The Nexus between Industrial Production and CO_2 Emissions in Oil-Exporting Countries and the Role of Variations in Oil Revenue in the Volatility of the Emissions: Evidence from Nigeria

By

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Abstract

Oil-exporting countries, such as Nigeria, are striving to diversify their economies, hence they engage in several industrial activities that lead to some dimension of CO_2 emissions. However, while several studies have examined CO_2 emissions in such countries, surprisingly, the volatility of the emissions has been overlooked. The volatility of CO_2 emissions points to the fluctuations of the emissions, which generates uncertainty and makes controlling the emissions to be difficult. Oil-revenue variations are a potential channel of the volatility of CO_2 emissions in oil-exporting countries. Therefore, the objective of this paper is to contribute to filling the observed gap in the literature by examining the impact of industrial production on CO_2 emissions in oil-exporting countries, by evaluating the volatility of the emissions, and by investigating the role of oil-revenue variations in the volatility, drawing inferences from Nigeria. Based on data spanning 1990 to 2021, the paper employs the multiplicative heteroscedastic linear regression (MHLR) model for the analysis. The main findings are: (i) Relative to the production of other sectors, such as the agricultural sector, industrial production is the main source of CO_2 emissions in Nigeria. (ii) The emissions demonstrate a statistically significant level of volatility. (iii) The volatility is driven largely by the variations in the country's oil revenue. (iv) Oil stabilization fund reduces the volatility largely through the channel of oil revenue. These findings imply that fiscal policy instruments that are designed to control oil revenue variations in oil-exporting countries, such as oil stabilization funds and oil-price-based fiscal rules, can also be employed to control CO_2 emissions in the countries by using the instruments to restrain the emissions from fluctuating beyond desired levels.

Keywords: Industrial production, CO_2 emissions, oil revenue, stabilization funds, oil-exporting countries, Nigeria

Introduction

The emission of CO_2 is the key driver of climate change, which is a phenomenon that refers to unfavourable and long-term changes in the patterns of the climate (e.g. high temperature and extreme rainfalls), due to human activities. IPCC (2014) shows that climate change points to unfavourable, long-term, identifiable and measurable changes in the climate, in that the changes last for decades or longer and can be identified and measured through statistical procedures.

Industrial activities that involve generating electricity and heat from the burning of fossil fuels, such as coal and oil, are part of the human activities that cause climate change. Oil-exporting countries are striving to diversify their economies, hence they engage increasingly in several industrial activities, leading to the emissions of some dimension of greenhouse gases, which are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapour, etc. However, climate change is attributed largely to CO_2 emissions relative to the emissions of the other greenhouse gases. This is why the policy of low-carbon economy is required to mitigate the challenge of climate change (Krogstrup and Oman, 2019).

Moreover, while there are several studies (e.g. Kivyoro and Arminen, 2014; African Development Bank, 2019) on CO_2 emissions, surprisingly, the volatility of CO_2 emissions has been overlooked in the literature. Therefore, the objective of this paper is to contribute to filling this gap in the literature by examining the impact of industrial production on CO_2 emissions in oil-exporting countries, by evaluating the volatility of the emissions, and by investigating the role of oil-revenue variations in the volatility, drawing inferences from Nigeria.

Nigeria is chosen as the reference country because it is a large oil exporter whose economy is driven largely by the natural resource. The remaining part of the paper is structured as follows: The review of relevant literature is done in the section that follows the present section. Data and methodology are discussed in section three. Results are presented and discussed in section four. Section five concludes the paper.

Literature Review

Conceptually, the volatility of a variable points to swings or fluctuations in its value. Sometimes such swings may be autocorrelated over time, so that a high level of swings persists for a period of time and a low level of swings persists for a period of time as well, a phenomenon described as volatility clustering. Volatility can also manifest in form of an extreme, sudden and large change called shock (Ebrahim, Inderwildi and King, 2014).

Volatility is synonymous with the panic of economic agents. The financial markets are the markets with the largest level of such panic. Hence, several studies (e.g. Johnson and Young, 2002; Dai, Zhou, Wen and He, 2020) have examined financial volatility, documenting various patterns of volatility, as well as its effects. However, international trade flows (i.e. exports and imports) have been having an increasing level of volatility in recent years, making trade volatility to get more attention in the literature. Several studies (e.g. Nguyen, Pham and Vallée, 2020; Bennett, Lederman, Pienknagura, and Rojas, 2016) have also examined trade volatility, documenting its drivers and its significant impacts.

Moreover, volatility is synonymous with uncertainty. Economic agents usually react to the uncertainty induced by volatility by delaying the execution of their decisions to consume, save, invest and produce (Jo, 2012). Such delay could impact negatively on sectoral output and overall economic performance in a country. In particular, the volatility of CO_2 emissions can have negative impacts on the economy via two key channels: (i) The uncertainty created by the volatility of CO_2 emissions can affect the expectations of economic agents regarding climate change. (ii) The uncertainty can also make the policies designed to achieve the objective of low-carbon economy to be ineffective.

At the theoretical side of the literature, the comparative advantage and factor endowment theories of trade show that a country that is endowed with natural resources, such as oil, will have comparative advantage over other countries that are not endowed with such resources (Ricardo, 1821; Heckscher, 1919; Ohlin, 1933). Ricardo's comparative advantage theory shows that comparative advantage makes nations to trade mutually and profitably. That is, comparative advantage makes countries to produce at relatively low costs. However, the joint theory of Heckscher and Ohlin, called the Heckscher-Ohlin (H-O) theory, gives further explanation on comparative advantage by showing specifically that factor endowment is the basis of the advantage.

Although a country that is endowed with a natural resource, such as oil, derives comparative advantage from the resource, the volatility of the price of the resource usually brings unfavourable outcomes. In particular, the volatility of oil price is one of the attributes of oil that affect other economic variables in an oil-producing country. Theoretically, the volatility of oil is one of the causative channels of the resource curse in oil-producing countries (Sala-i-Martin and Subramanian, 2003). The volatility of oil price is usually transmitted into oil revenue. Consequently, other variables, such as government expenditure and sectoral output (e.g. industrial output) become volatile.

However, empirical studies show that stabilization funds are effective fiscal policy instruments for addressing the challenge of the volatility of resource price in resource-rich countries. Bagattini (2011), investigates the effectiveness of stabilization funds in ten developing resource-rich countries, namely Nigeria, Kazakhstan, Trinidad and Tobago, Algeria, Ecuador, Russia, Peru, Azerbaijan, Iran and Chad. The analysis involves separate investigation of the effectiveness of each country's fund, as well as a panel model that covers all the countries. Overall, the findings show that stabilization funds have significant contributions to the success of the fiscal policies of the ten countries.

Basically, in resource-rich developing economies, such as the ten countries, smoothening resource revenues through stabilization funds should be prioritized over developmental projects and intergenerational savings, in that the resources that will be employed for developmental projects and intergenerational savings come mainly from resource revenues (Dixon and Monk, 2011). Dixon and Monk also show that the objectives of building developmental projects and intergenerational savings cannot be achieved in a volatile macroeconomic environment. Furthermore, Ibironke (2018) studies the level of the effectiveness of Nigeria's oil stabilization fund and compares the fund with those of Norway and Mexico. The author finds that Nigeria's oil stabilization fund is an effective policy instrument whose effectiveness is comparable to the effectiveness of the funds of the other two countries.

Data and Methodology

Data

The data used by the paper were obtained from different sources. Information on the data is summarized in Table 1 below.

Table 1: The Data of the Study

Variable	Time Coverage	Data Source
Nigeria's CO_2 emissions per capita	1990- 2021	United Nations Development Programme database
GDP of Nigeria's industrial sector	1990- 2021	Central Bank of Nigeria Statistical Bulletin
GDP of Nigeria's agricultural sector	1990- 2021	Central Bank of Nigeria Statistical Bulletin
Nigeria's CPI inflation	1990- 2021	World Development Indicators
Nigeria's oil revenue	1990- 2021	Central Bank of Nigeria Statistical Bulletin
Nigeria's oil stabilization fund dummy	1990- 2021	Dummy variable constructed by the author

Note: Following Sugawara (2014), IMF (2009) and IMF (2015), Nigeria's oil stabilization fund was introduced in 2004, with an oil-price-based fiscal rule introduced in the same year to work with the stabilization fund. Hence, the stabilization fund dummy takes value 1 from 2004 and zero otherwise.

Methodology

The analysis starts with unit root tests, conducted to determine the stationarity properties of the considered variables, using the augmented Dickey-Fuller (ADF) and Dickey-Fuller generalized least-squares (DF-GLS) techniques. However, unit root tests are not conducted on the oil stabilization fund dummy because its values are 0 and 1 only. After the unit root tests, a correlation analysis of the nexus between CO_2 emissions and industrial production is undertaken. Finally, the main model of the paper, the multiplicative heteroscedastic linear regression (MHLR) model, is estimated to study the impact of industrial production on CO_2 emissions and the impact of the variability of oil revenue on the volatility of the emissions.

Basically, heteroscedasticity occurs in a regression when the variance of the error term of the regression is not constant over time. Hence, the MHLR model is based on the assumption that the variance of the error term of a linear regression model is not constant because the variance is a multiplicative function of one or more variables. Therefore, the MHLR model has two equations: (i) the mean equation in which a dependent variable is regressed against independent variable(s); and (ii) the variance equation in which the variance of the error term of the mean equation is expressed as a multiplicative function of one or more independent variables. This means that the variance is an exponential function of the independent variables of the variance equation.

The MHLR model of this paper is of the form

$$y_t = \boldsymbol{x_{it}}\boldsymbol{\omega} + u_t \qquad (1)$$

$$\sigma_i^2 = \exp(\boldsymbol{z_{it}}\boldsymbol{\beta}) \qquad (2)$$

where, in equation (1) which is the mean equation, y_t is the dependent variable, which is CO_2 emissions per capita; $\boldsymbol{x_{it}}$ = $(x_{1t}, x_{2t}, x_{3t}, \dots, x_{kt})$ are k independent variables of the mean equation, which are the GDP of the industrial sector, the GDP of the agricultural sector and CPI inflation; $\boldsymbol{z_{it}} = (z_{1t}, z_{2t}, z_{3t}, \dots, z_{mt})$ are m independent variables of the variance equation, which are oil revenue, oil stabilization fund dummy and the multiplicative interaction of oil revenue and the stabilization fund dummy; $\boldsymbol{\omega}$ are the parameters of the mean equation; $\boldsymbol{\beta}$ are the parameters of the variance equation; while u_t represents serially uncorrelated errors.

There are important facts about the variance equation and oil-revenue variability in the analysis:

(i) Following the results of unit root tests, the first-difference form of oil revenue is used as the proxy for the variability of the variable.

(ii) The MHLR model is first estimated with the first-difference form of oil revenue treated as the only independent variable of the variance equation, before the oil stabilization fund dummy and the multiplicative interaction of the first-difference form of oil revenue with the dummy are included as additional independent variables in the variance equation as a sensitivity test.

The null hypotheses tested are:

(i) Industrial production does not have a statistically significant impact on CO_2 emissions in Nigeria.

(ii) The volatility of CO_2 emissions is not statistically significant in Nigeria.

(iii) The variability of oil revenue does not play any role in the volatility of CO_2 emissions in Nigeria.

(iv) Oil stabilization fund does not have a statistically significant impact on CO_2 emissions in Nigeria.

Results

Unit Root Tests Results

The results of the unit root tests are presented in Table 2 below:

Table 2: Unit Root Tests

Variable	ADF Test Stat.	5% Critical Value	Decision	DF-GLS Test Stat.	5% Critical Value	Decision
lcodxd	−1.083	−1.950	NS	−2.029	−3.360	NS
D(lcodxd)	−4.376	−1.950	I(1)	−4.368	−3.373	I(1)
lindgdp	−1.847	−1.703	NS	−1.978	−3.360	NS
D(lindgdp)	−4.327	−1.706	I(1)	−5.311	−3.373	I(1)
lagricgdp	−2.837	−3.580	NS	−1.037	−3.360	NS
D(lagricgdp)	−4.100	−3.584	I(1)	−5.221	−3.373	I(1)
inf	−1.564	−1.950	NS	−2.550	−3.296	NS
D(inf)	−4.298	−1.950	I(1)	−5.257	−3.305	I(1)
loilrev	−1.359	−3.580	NS	−1.223	−3.360	NS
D(loilrev)	−5.785	−3.584	I(1)	−5.407	−3.373	I(1)

Note: lcodxd, lindgdp, lagricgdp, inf, and loilrev stand for the natural log of CO_2 emissions per capita, the natural log of the GDP of the industrial sector, the natural log of the GDP of the agricultural sector, CPI inflation, and the natural log of oil revenue respectively; "D" is the first-difference operator, "NS" points to "not stationary," while ADF and DF-GLS stand for augmented Dickey-Fuller and Dickey-Fuller generalized least-squares techniques respectively.

As shown in Table 2, all the variables considered in the study are integrated of order one (i.e. I(1)), in that they become stationary after they are differenced once. In this line, the variables are modelled as I(1) variables in the MHLR model. The variables are also treated as I(1) variables in the correlation analysis undertaken before the estimation of the MHLR model.

Correlation Analysis of the Nexus between Industrial Production and CO_2 Emissions in Nigeria

A correlation analysis of the nexus between industrial production and CO_2 emission in Nigeria is undertaken under this section, in order to study the nature of the association between the two variables. The analysis involves calculating and discussing simple, partial and semi-partial correlations between the two variables. Furthermore, correlations between agricultural output and CO_2 emission are also studied for a comparative purpose. The calculated correlations are presented in Table 3 and 4.

Table 3: Simple Correlations among CO_2 Emissions, Industrial Production and Agricultural Production in Nigeria

	D(codxd)	D(indgdp)	D(agricgdp)
D(codxd)	1.0000		
D(indgdp)	0.1861	1.0000	
D(agricgdp)	− 0.1421	0.6709	1.0000

Note: codxd, indgdp and agricgdp stand for CO_2 emissions per capita, the GDP of the industrial sector and the GDP of the agricultural sector respectively; while "D" is the first-difference operator.

As shown in Table 3, there is positive correlation of about 19% between the first differences of CO_2 emissions per capita and the first differences of industrial production in Nigeria. This means that there is a positive correlation between the annual changes of the variables. On the other hand, there is a negative correlation of about 14% between the first differences of CO_2 emissions per capita and agricultural production in Nigeria. These correlations imply that while changes in CO_2 emissions per capita and industrial production move in the same direction, changes in CO_2 emissions per capita and agricultural production do not. Therefore, it is necessary to employ the partial correlations of Table 4 for further study of the relationships among the variables under consideration.

As Table 4 shows, there are partial positive and negative correlations between CO_2 emissions per capita and industrial production and between CO_2 emissions per capita and agricultural production respectively, which are consistent with the signs of the simple correlations of Table 3. Therefore, it seems that while increases in industrial production makes CO_2 emissions per capita to increase at an increasing rate, increases in agricultural production makes CO_2 emissions per capita to increase at a decreasing rate.

Table 4: Partial Correlations among CO_2 Emissions, Industrial Production and Agricultural Production in Nigeria

	Partial correlation of D(codxd) with				
Variable	Partial corr.	Semipartial corr.	Partial corr^2	Semipartial corr.^2	Significance value
D(indgdp)	0.3834	0.3795	0.1470	0.1440	0.0365
D(agricgdp)	− 0.3664	− 0.3600	0.1343	0.1296	0.0464

Note: codxd, indgdp and agricgdp stand for CO_2 emissions per capita, the GDP of the industrial sector and the GDP of the agricultural sector respectively; while "D" is the first-difference operator.

In Table 4, the partial correlation between CO_2 emissions per capita and industrial production points to the correlation between the two variables if agricultural production does not vary. The semipartial correlation between CO_2 emissions per capita and industrial production points to the correlation between the two variables if the effect of agricultural production is removed from industrial production but not from CO_2 emissions per capita. The partial correlation between CO_2 emissions per capita and agricultural production points to the correlation between the two variables if industrial production does not vary. The semipartial correlation between CO_2 emissions per capita and agricultural production points to the correlation between the two variables if the effect of industrial production is removed from agricultural production but not from CO_2 emissions per capita.

Furthermore, the squared partial correlation between CO_2 emissions per capita and industrial production points to the proportion of the variance in CO_2 emissions per capita not explained by agricultural production that is explained by industrial production. In the same way, the squared partial correlation between CO_2 emissions per capita and agricultural production points to the proportion of the variance in CO_2 emissions per capita not explained by industrial production that is explained by agricultural production. The squared semipartial correlation between CO_2 emissions per capita and industrial production points to the proportion of the variance in CO_2 emissions per capita explained by industrial production only. In the same way, the squared semi partial correlation between CO_2 emissions per capita and agricultural production points to the proportion of the variance in CO_2 emissions per capita that is explained by agricultural production only. As shown by the significance values of Table 4, all the estimated partial and semi partial correlations are statistically significant.

Results of Multiplicative Heteroscedastic Linear Regression Model

The results of the MHLR model are presented in Table 5 below. The results are for the baseline model and the extended model in which the oil stabilization fund dummy and the multiplicative interaction of oil revenue and the dummy are included as additional independent variables in the variance equation of the MHLR model.

Table 5: The Multiplicative Heteroscedastic Linear Regression Model

	Baseline Model: Model with the first-difference form (i.e. variability) of oil revenue as the only regressor of the variance equation		**Extended Model:** Model with the inclusion of oil stabilization fund dummy and the multiplicative interaction of the first-difference form of oil revenue and the dummy as additional regressors of the variance equation	
	Mean Equation		**Mean Equation**	
	Wald chi2 (3) = 7.47 Prob > chi2 = 0.0584		Wald chi2 (3) = 27.97 Prob > chi2 = 0.0000	
Dependent variable: D(lcodxd)	Coeff.	P-value	Coeff.	P-value
D(lindgdp)	0.3598612	0.011	0.6989069	0.000
D(lagricgdp)	− 0.2614121	0.029	− 0.8316533	0.000
D(inf)	− 0.0014857	0.517	0.0005409	0.846
Variance Equation			**Variance Equation**	
Dependent variable: variance of D(lcodxd)				
D(loilrev)	0.9752463	0.042	− 0.6304763	0.372

L.stabfnd			− 2.588907	0.000
L.[D(loilrev)*stabfnd]			− 1.973735	0.033
Cons	− 4.088258	0.000	− 2.629861	0.000
	Likelihood-ratio model test that the variance of D(lcodxd) = 0: chi 2 (1) = 3.75 Prob > chi 2 = 0.0527		Likelihood-ratio model test that the variance of D(lcodxd) = 0: chi 2 (3) = 12.87 Prob > chi 2 = 0.0049	

Note: lcodxd, lindgdp, lagricgdp, inf, loilrev and stabfnd stand for the natural log of CO_2 emissions per capita, the natural log of the GDP of the industrial sector, the natural log of the GDP of the agricultural sector, CPI inflation, the natural log of oil revenue, and oil stabilization fund dummy respectively; while "D" is the first-difference operator.

As Table 5 shows, the signs of the correlations of Tables 3 and 4 are maintained in the mean equations of the baseline and extended MHLR models. In the baseline MHLR model, industrial production has a statistically significant positive impact of 36% on CO_2 emissions per capita, while agricultural production has a statistically significant negative impact of 26%. In the extended MHLR model, industrial production has a statistically significant positive impact of 70% on CO_2 emissions per capita, while agricultural production has a statistically significant negative impact of 83%. Since the variables are in the first-difference form in the MHLR model, the observed impacts point to changes in CO_2 emissions per capita induced by changes in industrial production and agricultural production. This suggests that increases in industrial production make CO_2 emissions per capita to increase at an increasing rate in Nigeria, while increases in agricultural production make CO_2 emissions per capita to increase at a decreasing rate in the country.

The possible reason why increases in agricultural production make CO_2 emissions per capita to increase at a decreasing rate within the sample period of the study (1990-2021) is that the techniques of agricultural production have become more efficient in Nigeria in the period, hence the techniques do not lead to large agricultural emissions of CO_2, compared to earlier decades such as the 60s and 70s. However, it seems changes in consumer prices do not contribute significantly to CO_2 emissions per capita in Nigeria in the period of the study, in that CPI inflation does not have statistically significant impacts on the emissions in the baseline and extended MHLR models.

Furthermore, in the variance equation of the baseline MHLR model of Table 5, variability (i.e. first differences) of oil revenue has a statistically significant positive impact of 98% on the variance of CO_2 emissions per capita, implying that variability of oil revenue increases the volatility of CO_2 emissions per capita highly. In the baseline model, the likelihood-ratio model test of the null hypothesis that the variance (i.e. volatility) of CO_2

emissions per capita is zero is rejected, implying that the volatility of CO_2 emissions per capita is statistically significant.

However, when the baseline model is augmented through the inclusion of oil stabilization fund dummy and the multiplicative interaction of oil revenue with the dummy, the impact of the variability of oil revenue on the volatility of CO_2 emissions per capita becomes negative and statistically insignificant. Besides, the first lag of the oil stabilization fund dummy has a negative and statistically significant impact of 259% on the volatility of CO_2 emissions per capita, while the first lag of the multiplicative interaction of oil revenue with the dummy has a negative and statistically significant impact of 197%. This means that the oil stabilization fund reduces the volatility of CO_2 emissions per capita through the channel of oil revenue. In the augmented model, the likelihood-ratio model test of the null hypothesis that the variance (i.e. volatility) of CO_2 emissions per capita is zero is also rejected, implying that the volatility of CO_2 emissions per capita in the model is also statistically significant.

A key policy implication of the findings is that fiscal policy instruments that are designed to control oil-revenue variability, such as oil stabilization funds and oil-price-based fiscal rules, can be tailored to control CO_2 emissions by using the instruments to restrain the emissions from fluctuating beyond desired levels. Krogstrup and Oman (2019) show in a review of the literature on the various macroeconomic and financial policies for mitigating climate change that fiscal policy instruments, such as government spending and investment, can be employed to control CO_2 emissions. This means that, in the context of oil-exporting countries, channeling the right amount of oil revenue to finance government spending in the industrial sector through the oil-revenue smoothening framework of oil stabilization funds can help control CO_2 emissions in the countries.

In line with the findings of the present paper, the hypotheses tested and the decisions made on them are presented in Table 6 below:

Table 6: Hypotheses of the Study and Decisions on Them

Hypothesis	**Decision**
Industrial production does not have a statistically significant impact on CO_2 emissions in Nigeria.	Hypothesis rejected
The volatility of CO_2 emissions is not statistically significant in Nigeria.	Hypothesis rejected
The variability of oil revenue does not play any role in the volatility of CO_2 emissions in Nigeria.	Hypothesis rejected

Oil stabilization fund does not have a statistically significant impact on CO_2 emissions in Nigeria.	Hypothesis rejected

Conclusions

This paper has reached five main conclusions. Firstly, changes in industrial production have a positive impact on changes in CO_2 emissions per capita in Nigeria, implying that the emissions increase at an increasing rate when industrial production increases in the country. Secondly, changes in agricultural production have a negative impact on changes in CO_2 emissions per capita in Nigeria, implying that the emissions increase at a decreasing rate when agricultural production increases in the country.

Thirdly, Nigeria's CO_2 emissions per capita demonstrates a statistically significant level of volatility, suggesting that the emissions tend to fluctuate over time. The fourth conclusion is that oil-revenue variability contributes significantly to the volatility of CO_2 emissions in Nigeria, implying that the variability of oil revenue feeds into other variables, particularly industrial production, that affect CO_2 emissions directly in the country. The fifth and final conclusion is that oil stabilization fund reduces the volatility of CO_2 emissions in Nigeria through the oil-revenue channel, albeit with a lag of time. The key policy implication of the findings for oil-exporting countries is that fiscal policy instruments that are designed to address the challenge of oil-revenue variations in the countries, such as oil stabilization funds and oil-price-based fiscal rules, can also be employed to control CO_2 emissions in the countries.

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