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The macroeconomic effect of COVID-induced economic policy uncertainty in Nigeria: a DSGE approach

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Abstract

Purpose – This study examined the macroeconomic effects of COVID-19-induced economic policy uncertainty (EPU) in Nigeria. The study considered the effects of three related shocks: EPU, COVID-19 and correlated economic policy uncertainty and COVID-19 shock.

Design/methodology/approach – First, the study presented VAR evidence that fiscal and monetary policy uncertainty depresses real output. Thereafter, a nonlinear DSGE model with second-moment fiscal and monetary policy shocks was solved using the third-order Taylor approximation method.

Findings – The authors found that EPU shock is negligible and expansionary. By contrast, COVID-19 shocks have strong contractionary effects on the economy. The combined shocks capturing the COVID-19-induced EPU shock were ultimately recessionary after an initial expansionary effect. The implication is that the COVID-19 pandemic-induced EPU adversely impacted macroeconomic outcomes in Nigeria in a non-trivial manner.

Practical implications – The result shows the importance of policies to cushion the effect of uncertain fiscal and monetary policy path in the aftermath of COVID-19.

Originality/value – The originality of the paper lies in examining the impact of COVID-19 induced EPU in the context of a developing economy using the DSGE methodology.

Keywords COVID-19, Economic policy uncertainty, Fiscal policy, Monetary policy, DSGE models, Stochastic volatility

Paper type Research paper

1. Introduction

The COVID-19 pandemic adversely impacted macroeconomic activity (IGM Economic Experts Panel, 2020). Its effects range from fatality and contagiousness; closed down businesses, disrupted global supply chains, lost jobs, slowed down investment and economic growth. The pandemic has heightened uncertainty about the future among households, businesses, and governments (Dietrich *et al.*, 2020). Economic policymakers became encumbered with the choice of policy responses to mitigate the impact of the pandemic. Therefore, the unprecedented nature of the pandemic spurred unprecedented economic policy responses such as stimulus spending and cash transfers. However, uncertainties are stemming from these policy responses in terms of their duration-temporary or permanent-and economic impact among others (Caracciolo *et al.*, 2020).

This study examines the macroeconomic impact of economic policy uncertainty (EPU) as induced by the COVID-19 pandemic in Nigeria using the DSGE approach. This is against the

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background that unpredictable fiscal and monetary policy decisions adversely impact agents' expectations and can delay investment and consumption decisions of households and businesses. In other words, whether existing fiscal and monetary policy directions will change and the predictability of its future path portends a significant impact on an economy (Ozili, 2022). It is important to examine the potential macroeconomic effects of EPU in Nigeria stemming from the notion that EPU has stifled Nigeria's ability to attract foreign investment and has posed a significant threat to how well domestic businesses thrive (African Economic Outlook, 2021). Secondly, the sudden disruptions of the COVID-19 pandemic that hit the Nigerian economy in 2020 and the recession that followed, preoccupied fiscal and monetary authorities with policy options on whether to modify existing policies or to introduce new decisions whose paths were uncertain. Furthermore, an inquiry on EPU can inform policymakers on the significance of EPU as a source of economic fluctuations in Nigeria.

Several studies have empirically examined the link between EPU and macroeconomic outcomes (Bloom, 2009; Baker *et al.*, 2016; Gupta *et al.*, 2020; Baker *et al.*, 2020; Basu and Bundick, 2017; Cesa-Bianchi and Fernandez-Corugedo, 2018; Alessandri and Mumtaz, 2019). A second set of studies have considered the macroeconomic (uncertainty) effect of the COVID-19 pandemic (Leduc and Liu, 2020; Jorda *et al.*, 2020; Fernando and McKibbin, 2020; Eichenbaum *et al.*, 2020).

Two empirical issues are noteworthy. First, most existing studies have examined the effect EPU as induced by other peculiar events such as the Global Financial Crisis and Great Recession in 2009. There is sparse evidence on EPU as induced by COVID-19. The exception to this is Baker *et al.* (2020) who attempted to construct measures to examine the macroeconomic effect of COVID-19 induced uncertainty in the United States using the VAR method. The authors examined EPU as induced by COVID-19 using (1) a reduced-form econometric approach and (2) in the context of developed economies. This study fills this gap by providing empirical evidence on the effect of COVID-19 induced EPU within a DSGE model and in the context of Nigeria as a developing economy.

The choice of DSGE modeling will help circumvent two methodological issues. The first issue surrounds the measurement of COVID-19 induced EPU and the second concerns insufficient data due to the short time-series span since COVID-19 occurred in 2020. This study circumvents these challenges by calibrating a general equilibrium model and constructing a COVID-19 induced EPU shock. Following this introductory section, the rest of this paper comprises the literature review and stylized facts in Sections 2 And 3; the DSGE model and its solution method is presented in Section 4, The results are presented and discussed in Section 5, whereas Section 6 contains the conclusion.

2. Literature review

Since the seminal contribution of Bloom (2009), several studies have attempted to investigate the macroeconomic effects of economic (policy) uncertainty. This review focuses on four emerging empirical issues arising from this research area. The first concerns the nature of the macroeconomic effect of EPU. Generally, existing theoretical and empirical studies agree to a large extent that EPU adversely impacts the macroeconomy (Bloom, 2009; Born and Pfeifer, 2014; Fernandez-Villaverde *et al.*, 2011, 2015). For instance, Baker *et al.* (2016) found that a shock to EPU induced a decline in aggregate economic activity in 13 economies including the United States. The results from Montiel and Nogueira (2021) revealed that EPU stifled business confidence and investment activity in Brazil.

A second issue arising from the literature borders on the measurement of EPU. Several studies have measured EPU using the stock market volatility indexes (Bloom, 2009), a text-based approach (Baker *et al.*, 2016; Huang and Luk, 2020). Another set of studies constructed the EPU measure using a survey-based approach (Bachmann *et al.*, 2013) and a macroeconomic model-based approach (Jurado *et al.*, 2015; Ghirelli *et al.*, 2019). Thirdly, there is debate on the magnitude of the EPU shocks. One set of studies finds that EPU shocks have negligible macroeconomic effects while the others found non-trivial effects of the EPU shocks. For instance, Born and Pfeifer (2014) support the hypothesis that EPU shocks are negligible while Fernandez-Villaverde *et al.* (2015) found conversely that EPU has strong macroeconomic effects.

The fourth empirical issue is that existing studies have examined economic (policy) uncertainty as induced by peculiar events such as the Global Financial Crisis and Great Recession in 2009 (Baker *et al.*, 2016). In the event of the COVID-19 pandemic, academics are beginning to consider the effect of economic (policy) uncertainty as induced by the pandemic (Caggiano *et al.*, 2020; Leduc and Liu, 2020; Baker *et al.*, 2020). This current study relates to these studies examining the effect of COVID-19 induced EPU. However, our study differs from two angles. The first is that these studies have been conducted mainly in the context of a developed economy and secondly, these studies have either used a descriptive approach (Leduc and Liu, 2020); reduced-form econometric and/or VAR approach (Baker *et al.*, 2020). Based on these, this current study provides empirical evidence macroeconomic effect of COVID-19 induced EPU in the context of a developing economy, Nigeria. Bloom (2014) expects that EPU shocks are stronger in developing economies than in their developed counterparts. This current study uses the time-varying volatility measure of EPU within a DSGE model in line with Fernandez-Villaverde *et al.* (2015).

3. Stylized facts: VAR evidence

Preliminary empirical facts bordering on the impact of EPU on main macroeconomic aggregates are presented here. First, an attempt is made to measure EPU using a stochastic volatility model (Born and Pfiefer, 2014; Oh, 2020). The nominal interest rate and government spending, both monetary and fiscal policy variables, are fitted to the stochastic volatility model. Once fitted, the log-volatility process of both series is extracted to proxy as monetary and fiscal policy uncertainty measures.

Thereafter, a standard VAR(3) model is fitted to quarterly Nigerian macroeconomic data over the sample period 2010Q1 to 2020Q1. The model consists of 4 endogenous variables: fiscal policy volatility measure, monetary policy volatility measure, Real Gross Domestic Product inflation rate. The generalized impulse response graphs are presented in Figure 1. The generalized impulses are non-responsive to the ordering of variables. They show the impulse response of RGDP and inflation to one-standard-deviation increases to both fiscal and monetary policy volatility. From Figure 1, the impact of fiscal volatility (GVOL) is seen to be negative but insignificant. In other words, fiscal volatility caused both output and inflation to decline, although in an insignificant manner. On the other hand, the impact of monetary policy volatility (RVOL) on output and inflation was also not statistically different from zero.

4. Methodology

4.1 Modelling COVID-19 induced EPU in Nigeria: DSGE model with stochastic volatility approach

A nonlinear DSGE model with stochastic volatility in this study is used to examine the macroeconomic effect of the COVID-19 pandemic-induced EPU. It draws from the works of Gali and Monacelli (2005), Castro (2020) and Zhang *et al.* (2021). The model is a closed economy and is assumed to comprise four optimization agents: households, firms, the central bank, and the government. The infinitely lived household is made up of two types of households: the Ricardian and Non-Ricardian. The firm consists of several intermediate-goods producers that operate in a monopolistic competitive environment. The model has a monetary authority that implements a Taylor-type rule, while the fiscal authority implements

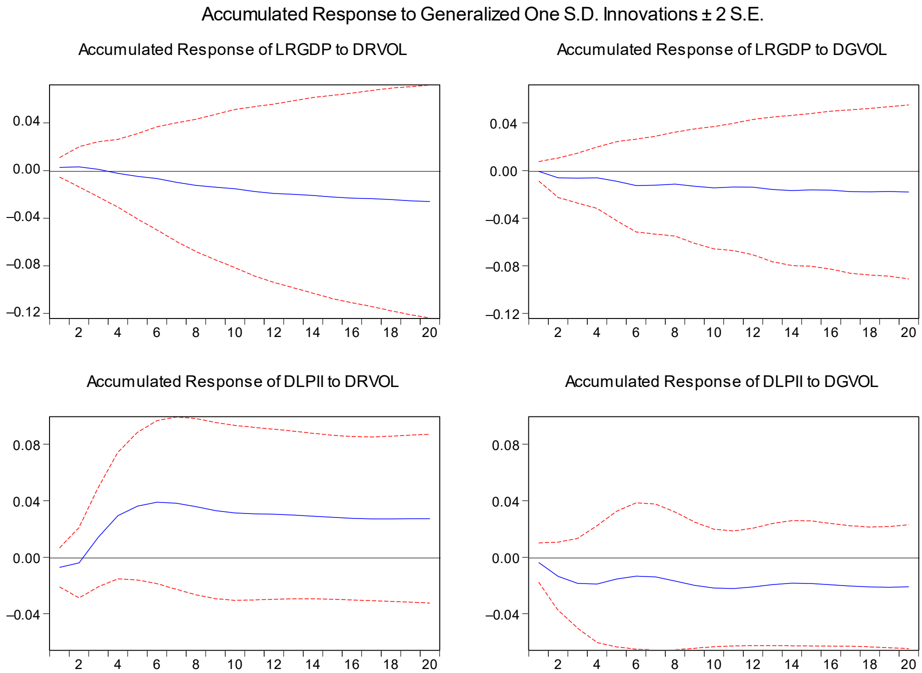

Figure 1.
Generalized Impulse response of RGDP and Inflation to fiscal policy volatility (GVOL) and monetary policy volatility (RVOL)

the fiscal policy. Finally, it is assumed that there are some exogenous shock processes (first and second-moment shocks) that perturb the domestic economy.

The COVID-19 pandemic is modeled in this study as an exogenous process. Firstly, it is assumed that the pandemic causes domestic output to fall. Furthermore, the pandemic adversely hits household consumption demand since several hand-to-mouth households who live on daily wages are restricted from working due to precautionary policies such as social distancing and lockdown. Based on this, a loss parameter (ϑ^{cov}) is introduced to measure how much has been lost from Nigeria's domestic GDP and household consumption because of this global health crisis. Secondly, the effect of the pandemic is modeled by assuming that the economy is hit by negative shocks. This assumption is expected to be able to capture the adverse effect of the COVID-19 crisis on the relevant macroeconomic aggregates.

On another note, the EPU is modeled in this study as uncertainty shock based on the stochastic volatility approach as proposed by Fernandez-Villaverde *et al.* (2011, 2015) which assumes that macroeconomic policy instruments are perturbed by the first-moment and second-moment exogenous processes.

4.1.1 Household sector. The household sector comprises infinitely lived individuals who consume and supply labor to firms to maximize its lifetime utility, subject to its intertemporal budget constraint. It is assumed to be made up of two types of households, where the fraction μ are Ricardian households, and the other fraction $(1-\mu)$ is non-Ricardian households

4.1.1.1 Ricardian households. These are forward-looking optimizing household agents who can access the financial markets to buy financial assets and can also make a profit by owning firms. The Ricardian consumer derives utility at the time t from consuming a composite good, C_t, good health status H_t and leisure $1-N_t$. Their utility is assumed to have been hit by negative preference and labor supply shocks arising from the COVID-19 pandemic. Thus, the intertemporal utility function is written as follows:

$$\boldsymbol{U_{Rt}} = U((C_{R,t} - hC_{R,t-1}), H_t, N_t) \tag{1}$$

The household maximizes the sum of discounted expected future utility subject to the nominal budget constraint as defined in equation (6):

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\varepsilon_t^c \left(\frac{(C_{R,t} - hC_{R,t-1})^{1-\sigma}}{1-\sigma} + \chi \ln H_t - \frac{\varepsilon_t^N}{1+\varphi} N_t^{1+\varphi} \right) \right] \tag{2}$$

where E_t is the rational expectation operator; β^t denotes the inter-temporal discount factor; $C_{R,t}$ is the consumption of goods by Ricardian households; H_t is the health asset held; N_t represents the labor supply. It is assumed that households form habits on their consumption where h denotes the co-efficient of habit formation; σ is the parameter on the inverse of elasticity of substitution; χ is the weight attached to health status; φ is the inverse of Frisch elasticity of labor supply. ε_t^c and ε_t^N denote preference shock and labor supply shock which are assumed to follow an AR(1) process. In line with Zhang *et al.* (2021) and Faria-e-Castro (2021), equations (3) and (4) depict that the preference (ε_t^c) and labor supply shocks (ε_t^N) follow an AR (1) process augmented also to be depending on COVID-19 shocks (ϑ_t^{cov})

$$\varepsilon_t^c = \rho_{ec}\varepsilon_{t-1}^c + e_t^c + \ln\left(1 - \vartheta_t^{cov}\right) \tag{3}$$

$$\varepsilon_t^N = \rho_{eN}\varepsilon_{t-1}^N + e_t^n + \ln\left(1 - \vartheta_t^{cov}\right) \tag{4}$$

It is also assumed that the Nigerian economy can switch between probability (P_t^{ϑ}) of an outbreak of COVID-19 or not such that the magnitude of the COVID-19 shocks depends on the probability of the pandemic occurring and on the COVID-19 loss parameter (ϑ^{cov}) that demonstrates the reduced consumer spending and the fall in the disposable income of households as a result of the pandemic. When $P_t^{\vartheta} = 0$, the economy unsusceptible to COVID-19 shocks, and when $P_t^{\vartheta} = 1$, COVID-19 shock hits the economy.

$$\vartheta_t^{cov} = P_t^{\vartheta}\vartheta^{cov} \tag{5}$$

The Ricardian household maximizes the CRRA utility function in equation (2) subject to a standard budget constraint in nominal terms. The budget constraint postulates that the household receives wages for their labor supply W_tN_t ,they own the firm and receive profit in form of dividend DV_t, they own stock of risk-free financial assets, D_t and receive a lump-sum transfer, that is palliative from the government TP_t. The household uses its resources to pay for consumption goods $P_tC_{R,t}$, to purchase health services P_tH_t, and to buy a portfolio of financial assets, D_{t+1}. This relation can be written as the following:

$$(1 - \vartheta^{cov})P_tC_{R,t} + E_t\left(Q_{t,t+1}D_{t+1}\right) + P_tH_t \leq (1 - \vartheta^{cov})W_tN_t + D_t + TP_t + DV_t \tag{6}$$

where $(Q_{t,t+1})$ is the one-period ahead stochastic discount factor; D_{t+1} denotes the payment at period $t+1$ of the portfolio held at the end of period t.

From the optimization problem of the Ricardian household, two major optimality conditions are derived: the consumption Euler (equation 7) and the intra-temporal consumption equations (equation 8). These are specified respectively as the following:

$$1 = \beta R_t E_t \left(\frac{C_{R,t+1} - hC_{R,t}}{C_{R,t} - hC_{R,t-1}} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \frac{\varepsilon_t^c}{\varepsilon_{t+1}^c} \tag{7}$$

$$\frac{W_t}{P_t} = (C_{R,t} - hC_{R,t-1})^{\sigma} N_t^{\varphi} (1 - \vartheta^{cov})\varepsilon_t^N \tag{8}$$

4.1.1.2 Non-Ricardian household. These are liquidity-constrained consumers who are unable to save and invest since they are hand-to-mouth individuals. The non-Ricardian households maximize their utility function in equation (2) subject to its budget constraint stated as the following:

$$(1-\vartheta^{cov})P_t C_{NR,t} \leq (1-\vartheta^{cov}) W_t N_{NR,t} + TP_t \tag{9}$$

The budget constraint shows that the household receives only wage bills $W_t N_t$ and lump-sum transfer from the government TP_t and uses its income to buy consumption goods. The consumption spending and income earned by the non-Ricardian household are also shown to dwindle as a result of the COVIID-19 pandemic. Equation (8) shows that the non-Ricardian household does not optimize but simply equates their consumption expenditure to wage income and government transfer payment.

The law of motion of the palliative transfer payment to the non-Ricardian household is

$$TP_t = \rho_{TP} TP_{t-1} + \varepsilon_t^{TP} \tag{10}$$

Equation (10) shows that the non-Ricardian household simply equates their consumption expenditure to wage income and government transfer payment.

4.1.1.3 Aggregation. Total consumption and labor supply aggregated over the Ricardian and Non-Ricardian households are given as the following:

$$\mathrm{C}_t = \mu \mathrm{C}_{R,t} + (1-\mu)\mathrm{C}_{NR,t} \tag{11}$$

$$\mathrm{N}_t = \mu \mathrm{N}_{R,t} + (1-\mu)\mathrm{N}_{NR,t} \tag{12}$$

4.1.2 The firms. It is assumed that there is a continuum of monopolistic competitive firms $j \in [0, 1]$, in the domestic economy, that produce differentiated goods using a linear production technology with labor as the only input. In aggregate, their production is defined as

$$(1-\vartheta^{cov}) Y_t = A_t N_t \tag{13}$$

where A_t is the Total Factor Productivity; N_t denotes the labor input for each firm j; Log $A_t \equiv a_t$ is assumed to evolve with an AR (1) process such that: $a_t = \rho_a a_{t-1} + \varepsilon_t^a$. The COVID-19 pandemic has stalled the productive capacity of firms worldwide leading to decreased supply of goods and services. ϑ^{cov} measures the lost production volume due to the pandemic

The firms minimize their total cost subject to the linear production technology to derive the real marginal cost (mc_t) stated as the following:

$$mc_t = \frac{W_t}{A_t P_t} \tag{14}$$

4.1.2.1 Price setting. The firms set prices following the Calvo (1983) price-setting mechanism such that at each period, $1-\theta$ fraction of randomly selected domestic firms set prices optimally, while the other θ fraction keeps their prices unchanged. The resetting firms choose the price, P_t^*, by maximizing their nominal discounted profits subject to demand constraints such that:

$$Max\, E_t \sum_{k=0}^{\infty} (\theta)^k E_t \left\lfloor Q_{t,t+k} [Y_{t+k}(P_t^* - MC_{t+k})] \right\rfloor \tag{15}$$

Subject to the firm's demand function for good (j):

$$Y_{t+k} = \left(\frac{P_t^*}{P_{t+k}^*}\right)^{-\varepsilon} C_{t+k} \tag{16}$$

where MC_{t+k} is the nominal marginal cost of the firm (j) in period $t + k$ and $Q_{t,t+k} = \beta^K \left(\frac{c_{t+k}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+k}}$ is the stochastic discount factor for k-period-ahead payoffs

The first-order condition of the maximization problem is such that:

$$\sum_{k=0}^{\infty} (\theta)^k E_t \left[Q_{t,t+k} Y_{t+k} \left(P_t^* - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k} \right) \right] = 0 \tag{17}$$

For the θ fraction of firms that keep their prices unchanged, the aggregate price evolves according to:

$$P_t = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta) \left(P_t^* \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{18}$$

4.1.2.2 Modeling economic policy uncertainty. We introduce uncertainty shocks into both monetary and fiscal instruments to depict the uncertain paths of both policies as. In line with Bloom (2009), Fernandez-Villaverde *et al.* (2011), Zhang *et al.* (2021), we assume that both fiscal and monetary policies have been hit by uncertainty shocks induced by the COVID-19 pandemic. The uncertainty shocks are modeled as a time-varying second-order moment, which contrasts with the conventional first-order stochastic shocks. In a novel way, we assume that the random uncertainty shocks are on one hand, partly an AR (1) process and partly dependent on the COVID-19 shocks, since the central argument of this study is that the EPU has been induced by the COVID-19 pandemic.

4.1.3 The monetary authority. The Central Bank of Nigeria is assumed to follow a simple Taylor-type rule. Accordingly, the CBN, under this rule, sets the interest rate by considering the past value of the interest rate, the deviation of inflation, output, and exchange rate from the target. In line with Fernandez-Villaverde *et al.* (2015), both the interest rate shock ($\varepsilon_{r,t}$) and an uncertainty shock ($\sigma_{r,t}$) perturbs the nominal interest rate.

$$\frac{R_t}{R} = \left[\frac{R_{t-1}}{R} \right]^{\rho_R} \left[\left(\frac{\pi_t}{\pi} \right)^{\upsilon_\pi} \left(\frac{Y_t}{Y} \right)^{\upsilon_Y} \right]^{1-\rho_R} \sigma_{r,t} \varepsilon_{r,t} \tag{19}$$

$$\sigma_{r,t} = \left(1 - \rho_{\sigma,r}\right) \vartheta_t^{cov} + \rho_{\sigma,r} \sigma_{r,t-1} + \left(1 - \rho_{\sigma,r}^2\right)^{½} + \eta_r \upsilon_{r,t} \tag{20}$$

where, R_t is the nominal interest rate; R_{t-1} is the lagged interest rate; π_t is the inflation rate; Y_t is the output; $\varepsilon_{r,t}$ denotes the innovation to monetary policy; ρ_R is the degree of interest rate smoothing. υ_π, υ_Y are parameters that measure the response of the interest rate to inflation and output. Also, R , π, and Y are the target values for the interest rate, inflation rate, and output.

4.1.4 The fiscal authority. The fiscal authority faces a budget constraint where it earns revenue by issuing bonds (D_t) and collecting lump-sum taxes (T_t) in addition to oil revenue, which is the mainstay of the Nigerian economy. The revenue collected is expended on government provision of goods and services (G_t), interest payment on government debt ($R_{t-1}D_{t-1}$) and palliative spending, which is a transfer payment (TP_t). The fiscal policymaker, therefore, has a nominal budget constraint given as the following:

$$(1 - \vartheta^{cov})(T_t + D_t + OR_t) = G_t + R_{t-1}D_{t-1} + TP_t \tag{21}$$

The government also implements fiscal rules in government spending and lump-sum tax as seen in equations (22) and (23) which show that both fiscal instruments react to debt, output, and two exogenous components: the fiscal shocks (ε_t^g, ε_t^T) and the fiscal uncertainty shocks ($\sigma_{g,t}$, $\sigma_{T,t}$). They are of the form:

$$G_t = \rho_g G_{t-1} + \left(1 - \rho_g\right)\left(\upsilon_d D_t - \rho_y Y_t\right) + \sigma_{g,t}\,\varepsilon_t^g \tag{22}$$

$$T_t = \rho_t T_{t-1} + (1 - \rho_t)\left(\upsilon_d D_t - \rho_y Y_t\right) + \sigma_{T,t}\,\varepsilon_t^t \tag{23}$$

The fiscal uncertainty shocks are also defined as:

$$\sigma_{g,t} = \left(1 - \rho_{\sigma,g}\right)\vartheta_t^{cov} + \rho_{\sigma,g}\sigma_{g,t-1} + \left(1 - \rho_{\sigma,g}^2\right)^{½} + \eta_g \upsilon_{g,t} \tag{24}$$

$$\sigma_{T,t} = \left(1 - \rho_{\sigma,\,T}\right)\vartheta_t^{cov} + \rho_{\sigma,\,T}\sigma_{T,t-1} + \left(1 - \rho_{\sigma,\,T}^2\right)^{½} + \eta_T \upsilon_{T,t} \tag{25}$$

where, η_g, η_T is the unconditional standard deviation of the fiscal uncertainty shock; $\rho_{\sigma,g}$, $\rho_{\sigma,\,T}$ denotes the shocks' persistence

4.1.5 Goods market-clearing condition. The goods market-clearing condition is given as:

$$Y_t = C_t + G_t \tag{26}$$

4.2 Solving the DSGE model: third-order approximation method

Consider the DSGE model represented in a canonical form as the following:

$$E_t f\left(y_{t+1}, y_t, x_{t+1}, x_t, u_{t+1}, u_t\right) = 0 \tag{27}$$

where y: Vector of control variables.

x: Vector of state variables

u: Vector of exogenous shocks

As a stochastic model, a scale variable, the perturbation parameter $\sigma > 0$ is introduced. The solution to the DSGE model present policy functions comprising of decision rules g and h such that:

$$x_{t+1} = h(x_t, u_{t+1}, \sigma) \tag{28}$$

and

$$y_{t+1} = g(x_t, u_{t+1}, \sigma) \tag{29}$$

The policy functions in equations (28) and (29) are approximated using a perturbation approach. This involves a Taylor expansion around the non-stochastic steady state given as:

$$\bar{x} = h\left(\bar{x}, 0, 0\right)$$

$$\bar{y} = h\left(\bar{x}, 0, 0\right)$$

$$\bar{u} = 0$$

Specifically, the DSGE model used in this study is solved using the third-order approximation to the policy functions around the steady states. From the literature, the third-order approximation method is standard in solving DSGE models with stochastic volatility or uncertainty (Fernandez-Villaverde *et al.*, 2011; Born and Peifer, 2014; Mutschler, 2018; Zhang *et al.*, 2021). Fernandez-Villaverde *et al.* (2011) demonstrate that stochastic volatility or uncertainty shocks, which are second-moments do not play a role under the first-order approximation. They are indirectly captured as they enter as cross-products with first-moment shocks under the second-order approximation. However, at third-order Taylor expansion, volatility shocks appear explicitly. The volatility shocks enter the policy function independently with non-zero coefficients at the third-order approximation.

The third-order Taylor expansion of equation (28) is

$$\begin{aligned}\widehat{x}_{t+1} &= h_x\widehat{x}_t + h_u u_{t+1} + \frac{1}{2}H_{xx}(\widehat{x}_t\otimes\widehat{x}_t) + H_{xu}(\widehat{x}_t\otimes u_{t+1}) + \frac{1}{2}H_{uu}(u_{t+1}\otimes u_{t+1}) + \frac{1}{2}h_{\sigma\sigma}\sigma^2\\ &+ \frac{1}{6}H_{xxx}(\widehat{x}_t\otimes\widehat{x}_t\otimes\widehat{x}_t) + \frac{1}{6}H_{uuu}(u_{t+1}\otimes u_{t+1}\otimes u_{t+1}) + \frac{3}{6}H_{xxu}(\widehat{x}_t\otimes\widehat{x}_t\otimes u_{t+1})\\ &+ \frac{3}{6}H_{xuu}(\widehat{x}_t\otimes u_{t+1}\otimes u_{t+1}) + \frac{3}{6}H_{x\sigma\sigma}\sigma^2\widehat{x}_t + \frac{3}{6}H_{u\sigma\sigma}\sigma^2 u_{t+1}\end{aligned}$$

The third-order Taylor expansion of equation (29) is:

$$\begin{aligned}\widehat{y}_{t+1} &= g_x\widehat{x}_t + g_u u_{t+1} + \frac{1}{2}G_{xx}(\widehat{x}_t\otimes\widehat{x}_t) + G_{xu}(\widehat{x}_t\otimes u_{t+1}) + \frac{1}{2}G_{uu}(u_{t+1}\otimes u_{t+1}) + \frac{1}{2}h_{\sigma\sigma}\sigma^2\\ &+ \frac{1}{6}G_{xxx}(\widehat{x}_t\otimes\widehat{x}_t\otimes\widehat{x}_t) + \frac{1}{6}G_{uuu}(u_{t+1}\otimes u_{t+1}\otimes u_{t+1}) + \frac{3}{6}G_{xxu}(\widehat{x}_t\otimes\widehat{x}_t\otimes u_{t+1})\\ &+ \frac{3}{6}G_{xuu}(\widehat{x}_t\otimes u_{t+1}\otimes u_{t+1}) + \frac{3}{6}G_{x\sigma\sigma}\sigma^2\widehat{x}_t + \frac{3}{6}G_{u\sigma\sigma}\sigma^2 u_{t+1}\end{aligned}$$

$\widehat{x}_t = x_t - \overline{x}_t$ and $\widehat{y}_t = y_t - \overline{y}_t$ show deviations from the non-stochastic steady state

$h_x h_u g_x g_u$: Gradients of h and g for states and shocks

$H_{xx}G_{xx}$: Second order matrices for the state and control variables

$H_{xu}G_{xu}$: Second order matrices for cross-product of states and shocks

$H_{uu}G_{uu}$: Second order matrices for products of shocks

$h_{\sigma\sigma}$ *and* $g_{\sigma\sigma}$: Hessians of h and g for the perturbation parameter σ

$H_{uuu}\ H_{xxx}H_{xxu}H_{xuu}H_{x\sigma\sigma}H_{u\sigma\sigma}$ and $H_{uuu}\ H_{xxx}H_{xxu}H_{xuu}H_{x\sigma\sigma}H_{u\sigma\sigma}$: third-order matrices

4.3 Calibration

The DSGE model used in this study is mostly calibrated to the Nigerian economy as shown in Table 1. The calibrations are matched to existing long trend data. Some other parameters are obtained from regression estimations using Nigerian data while others are borrowed from values reported in existing studies and the researchers' subjective beliefs as informed by the literature. The shock processes are assumed to be Gaussian with zero mean and variance of σ_i^2 while the persistent parameters are calibrated by fitting them to AR (1) models. The calibrated parameters are presented in Table 1.

Symbol	Parameters	Calibrated value	Source
Structural parameters			
H	Habit formation	0.70	Tule *et al.* (2017)
(σ)	Inverse elasticity of substitution	2	Oye *et al.* (2018)
(ψ)	Share of non-Ricardian households	0.50*	Matched to the World poverty clock statistic on Nigeria for proportion of population living below $1.90
(φ)	Inverse elasticity of labor	4.38	Oye *et al.* (2018)
(θ)	Calvo Price Stickiness	0.50	Tule *et al.* (2017)
Coronavirus pandemic parameter			
(ϑ)	Coronavirus loss parameter	0.50*	Quote from Ms. Songwe, Head of UNECA “Africa may lose half of its GDP with growth falling . . . due to a number of reasons which include the disruption of global supply chains”
Fiscal policy parameter			
(ρ_y)	Reaction of Government spending to output	2.64*	ARMAX regression fitting the government spending rule for Nigeria (1981–2017)
(λ)	Reaction of Government spending to debt	−0.09*	ARMAX regression fitting the government spending rule for Nigeria (1981–2017)
Monetary policy parameter			
(υ_π)	Taylor feedback on Inflation	0.03*	ARMAX regression fitting the Taylor rule for Nigeria (1981–2017)
(υ_y)	Taylor feedback on Output	0.50*	ARMAX regression fitting the Taylor rule for Nigeria (1981–2017)
(ρ_r)	Interest rate smoothening	0.70*	ARMAX regression fitting the Taylor rule for Nigeria (1981–2017)

Note(s): Parameter values asterisked (*) are those calibrated to data on the Nigerian economy

Table 1. Calibrated values

5. Results and discussion

5.1 Impulse response analysis

In the following, we analyze the effects of three forms of shocks on the main macroeconomic aggregates using impulse response functions. These include: (1) EPU shock, (2) COVID-19 shock, and (3) correlated EPU and COVID-19 shock.

(1) EPU Shocks

We assume that symmetric shock of the same persistence and magnitude hits the fiscal and monetary policy instruments of government spending, taxes, and the nominal interest rate. The impulse response graph displayed in Figure 2 shows that a sudden increase in EPU is negligible but expansionary. In other words, there is a contemporaneous increase in output and total consumption when faced with the EPU shock, even though drastically short-lived. The expansionary nature contrasts with apriori expectations that increased uncertainty adversely impacts macroeconomic aggregates (Bloom, 2009; Basu and Bundick, 2017; Fernandez-Villaverde *et al.*, 2015). Furthermore, existing studies linking EPU and macroeconomic outcomes found that EPU mostly adversely impacts economic performance (Bloom, 2009; Luo and Zhang, 2020; Luk *et al.*, 2020).

However, Basu and Bundick (2017), Fernandez-Villaverde and Guerrón-Quintana (2020) postulate the expansionary effects of uncertainty under assumptions of flexible labor supply and no nominal rigidities. The contractionary effect of uncertainty depends on both sticky

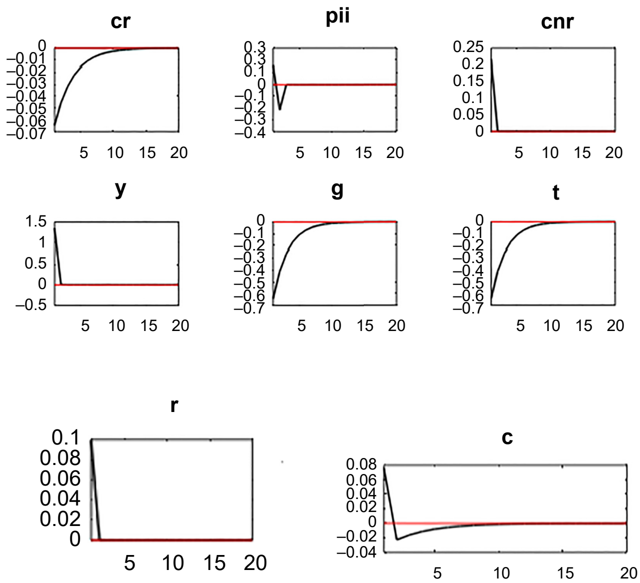

Figure 2.
Impulse response to an EPU shock

price and wage. This study, however, abstracts away from sticky wages by assuming flexible wages. Under flexible labor prices, when hit by uncertainty, risk-averse households take precautions by reducing consumption and they increase labor supply, which raises output. The positive response of non-Ricardian consumption to EPU shock is consistent as Ricardian households cannot smooth their consumption and had to spend all their income in the current period. In contrast, Ricardian consumption declined in response to the EPU shock since they can smooth consumption. However, the magnitude of the decline is observed to be smaller relative to the increase in consumption by Non-Ricardian consumers, leading to a contemporaneous increase in overall consumption and hence output.

The impulse response graphs also displayed in Figure 2 depict that EPU shocks have a negligible effect on the main macroeconomic aggregates, in line with the literature (Bonn and Pfeifer, 2014). Another feature of the results presented shows that economic policy variables (government spending and taxes) fall in response to the policy uncertainty shock. Furthermore, its impact is persistent as it declines over the entire period. The intuition backing the decline in government spending and taxes is that due to the precautionary reaction to the outbreak of COVID-19, the government took caution by delaying fiscal spending decisions (alongside fiscal vulnerability issues) that dipped government spending. Tax revenue was also contracted in line with delayed fiscal decisions.

(2) COVID-19 Shock

The impulse response graph shown in Figure 3 depicts that COVID-19 shock-whether initial or resurgence of COVID-19 waves-has a recessionary effect on the economy. This contrasts with the expansionary effect of the EPU shock. The output declined over the horizon stemming from both the demand and supply sides. There is a loss of labor supply due to morbidity and ill-health on the supply side and decreased household consumption on the demand side which has invariably dipped output in the economy. This finding conforms to the results of Fornaro and Wolf (2020) that showed that the COVID-19 shock reduced output. Although the non-Ricardian household positively responded to the COVID-19 shock, Ricardian consumption dipped leading to a fall in overall consumption and output.

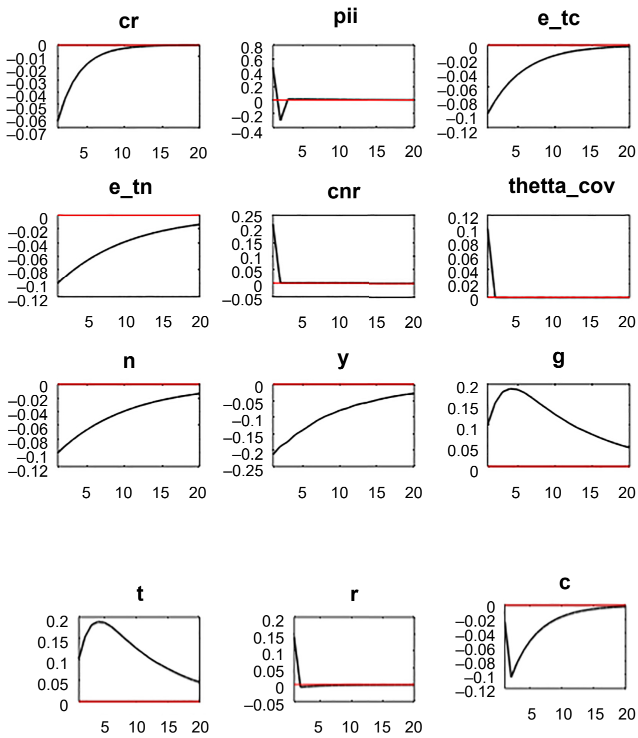

Figure 3.
Impulse response to COVID-19 shocks

Concerning policy variables, government spending responded positively despite the COVID-19 shock. This captures increased transfers and palliative spending by the government in mitigating the effect of the pandemic. From the impulse response graph, there was an obvious monetary policy lag in response to COVID-19, as the nominal interest rate was unchanged on impact. Also, the monetary policy reflected an uncertain path as interest rates varied from neutral to rise and then to fall. For most of the horizon from quarters 4–20, the nominal interest rate fell. Therefore, fiscal and monetary policy decisions were mainly expansionary to address the contractionary effect of the COVID-19 pandemic.

(3) Combined COVID-19 and EPU Shock

We also construct the combined shock capturing innovations for both COVID-19 and EPU. Following the combined shock, the impulse response graph presented in Figure 4 shows that the Ricardian consumption declines while there is a contemporaneous increase in non-Ricardian consumption. Both total household consumption and output rise contemporaneously. However, after a lag of one period, overall consumption and output decline over the horizon. It can then be deduced that the correlated shock is mainly recessionary as output declines after a lag even as household consumption and labor supply fall. This is expected as labor supply falls, and household income declines, which implies that consumer spending will dip and invariably decrease output. One implication of this is that COVID-19 induced EPU posed contractionary risks to the economy.

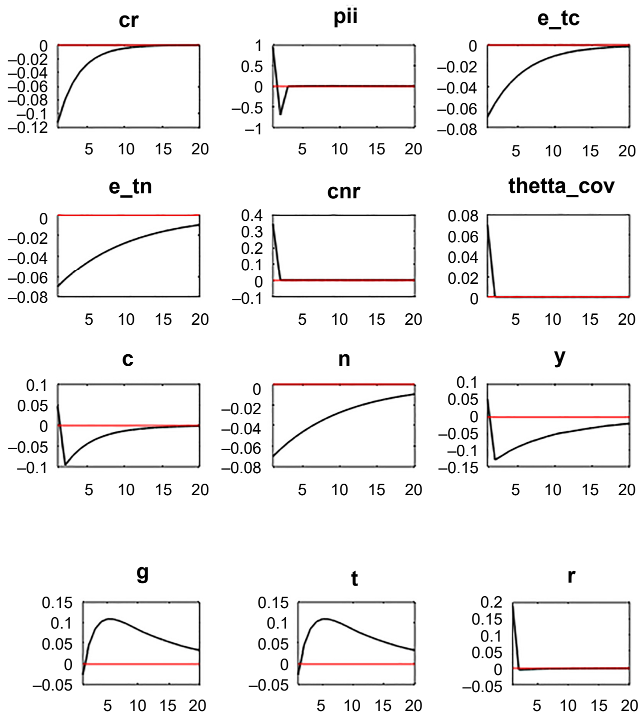

Figure 4.
Impulse Response to correlated shocks

6. Conclusion

This study examined the macroeconomic effect of EPU (EPU) shocks induced by the COVID-19 pandemic. First, it presents VAR evidence to show that both fiscal and monetary policy volatility induces a fall in real output. Thereafter, a nonlinear DSGE model with second-moment fiscal and monetary policy shocks was solved using the third-order Taylor approximation method to measure the uncertainty shocks. The main results of the study showed that the EPU shock was negligible and expansionary. In contrast, COVID-19 shocks had strong contractionary effects on the economy. The combined shocks capturing the COVID-19 induced EPU shock were ultimately recessionary after an initial expansionary effect. The implication is that the COVID-19 pandemic-induced EPU has adversely impacted macroeconomic outcomes in Nigeria. Policymakers should propose measures to reduce or eliminate uncertainty in fiscal and monetary policies. Such measures should include well-structured and stronger communication of medium-term fiscal plans, structural reforms, and monetary policy decisions.

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