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Article

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Renewable Energy, Shocks and the Growth Agenda: A Dynamic Stochastic General Equilibrium Approach

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ABSTRACT

Macroeconomic fluctuations observed in real economies are results of identifiable shocks in form of technology, monetary, fiscal, trade, energy or a combination of these shocks. The adverse effects of energy price shocks, in recent decades, have made the call for renewable energy source important. This call is most appropriate in a mono-cultural economy where the fluctuations in crude oil pricing are easily transmitted into the economy. Therefore, this paper seeks to investigate the consequences of technology, and energy shocks on key macroeconomic variables including output and consumption using an energy augmented small open economy dynamic stochastic general equilibrium model. The model is estimated using Bayesian techniques under different scenarios in order to show the various ramifications of the shocks to the Nigerian economy. The findings show that shocks to the renewable energy sector have more impact of the Nigerian economy compared to shocks to the fossil fuel sector.

Keywords: Fossil Fuels, Technology Shocks, Demand Shocks, Renewable Energy, Small Open Economy Dynamic Stochastic General Equilibrium
JEL Classifications: E32, K32, P18

1. INTRODUCTION

The pursuit of renewable energy options, by government, has become necessary in the face of addressing socio-economic and environmental challenges arising from the use of fossil energy. The adoption of renewable energy is expected to create increased access to electricity. For instance, this alternative energy source will help to balance up existing production and supply of electricity in Nigeria (National Renewable Energy and Energy Efficiency Policy, 2015). The increased access to renewable energy is also essential as a channel for employment generation. At the same time, the promotion of these alternative sources of energy will provide clean forms of energy that will combat environmental degradation and reduce health risks. It will also cushion the Nigerian economy against petroleum price shocks.

Several policy plans have been proposed and adopted in Nigeria in order to promote the use of renewable energy sources. These include the Renewable Energy Master Plan in 2012 which seeks to provide an enabling environment for the development of renewable energy in order to facilitate the development of the nation's energy sector. The plan targets that 95% of Nigerian household should access energy by 2030 and renewable energy sources should constitute 20% of total energy mix. National Renewable Energy and Energy Efficiency Policy 2015 also propose that renewable sources should contribute 20% to of total electricity generation by 2030. It can be deduced from these policy plans that the right combinations of instruments are required to aid the development of the renewable energy sector in Nigeria. These instruments include strategic policies and institutions, financial investment, modern technology and trained manpower.

To this end, this study examines the mix of investment, technology and manpower and their importance in promoting alternative energy sources. The study also investigates the impact of shocks to the renewable energy sector on the Nigerian economy. The objectives of this paper are, therefore, to assess the economy-wide effect of shocks to the renewable energy and fossil fuel sectors, within a small open economy dynamic stochastic general equilibrium (SOEDSGE) model. The model is augmented to capture the fossil fuel and renewable energy sources. Secondly, the study will also gauge the importance of the investment, technology and manpower mix in developing the renewable energy sector. The parameters of the SOEDSGE model are calibrated to suit the Nigerian economy and the model is solved using the log-linear approximation method. Also, the study documents business cycle stylised facts in Nigeria with relation to energy sources.

The rest of this paper is structured as follows: Section 2 provides a review of the literature. Section 3 discusses the business cycle method and presents the business cycle stylised facts of Nigeria in relation to renewable energy. The SOEDSGE model of the study is presented in Section 4 and the empirical findings and discussion of result are in Section 5. The conclusion of the study is documented in Section 6.

2. LITERATURE REVIEW

Empirical studies related to energy sources and most especially renewable energy and its linkages to the economy have received a lot of attention over the years. Ogundipe et al. (2016) attribute this to partly the significant role energy plays in the achievement of sustainable economic development. Furthermore, the threat of climate change as a result of emissions into the atmosphere places energy utilisation, its sources and policies at the forefront of environmental debate (Adenikinju, 1995). This section provides a review of relevant and related literature in the area of non-renewable and renewable energy sources in relation to sustainable growth and development.

Dogan and Seker (2016) investigated the effects of renewable energy, non-renewable energy, real income and trade openness on carbon dioxide emissions for the European Union over the period 1980-2012 using panel estimation techniques. The findings of the paper revealed that there is evidence of panel co-integration, hence a long run relationship between the macroeconomic variables. Furthermore, it was observed that an increase in renewable energy leads to a decline in the level of emissions. On the other hand, an increase in non-renewable energy contributes to environmental degradation. Through the use of an agent-based Eurace model; Ponta et al. (2018) examined the effects of a tariff policy mechanism allowing for the transformation of an economy from fossil fuel based to renewable energy based. The results indicated that in the presence of a feed-in tariff policy mechanism for renewable energy, there is a significant difference in the economic performance in relation to employment and investment decisions.

Contrary to expectations; Tugcu and Tiwari (2016) in their study showed that there are no causal links between renewable energy consumption (REC) and economic growth in the BRICs. In addition, it was observed that non-renewable energy creates a positive externality for countries like Brazil and South Africa thereby aiding economic development. Dogan (2016) obtained similar results as it was found out that REC had an insignificant effect on economic growth in Turkey, while non-renewable energy had a positive effect. However, in another study for the German economy; Rafindadi and Ozturk (2017) employed two distinct co-integration techniques to investigate whether renewable energy has impacted the growth of the economy. The results provided evidence of a long run relationship and an increase in renewable energy leads to an increase in economic growth. The contradicting result could be as a result of country-specific factors causing the differences.

Recent development in the area of energy studies have seen the application of DSGE models to understand how exogenous and energy shocks affect the behaviour of agents in an economy. In that manner, Fischer and Springborn (2011) explore the impacts of emissions caps and emissions tax on the business cycle. The study makes use of a DSGE model to evaluate the dynamic effects of these policy choices in the advent of a productivity shock. The major finding of the work was that an emission cap and tax reduces the effects of productivity shock on the economy. However, the effect of an emission tax comes with greater volatility. Similarly, Heutel (2012) investigated the optimal environmental policy decision in response to macroeconomic fluctuations caused by persistent productivity shocks for the United States economy. A DSGE model was calibrated and the results indicated that optimal policy response is to increase emissions during periods of economic expansion and reduce emissions during periods of economic recession. Also; Annicchiarico and Dio (2015) through the use of a DSGE model accounting for nominal and real uncertainty found out that an emission cap is likely to dampen the effects of business cycles and optimal policy is largely influenced by price adjustment.

Argentiero et al. (2014) used a DSGE model to assess the effectiveness of an incentive mechanism incorporating a carbon tax and a stock of public capital. This was done to show the behaviour of investors' commitment towards renewable energy. The model was simulated and the findings favour the use of a stock of public capital in place of subsidies because subsidies reflect a short run policy which does not encourage investors' confidence. Argentiero et al. (2017) analysed the role of environmental policy in renewable energy sources based on carbon tax and renewable energy subsidies for 15 members of the European Union, United States and China within a DSGE model incorporating both a fossil-fuel and renewable energy sector. The model was solved using Bayesian techniques and the results showed that in the presence of a total factor productivity shock in the fossil-fuel sector, an energy policy shock serves as a driving force for dampening the energy sector.

Acemoglu et al. (2012) introduced an endogenous and directed technical change in a two-sector model to evaluate the response of different types of technologies to environmental policies. The model was able to show that sustainable growth can be achieved via carbon taxes and subsidies. Also, delay in intervention is costly to the economy. Likewise; Argentiero et al. (2018) investigated the effectiveness of a cost-effective strategy for the implementation of renewable energy strategies based on either technology push and demand pull measures in a DSGE model. They found out that a technology push measure is more suitable and effective.

Examining studies in Nigeria, the relationship between energy consumption and economic development was investigated by Ogundipe et al. (2016) through the use of co-integration estimation techniques. The study found out that there is a long run relationship. Furthermore, a unidirectional relationship exists between economic development and electricity consumption. Akinyemi et al. (2017) investigated the effects of the removal of fuel subsidy on carbon emissions through the use of a recursive Computable General Equilibrium model. Simulations of the model revealed that carbon emissions marginally increased as a result of a partial subsidy removal. Alege et al. (2017) documented business cycle facts between carbon emissions and total output, agricultural output as well as industrial output for Nigeria. In addition, they examined the effects of real shocks on carbon emissions. The findings revealed that emissions are countercyclical to output, and pro-cyclical to both agricultural and industrial output. Real shocks were seen to have a positive effect on the level of carbon emissions.

In summary, from the literature reviewed, it can be seen that the energy sector plays an important role in ensuring sustainable development. Renewable energy sources have become the forefront for policymakers as it is crucial in ensuring a clean and green environment.

3. THE BUSINESS CYCLE METHOD: SOME STYLISED FACTS

Towards the documentation of business cycle stylised facts for Nigeria in relation to energy sources and consumption, this approach of this study follows the common practice in the business cycle literature by decomposing the time series into trend and cyclical components through the use of a filtering technique, such as the Hodrick-Prescott (HP) filter (Agenor et al., 2000; Alege et al., 2017; and Kim et al., 2003). The approach is as follows: Taking the natural logarithm of the series; testing the stationary properties of the series; obtaining the cyclical component by detrending the series; computing the autocorrelation statistics of the series; and computing the cross correlation of the series (Alege, 2008).

The HP filter allows us to examine three key statistical issues: (1) The amplitude of fluctuations measured by the volatility and relative volatility. The volatility is derived from the percentage standard deviation of a series, while relative volatility is obtained from the ratio of the percentage standard deviation of a series to that of output. A variable is considered to be subject to high fluctuations when the relative volatility is >1. (2) The measurement of phase shift, that is, whether a variable change before or after changes in output. A variable is considered to lead the cycle if the maximum cross correlation coefficient is positive and lags the cycle if the maximum cross correlation is negative. (3) The contemporaneous correlation of a series with respect to output as measured by the cross-correlation coefficient. This helps to determine whether a series is pro-cyclical or countercyclical. A positive (negative) correlation between output and a macroeconomic variable indicates that the variable is proc-cyclical (countercyclical), whereas a correlation of zero suggests that the variable is acyclical. Furthermore, one can say the variables are strongly contemporaneously correlated if $0.26 \leq |\delta j| \leq 1$, weakly contemporaneously correlated if $0.13 \leq ||\delta j| \leq 0.26$, and contemporaneously uncorrelated with the cycle if $0 \leq |\delta j| \leq 0.13$.

The study makes use of annual data from 1990 to 2014 in order to derive the stylised facts for business cycles in Nigeria with respect to energy sources. The macroeconomic variables used in the study are: Real gross domestic product (RGDP), electricity production from hydroelectric sources (EPHS), electricity production from natural gas sources, electricity production from oil, gas and coal sources, and REC (Table 1).

Table 2 presents the result of the stylised facts for the Nigerian economy in relation to energy sources. In terms of output fluctuations, RGDP in Nigeria over the time period measured by the percentage standard deviation is about 5.352%. The volatility of EPHS and natural gas sources are 6.572% and 6.792%, respectively. REC has a volatility of 1.412% and that of electricity produced from oil, gas and coal sources is 3.586%. Examining the amplitude of fluctuations measured by the relative volatility, electricity produced from both hydroelectric and natural gas sources are all >1. This suggests that they are highly volatile and subject to macroeconomic fluctuations. On the other hand, REC and electricity produced from oil, gas and coal sources are subject to less volatility from the results.

The degree of contemporaneous correlation between output and electricity produced from hydroelectric sources is −0.297 indicating a countercyclical relationship. This implies that an expansion in RGDP

Table 1: Data description

Variables	Identifier	Description	Source	Measurement
Real gross domestic product	RGDP	Real gross domestic product measured at 2010 constant prices in US dollars.	WDI (2016)	2010 constant basic prices, billion (Naira)
Electricity production from hydroelectric sources	EPHS	It refers to electricity produced by hydroelectric power plants.	WDI (2016)	Percentage
Electricity production from natural gas sources	EPNS	It refers to electricity produced by natural gas but excludes natural gas liquids.	WDI (2016)	Percentage
Electricity production from oil, gas and coal sources	EPOS	Sources of electricity refer to the inputs used to generate electricity. Oil refers to crude oil and petroleum products. Gas refers to natural gas but excludes natural gas liquids.	WDI (2016)	Percentage
Renewable energy consumption	REC	Renewable energy consumption is the share of renewable energy in total final energy consumption.	WDI (2016)	Percentage

WDI denotes World Development Indicators (WDI) database* is usually accompanied by a reduction in electricity produced from hydroelectric sources. This finding is not surprising as statistics from the WDI reveal that despite the positive growth rate experienced during the time period, electricity produced from hydroelectric sources has been declining. Specifically, while RGDP growth rate in 2010 was 7.84%, in 2011 it was 4.89% and in 2012 it was 4.28%; however, within that time period electricity from hydroelectric sources' growth rate declined to −10.82% in 2011 from 6.56% in 2010 and declined to −9.41% in 2012. REC; electricity produced from natural gas sources and oil, gas and coal sources; electricity produced from natural gas sources all have a pro-cyclical relationship with RGDP in Nigeria. However, based on the proposition of Agenor et al. (2000), REC is weakly correlated; electricity produced from oil, gas and coal sources is strongly correlated; and that of natural gas sources is contemporaneously uncorrelated. The implication of this is that electricity produced from oil, gas and coal sources as an energy source is very important to the economy.

In relation to phase shift, the entire macroeconomic variable leads the cycle of RGDP in Nigeria with the exception of electricity produced from natural gas sources which can be seen to be lagging the cycle over the time period.

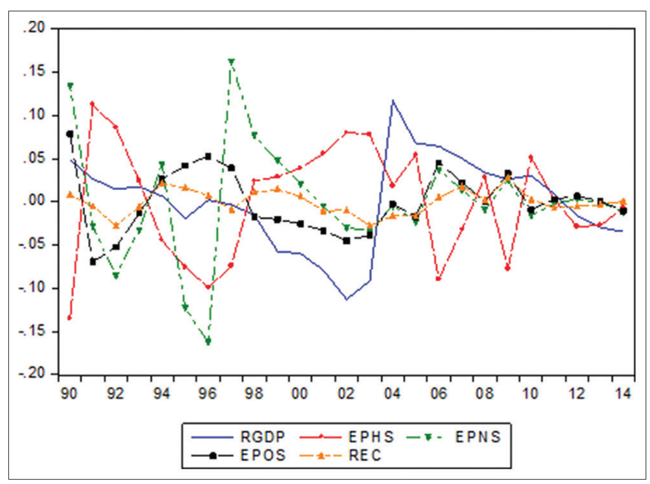
The graphical illustration in Figures 1 depicts the cyclical movements of the macroeconomic variables used in the study.

Table 2: Cyclical behavior of RGDP and energy sources

RGDP volatility	Nigeria (1990-2014) 5.352%
EPHS	Countercyclical
Contemporaneous correlation	−0.297
Volatility (%)	6.577
Relative volatility	1.229
Phase shift	Leading
EPNS	Pro-cyclical
Contemporaneous correlation	0.099
Volatility (%)	6.792
Relative volatility	1.269
Phase shift	Lagging
EPOS	Pro-cyclical
Contemporaneous correlation	0.390
Volatility (%)	3.586
Relative volatility	0.670
Phase shift	Leading
REC	Pro-cyclical
Contemporaneous correlation	0.109
Volatility (%)	1.413
Relative volatility	0.264
Phase shift	Leading

Source: Researchers' computation from EViews 9.0. Real GDP: Real gross domestic product, EPHS: Electricity production from hydroelectric sources, EPNS: Electricity production from natural gas sources, EPOS: Electricity production from oil, gas and coal sources, REC: Renewable energy consumption

Figure 1: Cyclical pattern of electricity production from hydroelectric sources, electricity production from natural gas sources, electricity production from oil, gas and coal sources, renewable energy consumption and real gross domestic product



Source: Researchers' computation from EViews 9.0

4. THE SOEDSGE MODEL

The SOEDSGE model that is adapted in this study is in line with Argentiero et al. (2018). The model assumes the existence of optimizing economic agents that base their current decision on their anticipation about the future. These agents seek to maximise their objective functions subject to corresponding constraints. It consists of three sectors- the household sector, production sector comprising of four types of perfectly competitive firms, government sector. The model is also assumed to be perturbed by technological shocks, investment shocks, labour demand shocks and policy shocks.

4.1. Household Sector

There exists a representative household that derives utility from consuming a composite good (C_t). This composite good comprises of energy and a non-energy good. The individuals in the household prefer leisure to work, that is, they get dissatisfaction from their labour efforts (N_t). In addition, the household earns labour income (W_tN_t) and capital returns (r_tK_t) with dividends (DV_t). They also receive lump sum transfer payment from the government (TP_t). The household, however, expends its income to purchase consumption goods (P_tCt), one-period bonds (D_{t+1}) and capital goods (K_{t+1}). The optimization problem of the representative household is, therefore, to maximize its intertemporal utility function subject to its budget constraint, such that:

$$Max \sum_{t=0}^{\infty} \beta^t \left(C_t, N_t\right) \tag{4.1}$$

The utility function specified in equation (1) is a Constant Relative Risk Aversion (CRRA) type which can be specified as:

$$Max \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \tag{4.2}$$

Subject to

$$K_{t+1}+P_tC_t+E_t(Q_{t,t+1}D_{t+1})=W_tN_t+r_tK_t+(1-\delta)K_t+TP_t+DV_t \tag{4.3}$$

The optimality conditions of the household sector are the labour supply schedule in equation 4.4 and the inter-temporal consumption equation showing that the marginal rate of substitution equals capital equation 4.5. They are written as:

$$\frac{W_t}{P_t} = c_t^{\sigma} N_t^{\varphi} \quad (4.4)$$

$$\left(\frac{C_t}{C_{t-1}}\right)^{-\sigma} \frac{1}{\pi_t} = \beta\left(r_t + (1-\delta)\right) \quad (4.5)$$

4.2. The Production Sector

The production sector comprises of four types of firms. There is a final good firm that uses labour $\left(n_t^y\right)$, capital $\left(k_{t-1}^y\right)$ and energy inputs (e_t) to produce final goods (Y_t) based on Cobb Douglas Production function. In addition, there are three intermediate goods firms producing energy (e_t), fossil fuels (FF_t) and renewable energy (RES_t). The energy producing firm combines both fossil fuels (FF_t) and renewable energy (RES_t) to manufacture its output using a Constant Elasticity of Substitution (CES) production technology. In the fossil-fuel sector, quantities of fossil fuels are produced using labour $\left(n_t^{ff}\right)$, capital $\left(k_{t-1}^{ff}\right)$ and energy (e_t) while the renewable energy firm employs labour $(n_t^r es)$, capital $(k_{(t-1)}^r es)$ and public capital $\left(k_{t-1}^g\right)$ to manufacture its output. The production functions of each individual firm are defined as:

Final goods firm: $Y_t = A_t^y \left(n_t^y\right)^{\alpha_y} \left(k_{t-1}^y\right)^{\chi_y} \left(e_t\right)^{(1-\alpha_y-\chi_y)}$ (4.6)

Energy firm: $e_t = A_t^e \left[\eta RES^{-\varepsilon} + (1-\eta) FF^{-\varepsilon}\right]^{\frac{-1}{\varepsilon}}$ (4.7)

Fossil fuel firm: $FF_t = A_t^{ff} \left(n_t^{ff}\right)^{\alpha_{ff}} \left(k_{t-1}^{ff}\right)^{\chi_{ff}} \left(e_t\right)^{(1-\alpha_{ff}-\chi_{ff})}$ (4.8)

Renewable Energy Firm:

$$RES_t = A_t^{res} \left(n_t^{res}\right)^{\alpha_{res}} \left(k_{t-1}^{res}\right)^{\chi_{res}} \left(k_{t-1}^{g}\right)^{(1-\alpha_{res}-\chi_{res})} \quad (4.9)$$

Where α_i and χ_i are the share of labour and capital inputs in the production of final goods, fossil fuel and renewable energy goods. A_t^i represents the Total Factor productivity in each of the four sectors while n_t^i and K_{t-1}^i are the labour and capital inputs in the individual sectors. $K_{(t-1)}^i$ is assumed to evolve according to $k_{(t-1)}^i = (1-\delta)k_{(t-1)}^i + i_t^i$. A_t^i, n_t^i and i_t^i follow an AR(1) process such that i=y,e,ff and res.

4.3. Government Sector

The fiscal authority is assumed to face a budget constraint where the revenue it earns from lump-sum taxation (T_t), bonds (d_t) and energy tax (pe_t) is expended on government provision of goods and services (g_t), transfer payment to the household sector (TP_t) and interest payment on government debt (r_{t-1} d_{t-1}). The fiscal policy maker, therefore, has a nominal budget constraint defined as:

$$T_t + d_t + pe_t = g_t + TP_t + r_{t-1} d_{t-1} \quad (4.10)$$

The government also implements a fiscal rule of the form:

$$d_t = (d_{(t-1)})^{(\rho_g)} ?_t^d \quad (4.11)$$

4.4. Exogenous Shock Processes

The model is perturbed by thirteen shock processes in technology, investment, fiscal policy and labour demand, which are expressed as:

Technology in Final output sector: $A_t^y = ?_A yA_{(t-1)}^y + \varepsilon_t^A y$ (4.12)

Technology in Energy sector: $A_t^e = \varepsilon_A eA_{(t-1)}^e + \varepsilon_t^A e$ (4.13)

Technology in Fossil fuel sector: $A_t^{ff} = \rho_{Aff} A_{t-1}^{ff} + \varepsilon_t^{Aff}$ (4.14)

Technology in Renewable Energy sector: $A_t^{res} = \rho_{Ares} A_{t-1}^{res} + \varepsilon_t^{Ares}$ (4.15)

Investment in Final output sector: $i_t^y = \rho_{iy} i_{t-1}^y + \varepsilon_t^{iy}$ (4.16)

Investment in Fossil fuel sector: $i_t^{ff} = \rho_{iff} i_{t-1}^{ff} + \varepsilon_t^{iff}$ (4.17)

Investment in Renewable Energy sector: $i_t^{res} = \rho_{ires} i_{t-1}^{res} + \varepsilon_t^{ires}$ (4.18)

Public investment in renewable energy sector: $i_t^g = \rho_{ig} i_{t-1}^g + \varepsilon_t^{ig}$ (4.19)

Labour in Final output sector: $n_t^y = \rho_{ny} n_{t-1}^y + \varepsilon_t^{ny}$ (4.20)

Labour in Fossil fuel sector: $n_t^{ff} = \rho_{nff} n_{t-1}^{ff} + \varepsilon_t^{nff}$ (4.21)

Labour in renewable energy sector: $n_t^{res} = \rho_{nres} n_{t-1}^{res} + \varepsilon_t^{nres}$ (4.22)

Fiscal Policy: $d_t = \rho_d d_{t-1} + \varepsilon_t^g$ (4.23)

Fossil Fuel Stock: $s_t = \rho_s s_{t-1} + \varepsilon_t^s$ (4.24)

Where, $\varepsilon_t^j \sim iiN\left(0, \sigma_i^2\right)$

4.5. Market Clearing Condition

The market clearing condition for the domestic economy requires that aggregate output equals aggregate domestic demand, investment and government spending such that:

$$Y_t = C_t + I_t^y + I_t^g + I_t^{res} + I_t^{ff} \quad (4.25)$$

5. ESTIMATION, FINDINGS AND DISCUSSION

5.1. Bayesian Estimation of DSGE Model

The Bayesian method is used to estimate the DSGE model in this study, in order to obtain numerical values of the model parameters. Researchers have used other methods that varies from the calibration approach to more formal econometric methods such as generalized method of moment, impulse response function matching moments and maximum likelihood. The Bayesian method, however, is the most preferred because it is a full - information method that estimates the system of equations in the DSGE model. It also includes the use of priors which aids in the identification of parameter. Furthermore, it addresses the issue of model misspecification (Grifolli, 2013). This method is summarized by Bayes' Theorem which links the likelihood function, prior and posterior distribution. It shows that the posterior distribution is proportional to the product of the likelihood function and priors.

The Bayesian estimation involves main procedures that include: (1) Specify priors based on researcher subjective belief; (2) Calculate the log likelihood function using the Kalman filter; 3. Simulate the posterior distribution using the Metropolis-Hasting algorithm.

5.1.1. Priors

Priors are the researchers' subjective belief about the parameters of the DSGE model. The parameters can be calibrated, that is fixed, based on the researchers' intuition, existing studies and/or data. The model parameters used in this study were borrowed from existing studies and the researchers' subjective belief based on literature. The prior mean of the inverse elasticity of substitution *(σ)* was fixed at 3.00 in line with Cebi (2011) using the beta distribution. The share of renewable energy in the output of the energy sector *(η)* was fixed at 0.12 based on Argentiero et al. (2018), following a beta distribution. The fixed value of this parameter depicts that the small portion of renewable energy technology that has been adopted in Nigeria. The calibrated values of the share of labor (α_{res}) and capital χ_{res} in the renewable energy sector are 0.20 and 0.50. This assumes that the renewable energy sector is capital intensive. In the same vein, the share of labor and capital in the output of the fossil fuel sector is fixed at 0.15 and 0.50, based on the researchers' subjective belief that the oil-sector in Nigeria employs a small fraction of labor. The persistence parameters on technology, investment and labor in the renewable energy and fossil fuel sector are fixed at 0.8 based on the assumption that the persistence parameters are highly persistent. Finally, the shock parameters are fixed are at 0.01 with an inverse gamma distribution. The prior mean and distribution are listed in Table 3.

5.1.2. Posterior estimates

Table 3 shows the posterior estimate of individual parameters of the DSGE model. The posterior estimate of the share of renewable sources in the production of the energy sector stands at 0.11 which is lower than its prior mean of 0.12. This implies that the proportion of renewable energy used is smaller at 11% compared to the proportion of non-renewable sources at 89 per cent. This is evident in the greater reliance of Nigerian households and businesses on petrol and diesel than on solar and other renewable energy sources. The share of labour and capital used in the production of renewable energy is estimated at 0.19 and 0.18. This shows that the renewable energy sector is labour-intensive contrary to the researchers' subjective belief. The estimated values of the share of labour and capital in the fossil fuel sector are 0.36 and 0.64. This depicts the fossil-fuel sector to be capital intensive.

Furthermore, the posterior mean of the persistence parameters in technology, investment and labour across the renewable and fossil fuel sectors are higher than their prior mean except in the case of investment in the fossil fuel sector. This implies that the Nigerian economy adjusts slowly to shocks from these sources. The posterior mean of the shock parameters indicates the extent of volatility of the individual exogenous process. The posterior estimates of the shock processes show that the shock to technology and investment in the renewable energy sector are the most volatile source of fluctuation. It can also be deduced that renewable energy shocks are more volatile than shocks to the fossil fuel sectors. This means that shocks to the renewable energy sector has more macroeconomic impact than those of fossil fuel sector.

5.2. Model Dynamics

The impulse response function is used to analyze the importance and impact of shocks to fossil fuels and renewable energy on the macro economy. The impulse response functions are obtained by solving the log-linearized DSGE model using a first order Taylor approximation around the steady state.

5.2.1. Impulse response to shocks in fossil fuel sector

Based on the impulse response graphs in Figures 2-4, an unexpected positive change to the existing technology in the fossil fuel sector has a positive ripple effect on the Nigerian economy. A shock to technology of fossil fuel increases the stock of technology. This has positive impact on both the fossil fuel production and combined energy output. Household consumption expenditure rises in response to this shock, which is a component of aggregate demand that invariably pushes the level of final output upwards. A positive shock to investment made in the fossil fuel sector raises the amount of investment, increases the capital stock and output produced in this sector. It also impacts positively on the Gross Domestic product. However, the unexpected increase in investment, initially, negatively affects the level of household demand before it rebounds by the seventh quarter. This may be as a result of the waiting period before returns is earned on investment. In the same vein, a positive shock to labor inputs in the fossil fuel sector also generates positive ripple effect on the fossil fuel sector and on the macroeconomic variables.

5.2.2. Impulse response to shocks in renewable energy sector

The Impulse response graphs presented in Figures 5-7 show that a positive shock to technology available in the renewable energy sector leads to a rise in the stock of technology and the amount

Table 3: Estimated parameters

Parameter		Prior distribution	Prior mean	Posterior mean
Symbol	Description			
Sigmma (σ)	Inverse elasticity of substitution	Normal	3.00	2.98
alphha_ff (*αff*)	Elasticity of labour in fossil fuel	Beta	0.15	0.36
cchi_ff (*χff*)	Elasticity of capital in fossil fuel	Beta	0.50	0.64
alphha_res (*αres*)	Elasticity of labour in Renewable energy	Beta	0.20	0.19
cchi_res (*χres*)	Elasticity of capital in Renewable energy	Beta	0.50	0.18
etta (η)	Share of renewable energy	Beta	0.12	0.11
rrho_Ares (*ρAres*)	AR (1) process in technology of renewable energy	Beta	0.80	0.94
rrho_Aff (*ρAff*)	AR (1) process in technology of fossil fuel	Beta	0.80	0.85
rrho_ires (*ρires*)	AR (1) process in investment of renewable energy	Beta	0.80	0.90
rrho_iff (*ρiff*)	AR (1) process in investment of fossil fuel	Beta	0.80	0.78
rrho_nres (*ρnres*)	AR (1) process in labour of renewable energy	Beta	0.80	0.8004
rrho_nff (*ρnff*)	AR (1) process in labour of fossil fuel	Beta	0.80	0.82
eps_Ares	Technology shock in renewable energy sector	Inverse gamma	0.010	0.020
eps_Aff	Technology shock in fossil fuel sector	Inverse gamma	0.010	0.005
eps_ires	Investment shock in renewable energy sector	Inverse gamma	0.010	0.014
eps_iff	Investment shock in fossil fuel sector	Inverse gamma	0.010	0.005
eps_nres	Labour shock in renewable energy sector	Inverse gamma	0.010	0.008
eps_nff	Labour shock in fossil fuel sector	Inverse gamma	0.010	0.007

Sources: Cebi (2011), Argentiero et al. (2018)

Figure 2: Impulse response to technology shock in fossil fuel sector

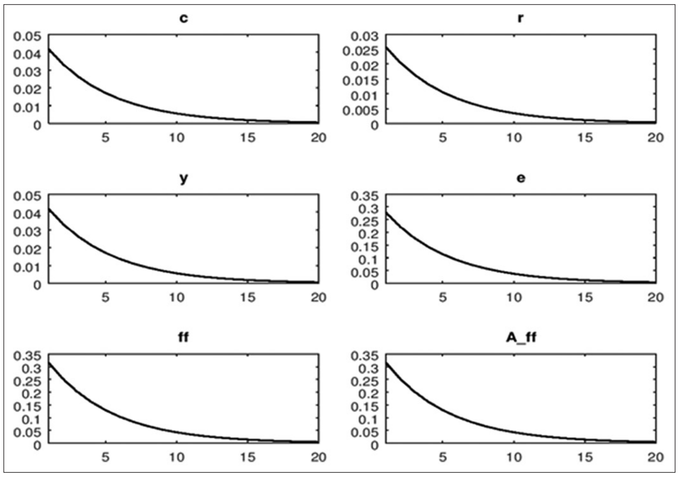


Figure 3: Impulse response to investment shock in fossil fuel sector

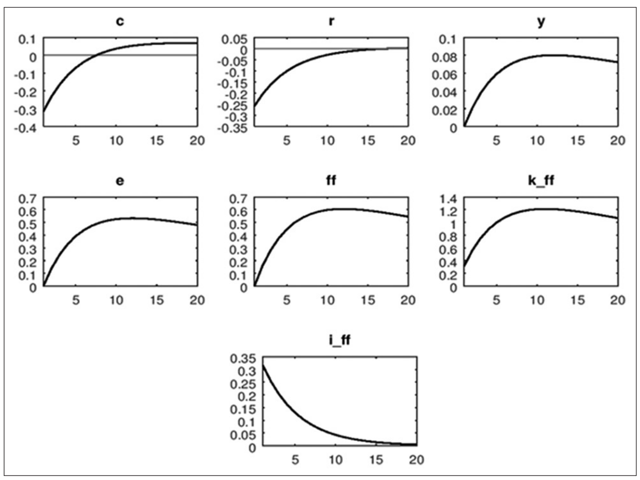
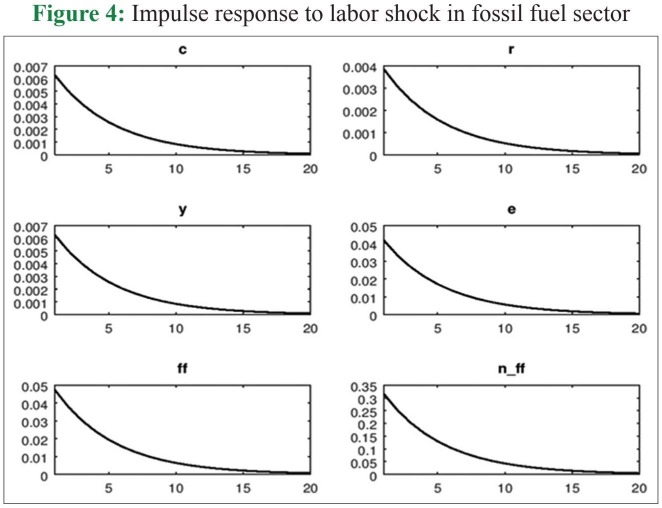


Figure 4: Impulse response to labor shock in fossil fuel sector



of renewable energy output. This has a positive externality on the level of consumption expenditure, as a result of the income effect. Final output, that is, the Gross Domestic product responds positively to this shock. An unexpected increase in the investment made in the renewable energy sector grows the available capital stock. This pushes up the production of this alternative energy. However, household consumption responds negatively to this

Figure 5: Impulse response to technology shock in renewable sector

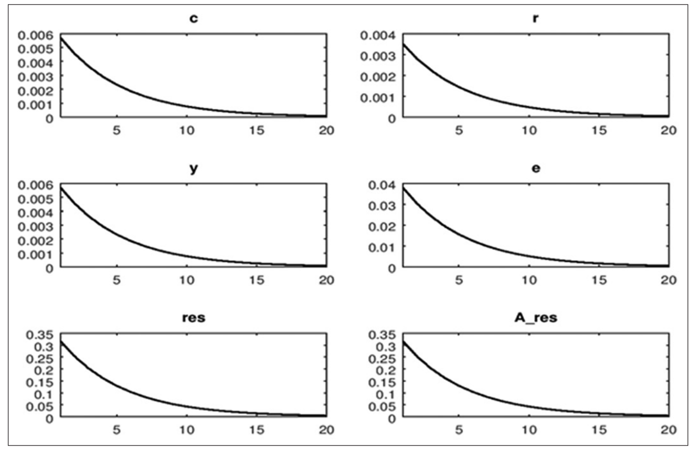


Figure 6: Impulse response to investment shock in renewable sector

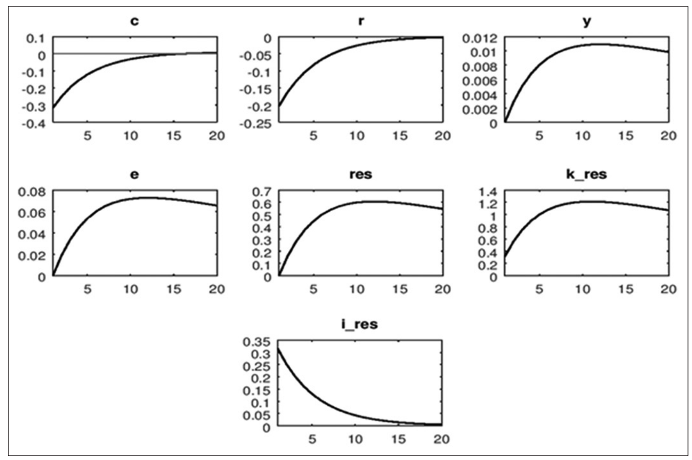
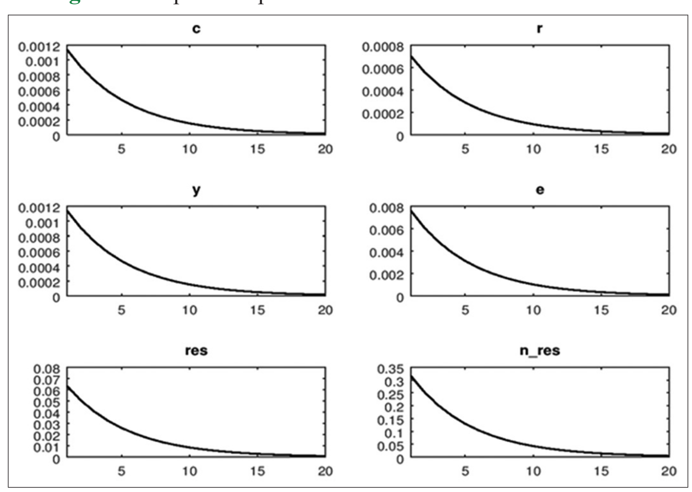


Figure 7: Impulse response to labor shock in renewable sector



shock, even into the horizon. This contrasts with the initial negative response of consumption to investment that is observed in the fossil fuel sector. This means that individuals who invest in the renewable energy sector may have to wait a longer time before they recoup their investment. Furthermore, a positive shock to labour inputs in the renewable sector has a positive multiplier effect on the renewable energy sector and on relevant macroeconomic variables such as consumption.

6. CONCLUSION

This study was conducted in order to document some business cycle stylized facts for the Nigerian economy in relation to energy sources; and secondly, to examine the economy-wide effect of the renewable energy sector on the Nigerian economy and also gauge the importance of financial investment, technology and manpower in promoting alternative energy sources in Nigeria.

Through the use of the HP filter and the procedure of Agenor et al. (2000), the study finds out that electricity produced from hydroelectric and natural gas sources are subject to high volatility. In terms of the degree of contemporaneous correlation, electricity produced from oil, gas and coal sources is pro-cyclical and strongly correlated to the cycle of output in Nigeria. This finding is not surprising given that the major source of foreign exchange earnings in the Nigerian economy is from crude oil. Alege et al. (2017) results relating to industrial sector corroborates this finding. In terms of renewable energy sources, electricity produced from hydroelectric sources has a countercyclical relationship with output reflecting the low use of hydro-powered energy in the economy. REC is pro-cyclical and weakly correlated to output. This indicates that there is the need for government to focus on promoting renewable energy sources.

The result from the Bayesian estimation of the DSGE model shows that the renewable energy sector in Nigeria is a labor-intensive one, while the fossil fuel sector was found to be capital-intensive. This shows that the alternative energy sector needs more labor relative to capital in its production. The alternative energy sector unlike the fossil fuel sector, therefore, has the potential to generate more employment for the teeming Nigerian population. The study also found that shocks to the renewable energy sector have more impact of the Nigerian economy compared to shocks to the fossil fuel sector. In specific terms, the result of the study showed that technology and investment shocks in the renewable energy sector is the most significant source of fluctuation relative to investment and labor shocks. This means that the adoption of technology and financial investment are critical to developing the renewable energy sector in Nigeria. The results from the impulse response analysis showed that shocks to alternative energy have a positive ripple effect on the Nigerian economy. However, household consumption responds negatively to investment shock in the renewable sector. This means that households which invest in renewable energy must give up their consumption when they invest in this sector. The results confirm that the Nigerian government's commitment to renewable energy holds positive potential for economic development.

This study recommends the creation of an enabling environment for the initiation and adoption of renewable technology. Furthermore, government should provide financial incentive to boost investment in this sector and to address necessary investment gaps such as shortage of investment capital and high interest rates for renewable energy.

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