Beta	0.70	0.57
ρ_{ec}	AR(1) for the climate shock	(-1,1)	Beta	0.50	0.78
σ_u	Standard deviation of the monetary policy shock	(0,+∞)	Inverse-gamma	0.01	21.62
σ_g	Standard deviation of the productivity shock	(0,+∞)	Inverse-gamma	0.01	0.61
σ_{es}	Standard deviation of the demand shock	(0,+∞)	Inverse-gamma	0.01	8.80
σ_{pr}	Standard deviation of the crude oil price shock	(0,+∞)	Inverse-gamma	0.01	18.54
σ_{ec}	Standard deviation of the climate shock	(0,+∞)	Inverse-gamma	0.01	0.03

Source: Authors' Compilation

Note: Para 1 is the priors, while Para 2 is the posteriors.

2.4 Post-Estimation Analysis

After estimating the parameters of both the baseline and extended models, we perform several post-estimation tests to verify the validity of the parameters. These tests include analysing the policy parameter matrix, which offers insights into how a unit change in monetary policy, productivity, exchange rate, crude oil prices, and climate change shocks influence interest rates, the output gap, and inflation in Nigeria. Additional tests involve examining trace, histogram, autocorrelation, and density plots, along with prior and posterior plots, to evaluate the informativeness of the priors and the data utilized in the analysis. Furthermore, the impulse response function (IRF) plots and tables, as well as combined IRF plots, are used to assess the persistence of responses in inflation, interest rates, and the output gap to various economic shocks and to evaluate the model's robustness.

3.0 Results and Discussion

Table 3.1 displays the estimated Bayesian linear DSGE results for both the baseline and extended models in the context of Nigeria. Initially, the models were estimated without the block option, using an MCMC of 30,000 and a burn-in period of 5,000. However, this approach revealed significant autocorrelation issues, prompting the re-estimation of the models with the block option enabled and an increase in the MCMC iterations to 67,000, along with a burn-in period of 7,000. The discussion, therefore, focuses on the model estimates obtained using the block option.

The structural parameters provide insights into the interplay between inflation and monetary policy instruments. The inflation coefficients of 1.02 and 1.01 in the baseline and extended models, respectively, suggest that a one percent standard deviation increase in inflation would likely lead to a significant corresponding increase of 1.02 percent and 1.01 percent in the policy interest rate in Nigeria. This finding underscores the responsiveness of the Central Bank of Nigeria (CBN) to inflationary pressures through adjustments in the policy rate.

Specifically, the results imply that to reduce inflation by one percent, the CBN would need to raise the policy rate by approximately 1.02 percent (102 basis points) in the baseline model and by 1.01 percent

(101 basis points) in the extended model. These outcomes align with Taylor's Rule, which emphasizes the proportional response of interest rates to deviations in inflation and are consistent with empirical findings by Obioma et al. (2022), Nkang et al., (2022), as well as the theoretical framework outlined by Woodford (2003).

Importantly, the analysis reveals that the relationship between the policy rate and inflation in Nigeria is not strictly one-to-one but rather slightly exceeds unity. This indicates a proactive stance by the monetary authority to contain inflationary pressures, reflecting the CBN's commitment to price stability in line with theoretical expectations.

The coefficients of expected inflation from the baseline and extended models, recorded at 0.9532 and 0.9379 respectively, suggest that a one percent increase in the expected inflation rate is likely to result in a significant rise in the current inflation rate by approximately 0.9532 percent and 0.9379 percent. This finding aligns with the New Keynesian Phillips Curve, which emphasizes the forward-looking nature of inflation dynamics, and is consistent with the theoretical framework of this study.

The results provide compelling evidence that current inflation is not solely driven by present demand and supply conditions but is also strongly influenced by anticipated future price levels. This underscores the importance of expectations in shaping inflationary trends. When economic agents anticipate higher prices in the future, their behaviour such as pre-emptive price-setting by firms and wage demands by workers, tends to reinforce current inflation.

In policy terms, the findings highlight the critical role of managing inflation expectations as part of the monetary authority's strategy to achieve price stability. By influencing expectations, the Central Bank of Nigeria can exert indirect control over inflationary pressures, thereby improving the effectiveness of its monetary policy tools.

The price adjustment parameter (k) in both the baseline and extended models is positive and significant, indicating that a 1% increase in the output gap raises inflation in Nigeria by 0.5367% and 0.6269%, respectively. This aligns with the New Keynesian Phillips Curve, highlighting a direct relationship between the output gap and inflation. The extended model shows that including factors like exchange rates, crude oil prices, and climate change amplifies this effect. These findings emphasize the need to address structural economic challenges and external vulnerabilities to mitigate inflationary pressures from output fluctuations.

The coefficients for the nominal effective exchange rate (ϕ) and crude oil price (Φ) in the extended model, at 0.1153 and 0.0513 respectively, suggest that both variables have a positive and significant impact on inflation in Nigeria. These findings align with the theoretical expectations of this study. Specifically, a 1% increase in the nominal effective exchange rate and crude oil price is likely to raise the inflation rate by 0.1153% and 0.0513%, respectively. This outcome is consistent with Nigeria's status as a crude oil export-dependent economy with a relatively weak currency. Exchange rate volatility and crude oil price shocks can adversely affect the economy. For instance, higher crude oil prices increase refining costs and the price of refined petroleum products, which subsequently fuel inflationary pressures.

The persistence coefficients in Table 3.1 indicate that the responses of inflation, interest rates, and the output gap are most enduring when influenced by output or technology shocks, followed by climate change impacts, crude oil price shocks, monetary policy disturbances, and exchange rate fluctuations, with respective coefficients of 0.8092, 0.7798, 0.5709, 0.4713, and 0.4111. This pattern aligns with economic reasoning, as production significantly drives price levels, particularly in an import-dependent economy like Nigeria. Output or technology shocks directly affect the supply side, influencing costs and availability of goods, which cascade into inflation and interest rate adjustments. Additionally, climate change and crude oil price shocks have substantial intermediate effects on production and energy costs, magnifying their persistence relative to policy or exchange rate shocks, which operate more indirectly on the economy.

The acceptance rates of 35.13% for the baseline model and 43.76% for the extended model, along with maximum efficiency values of 0.0187 and 0.2390, respectively, demonstrate that both models are well-suited and robust for the analysis. These metrics indicate that the extended model, with its higher acceptance rate and efficiency, better captures the dynamics and complexities of the variables under study. This suggests that incorporating additional explanatory variables or structural adjustments improves the model's capacity to reflect economic realities and provide reliable insights, enhancing its predictive and analytical utility.

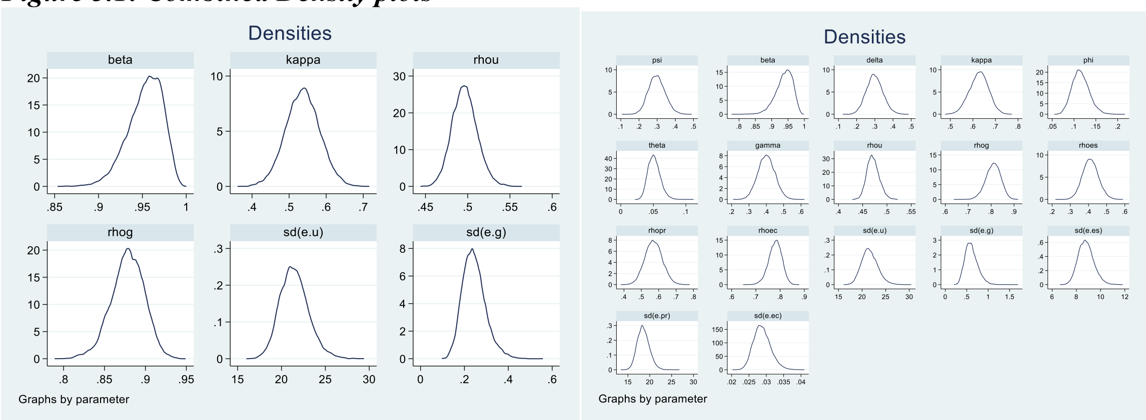
Table 3.1: Estimated Bayesian Linear DSGE results

Parameters	Baseline Model	Extended Model	Remark
Structural Parameters			
$\boldsymbol{\beta}$	0.9532*(0.0198)	0.9379*(0.0261)	Significant
$\boldsymbol{k}$	0.5367*(0.0455)	0.6269*(0.0419)	Significant
$\boldsymbol{\phi}$		0.1153*(0.0193)	Significant
$\boldsymbol{\Phi}$		0.0513*(0.0094)	Significant
$\boldsymbol{\partial}$		0.2991*(0.0452)	Significant
$\boldsymbol{\delta}$		0.4007*(0.0487)	Significant
$\boldsymbol{\varphi}$		0.2982*(0.0454)	Significant
$\boldsymbol{1/\beta}$	1.0146*(0.0053)	1.0050*(0.0082)	Significant
Persistence Parameters			
$\boldsymbol{\rho_u}$	0.4965*(0.1485)	0.4714*(0.0127)	Significant
$\boldsymbol{\rho_g}$	0.8783*(0.0204)	0.8092*(0.0324)	Significant
$\boldsymbol{\rho_{es}}$		0.4111*(0.0437)	Significant
$\boldsymbol{\rho_{pr}}$		0.5709*(0.0495)	Significant
$\boldsymbol{\rho_{ec}}$		0.7798*(0.0268)	Significant
Log-MLH	-608.9350	-1300.0647	
Acceptance rate	0.3513	0.4376	
Max Efficiency	0.0187	0.2390	

Source: Authors' computation.

Note: * represent 5% significance level, the study used MCMC iterations of 67,000 with 7,000 burn-ins, MCMC sample size of 60,000. Log-MLH stands for log marginal-likelihood and the acceptance rate is the random-walk Metropolis-Hasting's sampling, values in the parentheses are the standard errors.

Figure 3.1: Combined Density plots



Source: Authors' computation.

Figure 3.1 presents the combined density plots as an additional validity check for the study's results. The plots confirm that the models are well-fitted and robust, reinforcing their reliability for economic analysis. This outcome is critical, as it ensures the models adequately capture the underlying relationships between key variables, allowing for more accurate insights into the dynamics of inflation, exchange rates, crude oil prices, and other macroeconomic factors under study.

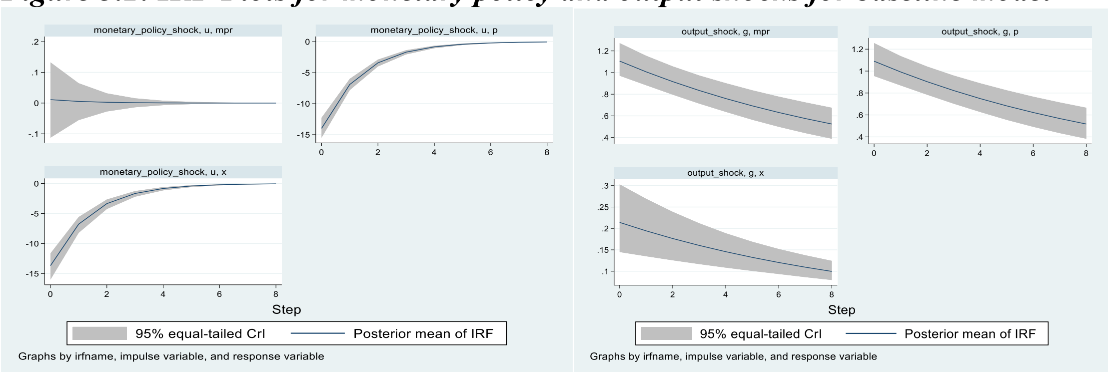
3.1 Discussion of the IRF results for the baseline model (monetary policy and output shocks)

Figure 3.2 and Table 3.2 illustrate the responses of the output gap, inflation rate, and interest rate to shocks arising from monetary policy and output in Nigeria. The findings indicate that a one percent standard deviation shock from monetary policy results in an initial output gap response of -13.6836%, while an output shock leads to an initial response of 0.2141%. These effects remain statistically significant throughout the forecast horizon, as they lie within the 95% confidence interval. This suggests that a monetary policy shock exacerbates the output gap by increasing production costs and reducing output. Conversely, an output shock tends to narrow the output gap, consistent with expectations. This aligns with Euler's theorem, supporting the theoretical underpinnings of the study. This finding corroborates Obioma et al. (2022) and Nkang et al., (2022) who found that output gap and inflation respond negatively and positively, respectively, to monetary policy shock in Nigeria.

Inflation exhibits a negative and statistically significant response to a 1% standard deviation monetary policy shock, with an initial impact of -13.9870%, and a positive and significant response to a negative output shock, starting at 1.0903%. These effects persist throughout the forecast horizon, aligning with the theoretical expectations grounded in the Taylor rule. The negative inflation response to monetary policy reflects the contractionary impact of tighter policy on price levels, while the positive response to a negative output shock suggests cost-push inflation driven by supply-side disruptions.

Interest rates respond positively and significantly to shocks from both monetary policy and negative output, with initial responses of 0.0111% and 1.1061%, respectively. These sustained positive reactions highlight the central bank’s role in adjusting rates to stabilize inflation and output, consistent with the Taylor rule’s prescription. The findings also resonate with Euler's theorem, which underscores the equilibrium relationships between economic variables in response to shocks.

Figure 3.2: IRF Plots for monetary policy and output shocks for baseline model



Source: Authors’ computation.

Table 3.2: Response of x, inf and r to monetary policy and output shocks

Forecast	Monetary policy Shock			Negative Output Shock		
Horizon	X	Inf	Mpr	X	Inf	mpr
0	-13.6836*	-13.9870*	0.0111*	0.2141*	1.0903*	1.1061*
1	-6.7657*	-6.9069*	0.0054*	0.1943*	0.9923*	1.0067*
2	-3.3474*	-3.4129*	0.0026*	0.1765*	0.9033*	0.9165*
3	-1.6573*	-1.6875*	0.0013*	0.1603*	0.8226*	0.8345*
4	-0.8211*	-0.8350*	0.0006*	0.1457*	0.7493*	0.7602*

Source: Authors' computation.

3.2 Discussion of the IRF results for the extended model (Climate change)

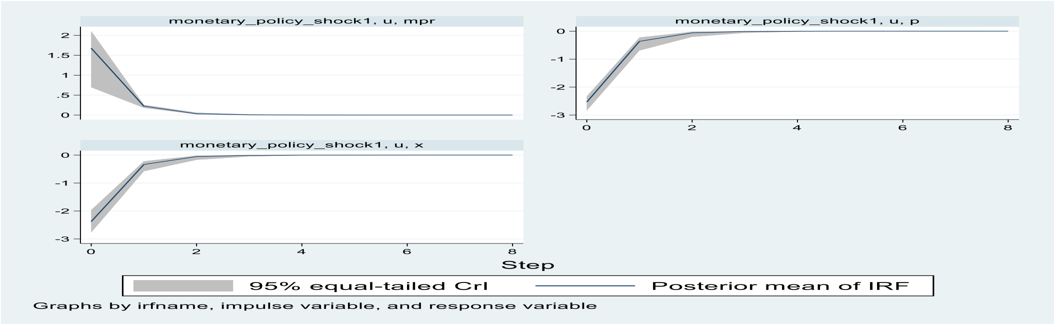
3.2.1 Discussion of the IRF results for monetary policy shock

Figure 3.3 and Table 3.3 present the responses of the output gap, inflation, and interest rates to monetary policy shocks in Nigeria. The results reveal that output and inflation react negatively and significantly to such shocks. Initially, output declines by 2.3796%, and inflation drops by 2.5354%, with these effects remaining statistically significant throughout the forecast horizon. This indicates that monetary policy shocks tend to widen the output gap by reducing production while simultaneously curbing inflationary pressures. In line with the Taylor Rule, monetary authorities respond to inflationary pressures by increasing the interest rate. A 1% standard deviation shock to monetary policy initially raises the interest rate by 1.6795%, with this effect remaining positive and significant over time. This reflects the central bank's countercyclical adjustment to stabilize inflation and output.

The findings also highlight the moderating role of climate change in the effectiveness of monetary policy. When a climate change variable is included in the model, the initial impact of monetary policy on inflation reduces from -13.9870% to -2.5354%. This suggests that climate change introduces uncertainty, diminishing the potency of monetary tightening in controlling inflation. The results underscore the need for monetary authorities to integrate climate mitigation strategies into their policy frameworks to enhance policy effectiveness.

The analysis aligns with the New Keynesian Phillips Curve, which links inflation dynamics to output gaps and supply-side factors. The moderation in inflation responsiveness due to climate uncertainty reinforces the importance of addressing structural and external factors that affect the supply side of the economy.

Figure 3.3: IRF Plots for monetary policy *shock*



Source: Authors' computation.

Table 3.3: Response of x, inf and mpr to monetary policy shock

Forecast Horizon	x	Inf	Mpr
0	**-2.3796**	**-2.5354**	**1.6795**
1	-0.3361	-0.3640	0.2228
2	-0.0539	-0.0595	0.0327
3	-0.0010	-0.0112	0.0054
4	-0.0021	-0.0024	0.0010

Source: Authors' computation.

3.2.2 Discussion of the IRF results for exchange rate shock

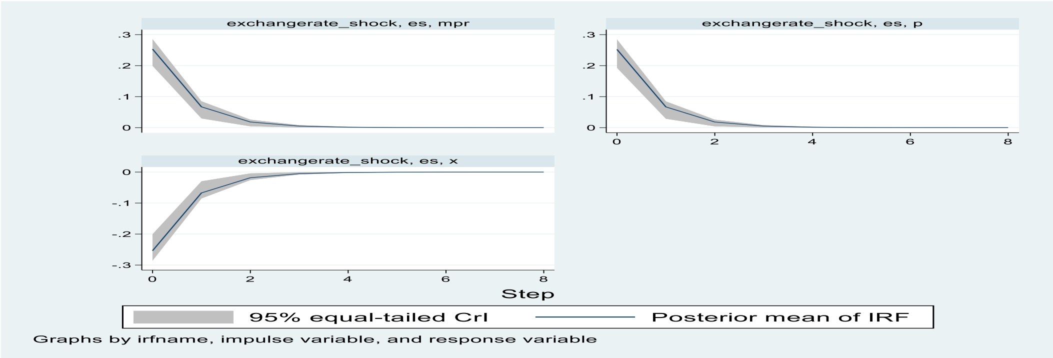
Figure 3.4 and Table 3.4 present the responses of the output gap, inflation, and interest rates to shocks in Nigeria's nominal effective exchange rate (NEER). The results reveal that inflation and interest rates respond positively and significantly to NEER shocks, with initial responses of 0.2523% each. These positive responses persist throughout the forecast horizon, indicating that NEER shocks are inflationary. This aligns with the theoretical expectation that exchange rate depreciation (a rise in NEER) increases import prices, contributing to cost-push inflation. In response, monetary authorities may raise interest rates by 0.2534% (25 basis points) to stabilize inflation, consistent with the Taylor Rule.

Conversely, the output gap responds negatively and significantly to a 1% standard deviation NEER shock, with an initial decline of 0.2538%. This negative impact also remains significant over time, suggesting that a higher NEER widens the output gap by increasing the cost of imported inputs and production. This aligns with economic theory, where exchange rate shocks affect the supply side, raising production costs and reducing output, particularly in import-dependent economies like Nigeria.

The findings underscore the dual role of exchange rate shocks in driving inflation and constraining output, reflecting the classic trade-off between stabilizing inflation and supporting economic growth.

This highlights the importance of exchange rate management and coordinated monetary policy in mitigating the adverse effects of exchange rate volatility on the economy.

Figure 3.4: IRF Plots for nominal effective exchange rate shock



Source: Authors' computation.

Table 3.4: Response of x, inf and mpr to nominal effective exchange rate shock

Forecast Horizon	X	Inf	mpr
0	**-0.2538**	**0.2523**	**0.2535**
1	-0.0673	0.0670	0.0672
2	-0.0183	0.0182	0.0183
3	-0.0051	0.0050	0.0051
4	-0.0014	0.0014	0.0014

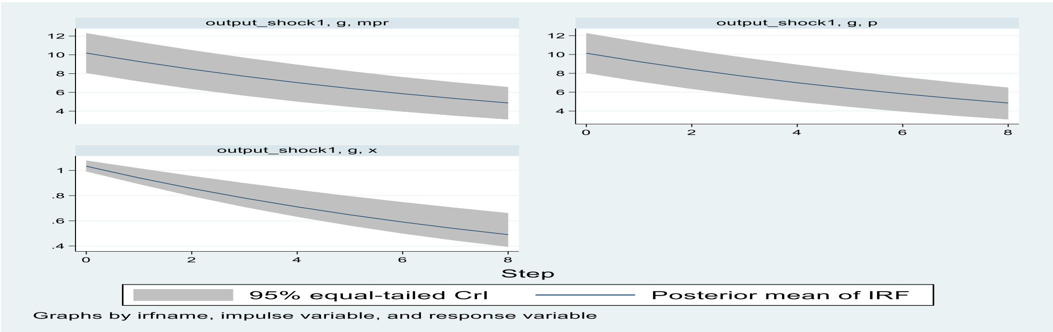
Source: Authors' computation.

3.2.3 Discussion of the IRF results for Output shock

Figure 3.5 and Table 3.5 present the responses of the output gap, inflation, and interest rate to output or technology shocks in Nigeria. The results show that all three variables respond positively and significantly to such shocks throughout the forecast horizon. Specifically, a 1% standard deviation shock to output initially lead to a positive output gap of 1.0332%, increase inflation by 10.1381%, and raise the interest rate by 10.1873%. This suggests that a negative output or technology shock is inflationary in Nigeria. Such shocks can disrupt production efficiency or supply, driving up prices (inflation). In response, monetary authorities may raise the policy rate by 1019 basis points (10.19%) to curb inflationary pressures, consistent with the Taylor Rule. Additionally, output shocks may narrow the output gap, as technological advancements or improvements boost production capacity and economic activity.

The results also reveal that inflation's response to negative output shocks is heightened during periods of climate change uncertainty compared to scenarios without climate change considerations. This underscores the role of climate change in exacerbating supply-side disruptions, amplifying inflationary pressures. As a result, incorporating climate change into the monetary policy framework is crucial for maintaining price stability and mitigating the adverse effects of such shocks on the Nigerian economy. This aligns with theoretical expectations that technological progress enhances productivity but also influences financial conditions, including interest rate adjustments due to increased demand for financing production expansion.

Figure 3.5: IRF Plots for Output shock



Source: Authors' computation.

Table 3.5: Response of x, inf and mpr to Output shock

Forecast Horizon	X	Inf	Mpr
0	**1.0332**	**10.1381**	**10.1873**
1	0.9407	9.2400	9.2853
2	0.8567	8.4228	8.4645
3	0.7802	7.6791	7.7176
4	0.7108	7.0022	7.0378

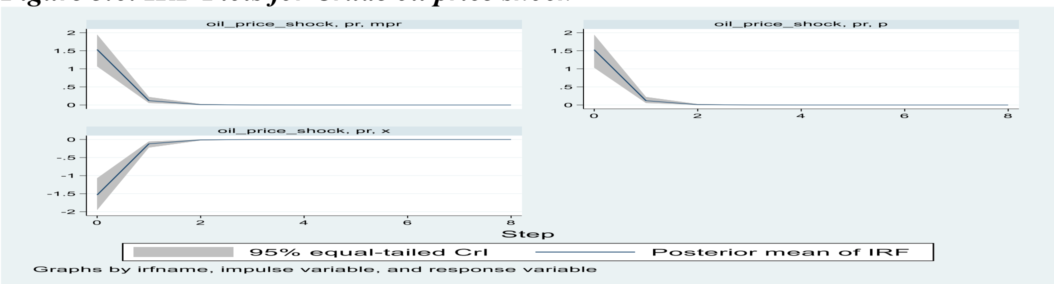
Source: Authors' computation.

3.2.4 Discussion of the IRF results for Crude oil price shock

Figure 3.6 and Table 3.6 illustrate the responses of the output gap, inflation, and interest rate to crude oil price shocks in Nigeria. The findings reveal that inflation and interest rates respond positively and significantly to a 1% standard deviation crude oil price shock, with initial increases of 1.5285% and 1.5351%, respectively. These responses remain statistically significant throughout the forecast horizon, indicating that crude oil price shocks are inflationary and may prompt monetary authorities to raise the policy rate by 1.5351% (154 basis points).

In contrast, the output gap responds negatively to crude oil price shocks from the initial period and continues to widen throughout the forecast horizon. This outcome aligns with the New Keynesian Phillips Curve, which links inflation and output dynamics to supply-side shocks, and is consistent with the theoretical expectations of this study. These findings corroborate the results of Obiama et al. (2022) and Nkang et al., (2022), who separately concluded that crude oil price shocks drive inflation, trigger policy tightening, and widen the output gap in Nigeria.

Figure 3.6: IRF Plots for Crude oil price shock



Source: Authors' computation.

Table 3.6: Response of x, inf and r to crude oil price shock

Forecast Horizon	X	Inf	Mpr
0	**-1.5356**	**1.5285**	**1.5351**
1	-0.1200	0.1195	0.1200
2	-0.0100	0.0099	0.0100
3	-0.0009	0.0009	0.0009
4	-0.0001	0.0001	0.0001

Source: Authors' computation.

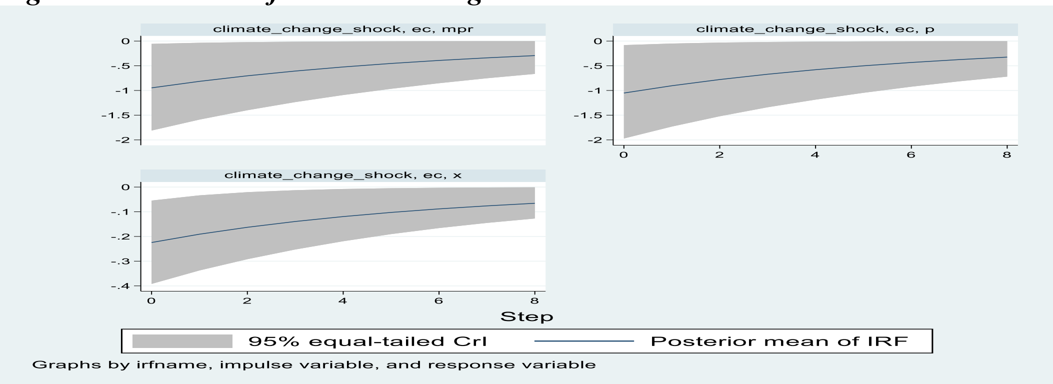
3.2.5 Discussion of the IRF results for Climate change shock

Figure 3.7 and Table 3.7 show the responses of the output gap, inflation, and interest rate to climate change shocks in Nigeria. The findings indicate that all three variables respond negatively and significantly to climate change shocks. The initial responses are -0.2244% for the output gap, -1.0517% for inflation, and -0.9471% for the interest rate, with these negative effects persisting throughout the forecast horizon. This suggests that climate change exacerbates output gaps and undermines the effectiveness of monetary policy in achieving price stability in Nigeria.

The negative response of inflation to climate change appears counterintuitive, as climate-related disruptions are often expected to lead to higher prices due to reduced supply and increased production costs. However, this anomaly can be explained by specific factors in the Nigerian context. Climate change may disproportionately disrupt rural and informal economies, which are significant contributors to Nigeria's GDP but are less integrated into formal markets. This could reduce overall aggregate demand, outweighing supply-side pressures and resulting in deflationary tendencies. Additionally, the reliance on subsistence agriculture and climate-sensitive industries might lead to output declines that suppress price levels, particularly in non-tradable goods.

Furthermore, the negative response of interest rates highlights the potential for monetary authorities to adopt an accommodative stance in the face of climate-induced economic challenges, attempting to stimulate demand and mitigate the broader economic impact. This underscores the importance of integrating climate considerations into Nigeria's monetary and fiscal frameworks to address the unique economic dynamics triggered by climate shocks.

Figure 3.7: IRF Plots for climate change



Source: Authors' computation.

Table 3.7: Response of x, inf and mpr to climate change

Forecast Horizon	X	Inf	Mpr
0	**-0.2244**	**-1.0517**	**-0.9471**
1	-0.1908	-0.9040	-0.8152
2	-0.1628	-0.7784	-0.7027
3	-0.1393	-0.6712	-0.6064
4	-0.1195	-0.5794	-0.5239

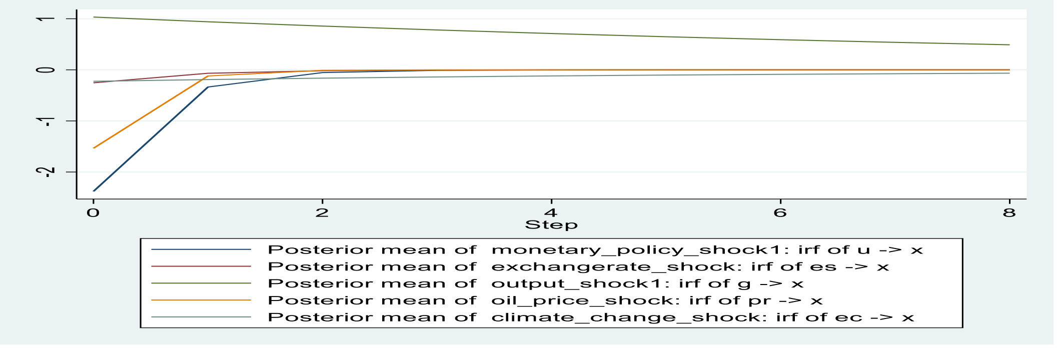
Source: Authors' computation.

3.10 Discussion of Combined IRFs

Figure 3.8 presents the combined response of the output gap (x) to shocks emanating from monetary policy, nominal effective exchange rate, output/technology, crude oil price and climate change. We find that the output gap responds positively and significantly not only to output shock but also negatively and significantly to monetary policy, nominal effective exchange rate, crude oil price, and climate change.

We also find that the output gap is more persistent to output/technology shock, followed by climate change, thencrude oil price, monetary policy, and lastly nominal effective exchange rate shocks.

Figure 3.8: The response of the output gap to shocks from monetary policy,exchange rate, output/technology, crude oil price, and climate change

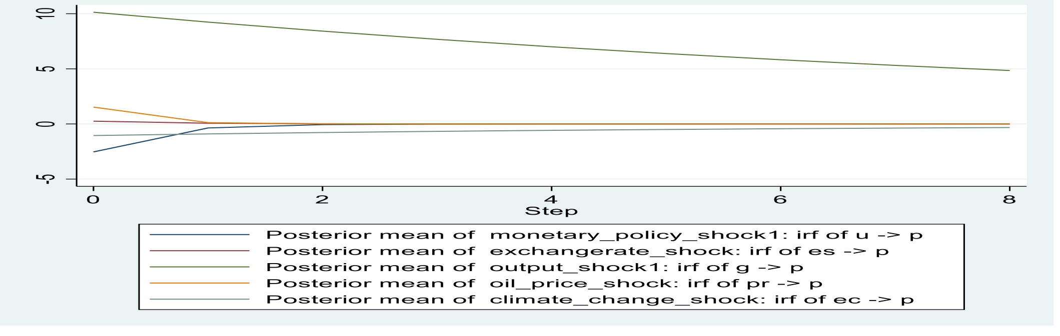


Source: Authors' computation.

Figure 3.9 illustrates the response of inflation to shocks from monetary policy, nominal effective exchange rate, output or technology, crude oil prices, and climate change. The findings reveal that inflation responds positively and significantly to negative output shocks, nominal effective exchange rate shocks, and crude oil price shocks. This indicates that these shocks are inflationary, as they are likely to drive up price levels in the economy. Conversely, inflation responds negatively and significantly to monetary policy shock, suggesting a dampening effect on inflation from these sources.

Notably, the inflationary response is more persistent for output shocks compared to those from climate change, monetary policy, exchange rates, and crude oil prices, highlighting the dominant role of output disruptions in driving inflation dynamics. These results align with the impulse response function (IRF) findings presented earlier, reinforcing the conclusion that negative output/technology shocks exert a more prolonged influence on inflation in Nigeria than other factors.

Figure 3.10: The response of inflation to shocks from monetary policy, exchange rate, output, crude oil price, and climate change

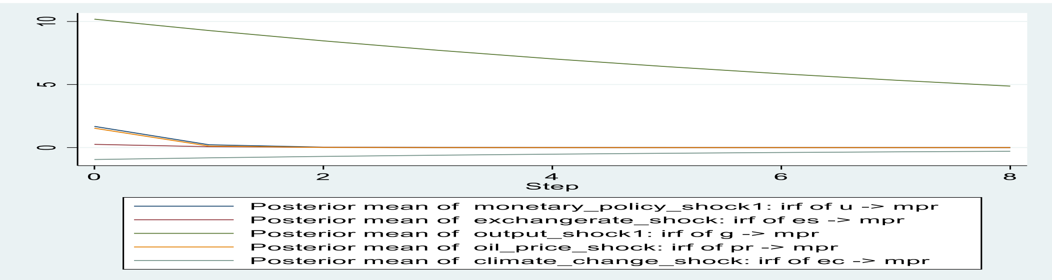


Source: Authors' computation.

Figure 3.10 depicts the interest rate response to shocks from monetary policy, nominal effective exchange rate, output/technology, crude oil prices, and climate change in Nigeria. The results indicate that interest rates respond positively and significantly to monetary policy, nominal effective exchange rate, output/technology, and crude oil price shocks. This suggests that monetary authorities are likely to raise the policy rate in response to these shocks to stabilize the economy.

Notably, the response to output/technology shocks is more persistent than the response to shocks from monetary policy, exchange rates, crude oil prices, or climate change. This aligns with the theoretical expectations of this study and corroborates the results of the impulse response functions (IRFs), emphasizing the central role of productivity-related shocks in shaping monetary policy adjustments in Nigeria.

Figure 3.11: The response of interest rate to shocks from monetary policy, exchange rate, output, crude oil price, and climate change

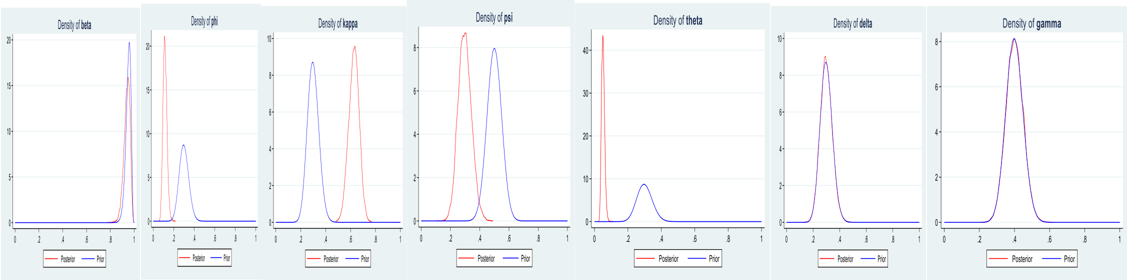


Source: Authors' computation.

3.11 Discussion of priors-posteriors plots

Figure 3.11 illustrates the priors and posterior distributions, providing insights into whether the priors utilized in this study are more informative than the data or vice versa. The density plots for beta (β), delta (∂), and gamma (δ) demonstrate that their priors contain more information than the data used for estimation. Conversely, the priors for kappa (κ), phi (ϕ), theta (Φ), and psi (φ) appear to be less informative, suggesting that the data offer greater explanatory power for these parameters. This conclusion is supported by the significant divergence of their posterior plots from the corresponding prior plots.

Figure 3.11: The prior-posteriors plots



Source: Authors' computation.

4.0Conclusion and Policy Recommendations

This study examines the effectiveness of monetary policy under climate uncertainty in Nigeria using a linear Bayesian Dynamic Stochastic General Equilibrium (BDSGE) approach. We sourced data from the CBN statistical bulletin (2023) and International Financial Statistics (IFS) between 2000Q1 and 2024Q2. We adopt Woodford's (2003) close economy theoretical foundation as our baseline model and modify it to incorporate nominal exchange rate, crude oil price, and climate change to account for the external sector and climate change shocks.

The baseline model reveals that inflation responds positively and significantly to negative output/technology shocks, while indicating negative and significant to monetary policy intervention. However, when climate change, exchange rate, and crude oil price shocks are incorporated into the model, the inflationary response to monetary and output shocks becomes more pronounced. These findings suggest that climate uncertainty amplifies the impact of economic shocks on price stability, thereby reducing the effectiveness of conventional monetary policy measures. The results underscore the need for monetary authorities to integrate climate mitigation strategies into the monetary policy framework to enhance its effectiveness in achieving macroeconomic stability in the face of growing climate-related challenges. The study further recommends that the monetary authorities adopt a more assertive and sustained restrictive monetary policy stance to curb rising inflationary trends. Tightening monetary conditions—through measures such as increasing policy rates or reducing excess liquidity—can help dampen demand-side pressures that contribute to persistent price increases. Additionally, the study underscores the importance of stronger coordination between monetary and fiscal authorities. Such collaboration is crucial not only for aligning policy objectives but also for implementing productivity-enhancing reforms. By improving output capacity, especially in key sectors, the economy can better respond to demand without triggering inflation, thus ensuring a more balanced and sustainable path to price stability in Nigeria.

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