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Article

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Carbon Emissions and the Business Cycle in Nigeria

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ABSTRACT

Investigating the behaviour of carbon dioxide emissions to different macroeconomic variables has become critical in the recent years in environmental policy. In fact, a number of studies have continued to analyse different possible determinants of carbon emissions. However, very little attention has been given to relating real business cycles (RBCs) to carbon emissions in Nigeria. Thus, the main objectives of the study are; first, to document some stylised facts between the cyclical components of carbon emissions and gross domestic product (GDP) including also the relationship with two major components of GDP that have been credited to be a major sources of emissions (agricultural sector and the industrial sector) through the use of the Hodrick-Prescott filter. Secondly, to investigate the response of emissions to real shocks using the structural vector autoregressive approach. The study is able to find out that emissions are countercyclical to output, however, a pro-cyclical relationship is established with the agricultural and industrial sector. RBC shocks are seen to have a positive effect on carbon emissions in Nigeria. The study, therefore, recommends the implementation of environmental policies targeted towards the agricultural and industrial sector given the pro-cyclical relationship obtained from the analysis.

Keywords: Carbon Emissions, Environmental Policy, Business Cycles
JEL Classifications: Q56, Q58, E32

1. INTRODUCTİON

Carbon emissions are basically gaseous substances that emanates as a result of human activities through the burning of fossil fuels, manufacturing of cement and agricultural land use (IPCC, 2007). The increasing level of carbon emissions into the atmosphere has become a global cause of concern. Anderson et al. (2008) highlighted that these emissions have increased substantially since the industrial era. The main issue with carbon emissions is that they cause changes in the climate that can negatively affect the environment and potentially both human and economic activities. According to Jiang and Li (2017), the increase in greenhouse gases poses a threat to an economy, as they have led to the massive decline in agricultural output.

Business cycles on the other hand can be regarded as the cumulative outcomes of the aggregate output and its component caused by random unexpected shocks. According to Sebastian and Volker (2012), these shocks over the years have been classified into two major categories, real or nominal shocks. The real shocks form the basis of the development of the real business cycle (RBC) literature where Kydland and Prescott (1982) identified that real shocks in the form of technology or productivity shocks are the major cause of these macroeconomic fluctuations or business cycles. Heutel (2012) noted that these business cycle shocks have the capacity to significantly affect an economy, therefore, prompting the development of policies by government agencies in order to address them.

In relation to carbon emissions, it has been widely acclaimed by environmentalist that carbon emissions are pro-cyclical to output. That is, there is the tendency for emissions to rise beyond their trend during periods of economic expansion and similarly fall during periods of economic recession (Doda, 2014; Khan and Knittel, 2015). In addition, these emissions are considered to be much more volatile than output. However, little empirical attention has been given to establishing these stylised facts especially for developing countries and Nigeria in particular and also the application of the RBCs phenomenon to carbon emissions especially in the area of the macroeconomic effects of real shocks, given that significant changes in commodity prices like the oil price can lead to fluctuations in carbon emissions. Therefore, examining the relationship between carbon emissions and the business cycle under the RBC framework can help in the development of environmental policies targeted at mitigating the effects of emissions on the Nigerian economy.

In light of this, the study intends to achieve two main objectives; first is to analyse the trend (stylised facts) between the cyclical component of carbon emissions and the gross domestic product (GDP) including also the relationship with two major components of GDP that have been credited to be a major sources of carbon emissions using annual data (agricultural sector and the industrial sector) (EEA, 2014). Secondly, it will investigate the response of emissions to real shocks using the structural vector autoregressive (SVAR) approach for the Nigerian economy. The paper is as structured as follows, Section 2.0 presents a review of relevant literature concerning carbon emissions and business cycles; Section 3.0 addresses the theoretical framework of the study; Section 4.0 presents the data and methodology of the study while Section 5.0 presents the discussion and interpretation of results. The conclusion and recommendations of the paper is presented in Section 6.0.

2. LITERATURE REVIEW

Studies have been conducted in the area of carbon emissions and business cycle. A wide consensus of literature reviewed, shows that carbon emissions are typically pro-cyclical; they increase during expansions and decrease during recessions, and in some cases countercyclical; they reduce during periods of economic expansion or growth. This section provides a review of a number of these literatures.

Heutel (2012) investigated how environmental policy should respond to economic fluctuations caused by persistent productivity shocks under the RBC framework for the United States economy. In order to do so, a dynamic stochastic general equilibrium (DSGE) model was developed and estimated using the calibration approach of estimating business cycles. The major findings of the paper are: The cyclical component of carbon dioxide emissions and the United States GDP was discovered to be inelastic; carbon emissions are much more volatile than GDP and pro-cyclical. Following the calibration of the model, a positive productivity shock increases wealth (output) resulting in a higher demand for green environment, thereby, reducing emissions. The optimal policy response according to the paper is that during an economic expansion, the government should increase emissions, due to the fact that the price effect through the wealth channel dominates the income effect.

Similar to Heutel (2012), Fischer and Springborn (2011) explore the impacts of economy-wide regulations which are emissions caps and emissions tax on the business cycle. This paper also develops a DSGE model to compare the dynamic effects of these policy choices under productivity shocks. The study incorporates three policies for regulating emissions; an emissions cap, an emissions tax and an intensity target that sets a maximum emission-output ratio. The results from this analysis showed that although a tax and cap can produce equivalent outcomes in expectation, an intensity target encourages greater economic growth than either a cap or tax. Moreover, it does not affect the aspects of the business cycle that is despite the regulations emissions are still pro-cyclical.

Doda (2014) attempted to document key facts about the relationship between carbon emissions and business cycle for a large sample of countries. The study made use of the Hodrick-Prescott (HP) filter to obtain the cyclical components of carbon emissions and GDP. As a result of this, four facts emerged; first, emissions are pro-cyclical and cyclically more volatile than GDP, however, 15 countries were discovered to have a countercyclical relationship; second, the cyclical volatility of emissions is negatively correlated with GDP per capita across countries; third, pro-cyclicality of emissions is positively correlated with GDP across countries; and fourth, the composition of GDP is crucial for the business cycle properties of emissions but the relationship is complex. The study, however, did not highlight the theoretical framework concerning emissions and business cycles.

In order to investigate the drivers of carbon dioxide emissions and the decoupling status of electricity in the United States, a multilevel logarithmic mean division index method was developed by Jiang and Li (2017). The study found out that electricity power production effect exerted a positive role in the increase of carbon dioxide emissions. Energy mix effect and conversion efficiency effect both contributed to curbing emissions. The decoupling index method indicated that a no decoupling status exists which implies that the development of the electricity sector to a large extent is driven by the burning of fossil fuels.

This paper is modelled after the work of Khan and Knittel (2015), which investigates how carbon emissions respond to business cycle shocks. They confirm previous assertions claiming that carbon dioxide fluctuations are pro-cyclical. The study applies structural autoregressive methodologies to examine the pro-cyclicality of carbon dioxide emissions with focus on the sources of the business cycle. The research was carried out in the United States from the period of 1973 to 2012 using quarterly data. Two major shocks were observed in this study and they were technology and investment shocks. The researchers discovered that carbon emissions falls after an unanticipated positive technology shock, unanticipated investment shock and anticipated technology shock. However, anticipated investment shocks lead to an increase in carbon emissions.

In conclusion, there is little literature concerning the relationship between carbon emissions and the RBC in the context of the Nigerian economy. This paper attempts to fill this void in literature towards the development of proper of environmental policies.

3. THEORETICAL FRAMEWORK

The theoretical framework of this study is premised upon the RBC theory. According to Alege (2008), the key assumption of the model is that there exist an infinite number of similar households and firms that take decisions to maximise utility and profit, respectively. Each of the respective agents' faces a budget constraint that gives to a social planner's problem. The theory, therefore, opines that macroeconomic fluctuations or business cycles in this model are solely driven by real or productivity shocks, while nominal shocks are of negligible consequences to the business cycle (McCallum, 1988). Rebelo (2005) noted that the RBC models placed emphasis on the role of real shocks, productivity shocks in motivating macroeconomic fluctuations.

Kydland and Prescott (1982) in their "time to build and aggregate fluctuations" paper identified that technological disturbance in the form of total factor productivity (TFP) otherwise known as the Solow residual accounted for the variations in total output for the United States economy. Similarly, Aleksandar (2016) found out that for Bulgaria and the Baltic countries, real shocks in the form of TFP explained the fluctuations in total output.

TFP according to Comin (2010) is that portion of total output (GDP) that is not explained by the factor inputs of production. This implies that is determined by the means through which the factor inputs are efficiently managed. It plays an important role on business cycles as it is seen to be strongly correlated and pro-cyclical with output. In what follows, the data and methodology of the study are discussed towards the achievement of the objectives of the study.

4. DATA AND METHODOLOGY

4.1. Data

The study employs annual data from 1981 to 2015 to achieve the objectives of the study. The carbon emissions dataset used was sourced from the Carbon Dioxide Information Analysis Center (CDIAC) published by Boden et al. (2017). According to Doda (2014) the CDIAC database is considered to be one of the most accurate and reliable source for annual emissions data. The dataset on real GDP (RGDP), agriculture's contribution to GDP (AGDP), and industrial's contribution to GDP (IGDP) were sourced from the Central Bank of Nigeria (CBN) statistical bulletin published by the CBN. TFP data was derived from the Solow residual. Finally, gross fixed capital formation (proxy for investment), household consumption (CONS) and government expenditure were sourced from the World Development Indicators published by the World Bank.

4.2. Business Cycle Identification Method

Agenor et al. (2000), Alege (2008), Doda (2014) and Aleksandar (2016) all employed an atheoretical method in the form of the HP filter in order to establish the existence of business cycles and document idiosyncratic features. In that same manner, this study adopts this method for this study in order to achieve the first objective, that is, to document some stylised facts. The use of this technique provides an avenue to examine three key statistical issues: First, is the measurement of volatility through the percentage standard deviation of a macroeconomic series; second, is the measurement of the co-movement between carbon emissions and output. This helps to identify whether emissions are either pro-cyclical, countercyclical or acyclical to output. Emissions is considered to be pro-cyclical if the cross correlation is positive, countercyclical if it is negative and acyclical if it is zero. Third, is for the determination of the phase shift, that is, whether carbon emissions is a leading or lagging indicator to output.

4.3. Methodology

The SVAR methodology was employed in order to examine how real shocks in the form of TFP affect carbon emissions in Nigeria. The SVAR methodology is used because of its capabilities to overcome the problem of "over-fitting" associated with the standard vector autoregressive (VAR) models. Furthermore, the SVAR approach has unique strengths such as: First, it is able to account for endogenous relationships and can summarise empirical relationships on the data being used without placing too many restrictions (Adebayo and Harold, 2016). Second, it provides the mechanisms to capture the behaviour of the data due to its ability and flexibility to accommodate various macroeconomic framework existing relationships (Raghavan and Silvapulle, 2006). Third, the categorisation of the contemporaneous relationship that exists among variables is based on economic theory. It can also isolate the response of each variable to structural shocks and policy innovations (Adebayo and Harold, 2016).

The model for this study can be specified in an implicit or functional form as:

$$RGDP_t = f(CO_{2t}, GFCF_t, TFP_t, CONS_t, GEX_t) \quad (1)$$

Where,
$RGDP_t$ is real gross domestic product at time t,
CO_{2t} is the total carbon emissions at time t,
$GFCF_t$ is the gross fixed capital formation at time t,
TFP_t is total factor productivity at time t,
$CONS_t$ is household consumption at time t,
GEX_t is government expenditure at time t.

Assuming a non-linear relationship exists between the dependent and independent variables, Equation (1) can be expressed in an explicit form as:

$$RGDP_t = A.CO_{2t}^{\alpha 1}.\ \mathrm{GFCF}_t^{\alpha 2}.\ TFP_t^{\alpha 3}.\ CONS_t^{\alpha 4}.\ GEX_t^{\alpha 5}.e_t \quad (2)$$

Equation (2) can be linearised by taking the double log of the equation so as to carry out the several estimation tests:

$$lrgdp_t = \alpha_0 + \alpha_1 lco_{2t} + \alpha_2 lgfcf_t + \alpha_3 ltfp_t + \alpha_4 lcons_t + \alpha_5 lgex_t + e_t \quad (3)$$

Following the structural form of the Nigerian economy as represented by Alege and Okodua (2014):

$$Dx_t = \alpha_0 + B(L)x_{t-i} + V\varepsilon_t \quad (4)$$

Where,

x_t is a vector of endogenous variables,
x_{t-i} is a vector of the lagged values of endogenous variables,
ε_t is a vector of random error of disturbance terms for every variable that captures exogenous factors in the model,
$B(L)$ is a matrix polynomial in the lag operator L of length p,

D represents a matrix of $n \times n$ dimension, n represents the amount of variables containing the structural parameters of the contemporaneous endogenous variables, and V is a column vector of dimension $n \times 1$, which contains the contemporaneous response of the variables to the innovations or shocks.

According to Alege and Okodua (2014), in order to estimate the SVAR model, the following steps are taken: The first step is to estimate the standard VAR in its reduced form as the coefficients in the matrices of equation (4) are unknown. This is done by multiplying both sides of the equation by the inverse of matrix D. This is represented as:

$$x_t = D^{-1}\alpha_0 + D^{-1}B(L)x_{t-i} + A^{-1}V\varepsilon_t \quad (5)$$

This can be simply represented as:

$$x_t = \gamma_0 + G(L)\, x_{t-i} + e_t \quad (6)$$

Where $\gamma_0 = D^{-1}\alpha_0$; $G(L) = D^{-1}B(L)$ and $e_t = A^{-1}V\varepsilon_t$

The purpose is to recover the underlying structural disturbances from the estimated VAR. Hence, we can estimate the random stochastic residual $D^{-1}V\varepsilon_t$ from the residual e_t of the estimated unrestricted VAR:

$$D^{-1}V\varepsilon_t = e_t \quad (7)$$

Reformulating (7), we have $D^{-1}V\varepsilon_t\varepsilon_t'V'D^{-1\prime} = e_te_t'$ and since $e_te_t' = I$ we have:

$$D^{-1}VV'D^{-1\prime} = e_te_t' \quad (8)$$

The second step is to identify the structural model from the estimated VAR. This is done by imposing restrictions on the structural model. For the purpose of this study, the non-recursive method of imposing restrictions in SVAR models is adopted using economic theory as the basic foundation. If there are n variables, equation (6) requires the imposition of $n(n+1)/2$ restrictions on the $2n^2$ unknown elements in D and V. Therefore, additional $n(3n-1)/2$ restrictions are required to be imposed.

$$De_t = V\varepsilon_t \quad (9)$$

From equation (9), it shows that the disturbances or innovations in the reduced form e_t, are complicated mixtures of the underlying structural shocks, which are not easily interpretable except it is directly linked to the structural shocks. The e_t is the source of variation in the VAR analysis.

The third step of the SVAR analysis is to use innovation accounting to access the response of carbon emissions to TFP shock. It uses the forecast error e_t from the estimated reduced form VAR to obtain the impulse response functions (IRFs) and forecast error variance decomposition (FEVD), to examine the fractional effects of TFP shock. The IRF show the response of each variable in the system to shocks from the system variables. This is, therefore, helpful in achieving the main objective of the study. The FEVD, on the other hand, provides information on the proportion of movements in a sequence due to its own shocks versus shocks to the other variables (Enders, 2010).

Equation (4) is called a structural VAR as it is assumed to be determined by some underlying economic theory. Thus the structural model of this study is described by the following dynamic system of simultaneous equations (10-15):

$$lrgdp_t = a_{10} - b_{12}lco_{2t} - b_{13}lgfcf_t - b_{14}ltfp_t - b_{15}lcons_t - b_{16}lgex_t + \sum_{j=1}^{p} a_{11}^{ij}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lrgdp_{t-j} + \varepsilon_t^{lrgdp} \quad (10)$$

$$lco_{2t} = a_{10} - b_{12}lrgdp_t - b_{13}lgfcf_t - b_{14}ltfp_t - b_{15}lcons_t - b_{16}lgex_t + \sum_{j=1}^{p} a_{11}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lco_{2t-j} + \varepsilon_t^{lco_2} \quad (11)$$

$$lgfcf_t = a_{10} - b_{12}lco_{2t} - b_{13}lrgdp_t - b_{14}ltfp_t - b_{15}lcons_t - b_{16}lgex_t + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lgfcf_{t-j} + \varepsilon_t^{lgfcf} \quad (12)$$

$$ltfp_t = a_{10} - b_{12}lco_{2t} - b_{13}lgfcf_t - b_{14}lrgdp_t - b_{15}lcons_t - b_{16}lgex_t + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}ltfp_{t-j} + \varepsilon_t^{ltfp} \quad (13)$$

$$lcons_t = a_{10} - b_{12}lco_{2t} - b_{13}lgfcf_t - b_{14}ltfp_t - b_{15}lrgdp_t - b_{16}lgex_t + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{15}^{ij}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lcons_{t-j} + \varepsilon_t^{lcons} \quad (14)$$

$$lgex_t = a_{10} - b_{12}lco_{2t} - b_{13}lgfcf_t - b_{14}ltfp_t - b_{15}lcons_t - b_{16}lrgdp_t + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{ij}lrgdp_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lgex_{t-j} + \varepsilon_t^{lgex} \quad (15)$$

The endogenous variables are $lrgdp_t$, lco_{2t}, $lgfcf_t$, $ltfp_t$, $lcons_t$ and $lgex_t$, while the exogenous error terms are ε_t^{lrgdp}, ε_t^{lc02}, ε_t^{lgfcf}, ε_t^{ltfp}, ε_t^{lcons}, and ε_t^{lgexp}. The exogenous error terms can be otherwise known as the structural innovations and are assumed to be independently and identically distributed with zero mean and a constant variance (σ^2). The realisation of each structural innovation is known as capturing unexpected shocks to its dependent variable respectively, which themselves are uncorrelated with the other unexpected shocks (ε_t).

Equation 10-15 can be written in matrix form as follows:

$$\begin{bmatrix} 1 & b12 & b13 & b14 & b15 & b16 \\ b21 & 1 & b23 & b24 & b25 & b26 \\ b31 & b32 & 1 & b34 & b35 & b36 \\ b41 & b42 & b43 & 1 & b45 & b46 \\ b51 & b52 & b53 & b54 & 1 & b56 \\ b61 & b62 & b63 & b64 & b65 & 1 \end{bmatrix} \cdot \begin{bmatrix} lrgdp_t \\ lco_{2t} \\ \lg fcf_t \\ ltfp_t \\ lcons_t \\ \lg ex_t \end{bmatrix} = \begin{bmatrix} a10 \\ a20 \\ a30 \\ a40 \\ a50 \\ a60 \end{bmatrix} + \begin{bmatrix} a11 & a12 & a13 & a14 & a15 & a16 \\ a21 & a22 & a23 & a24 & a25 & a26 \\ a31 & a32 & a33 & a34 & a35 & a36 \\ a41 & a42 & a43 & a44 & a45 & a46 \\ a51 & a52 & a53 & a54 & a55 & a56 \\ a61 & a62 & a63 & a64 & a65 & a66 \end{bmatrix} \cdot \begin{bmatrix} lrgdp_{t-1} \\ lco_{2t-1} \\ \lg fcf_{t-1} \\ ltfp_{t-1} \\ lcons_{t-1} \\ \lg ex_{t-1} \end{bmatrix} + \begin{bmatrix} lrgdp_{t-1} \\ lco_{2t-1} \\ \lg fcf_{t-1} \\ ltfp_{t-1} \\ lcons_{t-1} \\ \lg ex_{t-1} \end{bmatrix} + c$$

Where, $j = 1, 2,\ldots, n$.

The reduced form of the VAR model in equation (6) is to be estimated first. This model does not have the instantaneous endogenous variables and is shown in equations (16-21) as follows:

$$lrgdp_t = a_{10} + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{i}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lrgdp_{t-j} + \varepsilon_t^{lrgdp} \quad (16)$$

$$lco_{2t} = a_{10} + \sum_{j=1}^{p} a_{11}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{ij}lco_{2t-j} + \varepsilon_t^{lco_2} \quad (17)$$

$$lgfcf_t = a_{10} + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{ij}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lgfcf_{t-j} + \varepsilon_t^{lgfcf} \quad (18)$$

$$ltfp_t = a_{10} + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}ltfp_{t-j} + \varepsilon_t^{ltfp} \quad (19)$$

$$lcons_t = a_{10} + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{j}lrgdp_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lcons_{t-j} + \varepsilon_t^{lcons} \quad (20)$$

$$lgex_t = a_{10} + \sum_{j=1}^{p} a_{11}^{j}lco_{2t-j} + \sum_{j=1}^{p} a_{12}^{j}lgfcf_{t-j} + \sum_{j=1}^{p} a_{13}^{j}ltfp_{t-j} + \sum_{j=1}^{p} a_{14}^{i}lcons_{t-j} + \sum_{j=1}^{p} a_{15}^{j}lgex_{t-j} + \sum_{j=1}^{p} a_{16}^{j}lgex_{t-j} + \varepsilon_t^{lgex} \quad (21)$$

Without imposing a number of restrictions, the parameters in the SVAR model (10-15) cannot be identified. These restrictions will allow for the contemporaneous interaction between carbon emissions and RBC shocks (TFP) in Nigeria.

To impose restrictions, we can use short run SVAR models where current values affect each other (contemporaneous effect), meaning such changes have no long lasting effect; or long run SVAR models where one variable has a long lasting effect in which case, such variable does not return to its initial level. For the short run model, restrictions have to be placed on the D and V matrix, where D matrix is the one for emphasis. The V matrix places restrictions on the error structure.

The resulting parameter restrictions for the short run SVAR model, therefore, becomes:

$$\begin{bmatrix} \varepsilon_t^{lrgdp} \\ \varepsilon_t^{lc02} \\ \varepsilon_t^{lgfcf} \\ \varepsilon_t^{ltfp} \\ \varepsilon_t^{lcons} \\ \varepsilon_t^{lgex} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a21 & 1 & 0 & 0 & 0 & 0 \\ a31 & a32 & 1 & 0 & 0 & 0 \\ a41 & a42 & a43 & 1 & 0 & 0 \\ a51 & a52 & a53 & a54 & 1 & 0 \\ a61 & a62 & a63 & a64 & a65 & 1 \end{bmatrix} \cdot \begin{bmatrix} \ell_t^{lrgdp} \\ \ell_t^{lc02} \\ \ell_t^{lgfcf} \\ \ell_t^{ltfp} \\ \ell_t^{lcons} \\ \ell_t^{lgex} \end{bmatrix} \quad (22)$$

5. DISCUSSION AND INTERPRETATION OF RESULTS

5.1. Some Stylised Facts

Table 1 presents the information used to document the key stylised facts between carbon emissions of RGDP and the main sectors contributing to carbon emissions towards the achievement of the first objective through the use of the HP filter technique.

5.1.1. Carbon emissions are much more volatile than output in Nigeria

The volatility as measured by the percentage standard deviation in Table 1 shows that carbon emissions are much more volatile than output. Specifically, it can be observed that the value of carbon emissions is 16.28% which is higher than that of RGDP (4.24%), AGDP (6.89%), IGDP (6.40%), and SGDP (3.14%).

5.1.2. Carbon emission are countercyclical, but pro-cyclical across some of the sectors of output in Nigeria

The information provided in Table 1 indicates that carbon emissions are countercyclical with total output (RGDP). This implies that carbon emissions tend to rise during periods of economic recession and fall during periods of economic expansion or growth. Although this finding is at variance with theoretical expectations, Doda (2014) obtained a similar finding for five African countries namely Cameroon, Ghana, Morocco, Niger, and Senegal. A major explanation for the result is that the Nigerian economy has continued to grow even during periods of annual decline in emissions. These can be observed from the respective growth rates of output and emissions. The Nigerian economy grew from 4.21% in 2012 to 5.49% in 2013 and by 2014; the economy had grown to about 6.22% (CBN, 2016). Carbon emissions during the same period declined from 2.94% in 2012 to −0.37% in 2013 and −1.89% in 2014 (Boden et al., 2017). Another explanation for this finding is changes in the source of energy. The development of renewable energy technologies such as solar energy has proven to be pivotal in the reduction of carbon emissions into the atmosphere.

However, while observing the relationship between emissions and the major sectors of total output (agriculture and industry). It can be seen that a pro-cyclical relationship exists between emissions and both the agricultural sector and industrial sector. This implies that the level of carbon emissions in the economy is mostly driven by the activities of the agricultural and industrial sector. Therefore, environmental policies concerning mitigating the effects of carbon emissions in Nigeria should be concentrated towards agriculture and industry.

Table 1: Contemporaneous correlation between emissions and GDP

Variables	Vol. (%)	Com. correlation	Decision	Phase shift
C02	16.28	-	-	-
RGDP	4.24	−0.14	Countercyclical	Lagging
AGDP	6.89	0.19	Pro-cyclical	Lagging
IGDP	6.40	0.05	Pro-cyclical	Lagging

Vol. represents the volatility of the cyclical component of the series, Com.: Correlation represents the contemporaneous correlation between RGDP and the variables. Source: Researchers' compilation using EViews 8.0. GDP: Gross domestic product

5.1.3. Carbon emissions is a lagging indicator in Nigeria

Table 1 also documents information concerning the phase shift. It indicates that carbon emissions are a lagging indicator to output in Nigeria. This means that fluctuations in carbon emissions happen after changes or fluctuations to output.

5.2. SVAR Stability Test

The results of the IRF and FVED are considered to be accurate only when the SVAR model is stable. The autoregressive (AR) roots table or graph is one way to assess the stability of a SVAR model. It presents information on the roots and modulus. If the modulus is less than one and lies inside the unit, then the model is considered to be stable or stationary. However, in the case where there is a violation of this rule, then there will be the need to take the first difference.

The results of the AR roots table shows that the modulus is less than one indicating that the SVAR model specified is stable or stationary. Therefore, the results obtained from the both the IRF and FVED are valid. In addition, the model converges to a long-run equilibrium path (Table 2).

Table 2: AR roots table

Roots	Modulus
0.9973082	0.997308
0.8001475+0.2265437i	0.8316
0.8001475−0.2265437i	0.8316
0.6632059+0.4765712i	0.816677
0.6632059−0.4765712i	0.816677
−0.7159489	0.715949
−0.2611377+0.6409606i	0.692115
−0.2611377+0.6409606i	0.692115
0.684743	0.684743
0.3071989	0.307199
−0.1272487+0.1324297i	0.183657
−0.1272487+0.1324297i	0.183657

Source: Researchers' compilation using STATA 13. AR: Autoregressive

5.3. Lagrange-Multiplier (LM) Test

The LM test is conducted to check for the presence of autocorrelation in the residuals. From Table 3, it can be observed that the P > Chi-square is not statistically significant at 5% at lag 1 and 2 hence; we do not reject the null hypothesis of no autocorrelation. Therefore, we conclude that there is no autocorrelation in the residuals.

5.4. IRF

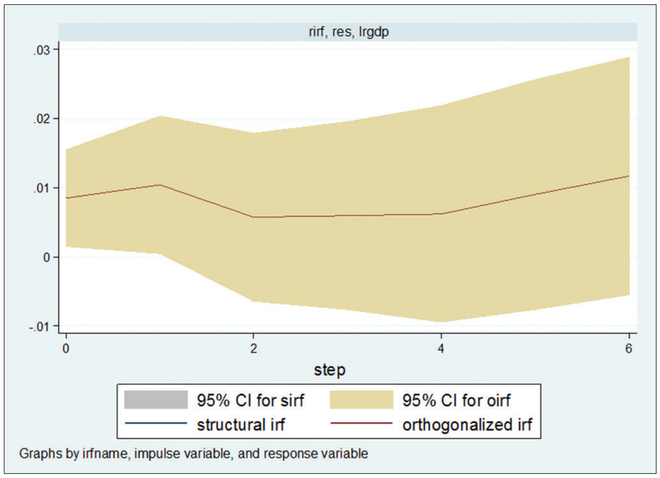
The IRFs measure the effects of a shock to an endogenous variable on itself or on another endogenous variable. The IRFs show the dynamics of responses of each variable in the model to structural one standard deviation shocks to other variables over

Table 3: LM test for autocorrelation

Lag	Chi-square	df	P>Chi-square
1	49.3138	36	0.06871
2	45.5517	36	0.13216

H_0: No autocorrelation at lag order. Source: Researchers' compilation using STATA 13. LM: Lagrange-Multiplier

Figure 1: Impulse response of carbon emissions to a productivity shock



Source: Researchers' compilation using STATA 13

time. However, given the area of interest of the study, only the impulse response of the carbon emissions to a productivity or real shock is discussed.

Figure 1 shows that a random productivity shock induces a generally positive effect on carbon emissions in Nigeria. This can be seen from the graph; the real shock causes emissions to increase before it gradually declines then picks up from the fourth period. The positive effect witnessed from the result draws attention to the pro-cyclical relationship witnessed between emissions and the two major sectors that drive carbon emissions: The agricultural and industrial sector.

6. CONCLUSION AND RECOMMENDATIONS

The study has been able to establish the relationship between carbon emissions and the business cycle, and also examining the effects of real shocks on emissions in Nigeria. The HP filter analysis revealed that there is a pro-cyclical relationship between emissions and two major sectors (agricultural and industrial) that emit the most emissions according to literature (EEA, 2014). However, examining the relationship with total output (RGDP) a countercyclical relationship was discovered, although surprising, Doda (2014) obtained similar results for five African countries. Furthermore, the paper was able to identify that real shocks generate a positive effect on carbon emissions, that is, it causes emissions to rise. This informs us that the positive effect witnessed can be traced to the activities of both the agricultural and industrial sector.

The study, therefore, recommends that environmental policies towards mitigating the effects and high levels of carbon emissions should be targeted towards the agricultural and industrial sector. This could be achieved through the imposition of emission intensity targets and emission caps in both sectors given that they are the major drivers of emissions in the Nigerian economy.

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