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Climate Change and Growth: A Regime Switching Approach

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Abstract: This study examines Nigeria-South Africa economic activities in the context of climate change. Globally, drivers of economic performance are largely sensitive to climate change. The effects of climate change are not limited to developed economies. The developing countries have also been perturbed by the rising costs of environmental degradation on the different sectors of the economy, especially, the overall output performance of the economy. We attempt to examine the level of output growth with varying intensities of climate change over the period 1990–2021 in Nigeria and South Africa. We develop a time-varying transition Switching model characterized by two regimes. Using the Regime Switching Approach, emissions have increasing effects on output growth. The results from the two-regime process showed the impacts of economic activities in Nigeria and South Africa affect CO_2 emissions differently. While changes in output production tend to contributes to CO_2 emissions more in Nigeria, the converse is the case for South Africa. Further, the transition probability of output affecting emissions occurs and stayed longer in the second regime in both countries. Based on the findings, switching to renewable energy is important for both countries to foster economic growth while mitigating the long-term effects of CO_2 emissions. Policy transmission mechanism needs be strengthen in Nigeria for policy effectiveness. If South Africa sustained the present drive towards renewable energy drive and policy articulation, mitigation efforts will be achieved rapidly. Finally, energy transition is paramount to the attainment of the 2030 agenda for sustainable development.

Keywords: Economic growth, Climate change, Nigerian, South Africa, Regimes.

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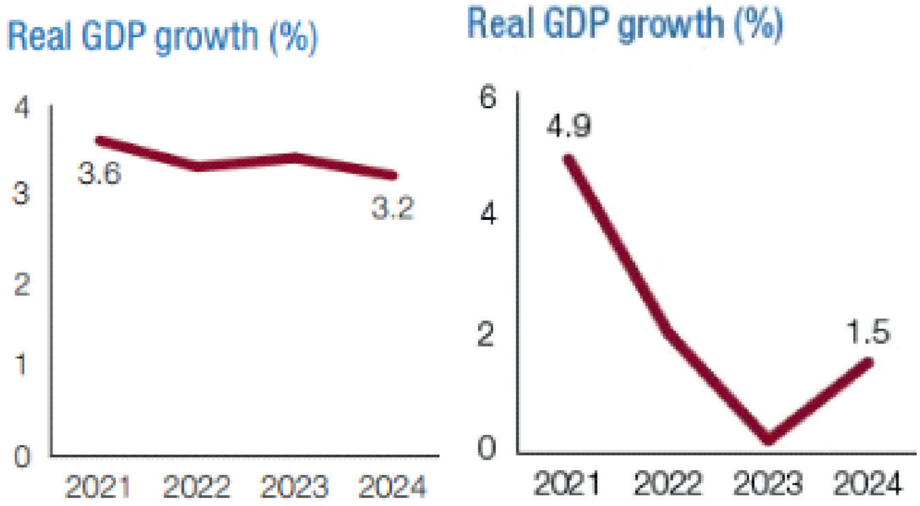
1. Background

Climate change is an evolving phenomenon and a source of uncertainty for the global economy stability (IMF, 2023). Increasing frequency and gravity of climate-related disasters is an impediment to economic development (Painter (2020). There are concerns and mixed reactions to climate change around the world. Arguably, associated with this development are the expanding economic activities. The Sustainable Development Goal 13 which is intrinsically connected with 2030 Agenda for Sustainable development focuses on combating climate change and its attendance effects. Since the greenhouse gas emission is rising, climate change is also occurring at rates much faster than expected. The debate in the literature is the fact that economic growth will be slowed down if emissions were to be reduced. Hence, the paradigm shifts from fossil fuel to renewable energy has been trail with different positions. The central question is if different levels of economic growth produce different level of emissions? This study attempts to characterize macroeconomic data as falling into different states or regimes. Consideration is given to changes in means; variances and model parameters transition at different levels of output.

Recent macroeconomic development shows that growth has slowed down in Africa region. According to the National Bureau of Statistics, Nigeria's economic growth in the second quarter of 2023 grew by 2.51 per cent year-on-year in real terms. Real GDP growth fell to 3.3 percent in 2022 from 3.6 percent in 2021. This decline was attributed to decline in oil production. In contrast, Real GDP growth in South Africa fell to 2.0 percent in 2022 from 4.9 percent in 2021, Occasioned mainly as a result electricity shortages, flooding and constraints in the transport sector (ADB, 2023).

The report by African Development bank shows that Nigeria's fiscal deficit was financed by borrowing; raising the public debt to $103.1 billion amounting to almost 22 percentage point of the GDP from $92.6 billion in 2021. Inflation peaked at 18.8 percent, majorly due to energy and food price rise and exchange rate depreciation. The unemployment rate remained high at 33.3 percent and multidimensional poverty rate, 63 percent. Real GDP growth will likely average 3.3 percent in 2023–24. For South Africa, on the other hand, unemployment average was an estimated 32.7 percent as at December 2022. Poverty also remains high in 2022, with an estimation of 30 percent of the population living in extreme poverty. In terms of economy projection, growth will be marginal, by 0.2 percent in 2023 and 1.5 percent through 2024.

On climate change and policy drive, between 2019 and 2020, average climate finance in Nigeria amounted to only $1.9 billion. The breakdown shows that $1.5 billion was from the public and $435 million from private sources. Nigeria needs $247 billion in climate finance through 2030. This indicates the investment needed in clean energy, especially in solar energy. South Africa, however, has embraced the private sector driven policy in its efforts to tackle climate change. South Africa was recipient



Source: African Economic Outlook (AEO), 2023. African Development Bank.

of private climate finance in Africa of $656 million in 2019/20. However, this is still limited when compared with climate finance challenges. Efforts have equally been geared towards promoting renewable and clean energy (ADB, 2023).

The concern of some persons in the society is majorly on how to improve their standard of living without any consideration over environmental protection. Arguably, economic measure of GDP growth that ignores the damages embedded in economic activities is the reason for the current backlog of environmental degradation. Not accounting for environmental pollutions over the centuries, except in the recent decades has huge impact for the present and future sustainable growth path.

Therefore, the ongoing concern is on how to sustain economic growth while mitigating the effects of climate change. While some suggest that growth is not bounded by environmental changes, others posit strongly that climate changes could limit economic growth. Reducing production activities with a bid to curtail environmental degradation could be counterproductive. Considering the different perspective, it is important to know that increasing income is necessary in adopt cleaner energy in the long run. Key sectors driving economic performance such as agriculture, energy, coastal and water resources and tourism in Sub-Saharan Africa region are largely vulnerable to climate change (Abidoyea and Odusolab (2015).

The effects of climate change include floods and drought, rising sea level, changing and unstable weather pattern. This has a lot of enormous negative implications on the economy. The inability to stay within the Paris climate goal of 2°C and 2.6°C in global temperature could be worrisome (Swiss RE, 2021).

The general consensus is the fact that renewable energy is a veritable energy source that is worth exploring. Although, the extent to which this new exploration will reduce emission is still a subject of debate in some quarters. This energy transition is at the heart of combating climate change and attaining net-zero by 2050. This is the reason for the gradual shift from fossil-fuels to renewable sources of energy with the goal of reducing emissions.

To achieve this objective of emission reduction, it calls for huge investment in new technologies, especially in power generation, storage and distribution, as well as carbon capture and storage (IRENA, 2023a). Recent trends in investment in the energy sector show a steady rise. Since after the COVID-19 pandemic, clean energy investment has continued to rise. It is expected to account for about two-thirds of the world total energy investment, exceeding $1.7 trillion in 2023 (see Figure 1). The factors fostering this development include enhanced policy support, alignment of energy supply and climate change goals as well as volatile crude oil prices (IEA, 2023a).

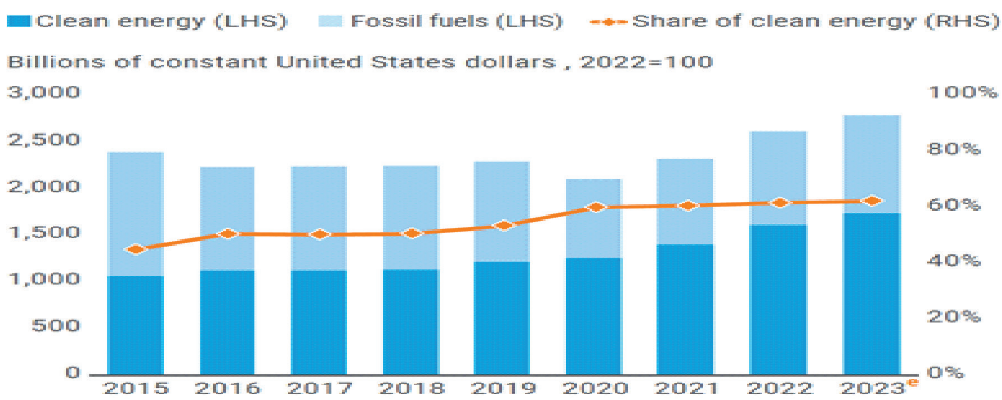


Figure 1: World total energy investment by source. Source: UN DESA, based on World Energy Investment 2023 (IEA, 2023a). Note: Left –hand-scale (LHS). Right-hand-scale (RHS), e = estimates for 2023.

However, the gap in renewable energy investment varies from countries to countries. The overall increase in energy investment is concentrated in few countries. Global investment in renewable power generation has doubled from $331 billion in 2015 to $658 billion in 2023. China, however, is at the heart of this increase, accounting for 41 per cent of global investment in renewable energy in 2023, while the rest of the developing countries account for only 17 per cent (see Figure 2).

This Main objective of this study was to employ a two-regime approach to identify hidden regimes changes with GDP growth rate on emissions. The paper is organised into five sections. Following this introduction is Section 2 that provides a brief insight

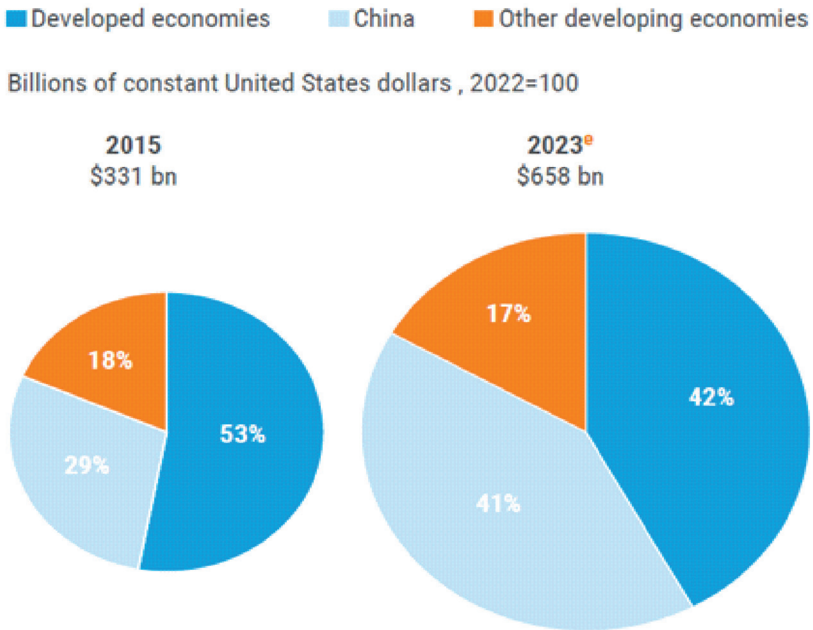


Figure 2: Global investment in renewable energy by economies in 2015 and 2023. Source: UN DESA, based on World Energy Investment 2023 (IEA, 2023a). Note: e = estimates for 2023.

on the extant literature with focus on the direct and indirect impacts of climate change on economic growth. Section 3 presents the model and how the parameters of interest are estimated while in Section 4, we present and discussed the key findings. Section 5 concludes with policy implication and recommendations.

2. Brief Review of the Literature

This brief review of the extant literature focuses on two major strands. First, is the direct effects of climate change and shocks on economic growth and secondly, the indirect effects via financial instruments and prices. Abidoyea and Odusolab (2015) provide the empirical linkages between climate change and economic growth in Africa using yearly data for 34 countries between 1961 and 2009. The study found out that climate change negatively affects economic growth. A 1°C rise in temperature reduces gross domestic product (GDP) growth by 0.67 percent. More specifically the study shows that in the Sub-Saharan Africa, Nigeria and South Africa has a significant role to play in minimizing the negative economic impact arising from climate change.

Burke *et al.* (2015) study support the fact that rising temperatures contributes significantly to reduction in economic growth in developing countries and hot climate regions. This was also corroborated by Kahn *et al.* (2021). Akyapi, Bellon, and Massetti (2022) found that climate change affects economic growth in the long-run even though it is not uniform across countries In a related study Cevik and Jalles (2023) shows that increasing climate variation can be associated with rising income inequality, particularly in emerging and developing countries and economies which lack adequate mitigating capacity against climate change. IMF (2023) affirms that economic growth in developing countries is affected by climate change. On average, a 1°C rise in temperature as a result of climate change reduces economic growth by 1.3 percent.

The indirect effects of climate change can also be observed from its attendance effects on debts and inflation. Cevik and Jalles (2022; 2023) show that climate change has significant effects on government bond, especially in developing countries. Similarly, Bansal *et al* 2016; Bernstein *et al*., 2019 and IMF, 2020, found that risks associated with climate change are its negative effect on asset valuations.

In addition and relatedly, Faccia *et al*. (2021) investigate the effects of temperatures on measures of inflation in forty-eight advanced and emerging countries from 1951 to 1980. The study shows that increasing temperatures drives price up, particularly for emerging market economies. However, Kabundi *et al*. (2022) found that the impact of climate change on consumer prices depends on the intensity of climate shocks, monetary policy regime and income level.

IMF (2023) examines the impact of climate change on inflation and growth dynamics. The results shows that both inflation and real GDP growth respond significantly to climate change but differently in relation to its impacts on the economy.

The debate in the literature is on-going since there is no consensus on the extent and nexus between climate change and macroeconomic variables. One of the areas which have received little attention is the role of regime change on output and its influences climate change. This is the gap that the present study tends to fill with focus on Africa two economies with large GDP growth rate—Nigeria and South Africa.

3. Data/Methodology

This section focuses on the dataset and the methodological approach. The behaviors of economic time series are characterized differently in periods of economic expansion and economic recession. Data employed in this study are the GDP growth rate of both Nigeria and South African as large economies in the region. We focus on how GDP at varied times influences emissions. Hence, the CO2 data in kt (energy) were also collated from the World Bank, 2022.

The Markov-switching model which assumes that unobserved states are determined by an underlying stochastic process was employed. Markov-switching model describes how data falls into unobserved regimes. A key feature of a Markov-chain is the transition probabilities. It does describe the likelihood that the present regime stays the same or varied with time. The limitation to this model however, in multivariate setting, is correlations between variables in which case, correlation may tend to skew the results.

The novel characteristic of the Markov switching model is the Markovian rule that the probability of moving to a particular state is dependent on the current state and not necessarily the sequence of the state that preceded it.

The simple approach to time series modelling is given in equation 1.

$$\begin{aligned} x_t &= \beta_1 x_{t-1} + \ldots + \beta_p x_{t-p} + \omega_t \\ &= \sum_{i=1}^{p} \beta_i x_{t-i} + \omega_t \end{aligned} \tag{1}$$

Following the work of Hamilton (1989), regime switching model, is a nonlinear time series models which involves multiple structures that can characterize the time series behaviours in different regimes or states. The mathematical probabilistic equation for Markov-switching model is presented in equation 2:

$$\Pr(\mathrm{Y}_{n+1} = y \,|\, Y_{1,} = y_{1,}\ \mathrm{Y}_2 = \mathrm{y}_{2\ldots,} \mathrm{Y}_n = \mathrm{y}_\mathrm{n}) = \Pr(\mathrm{Y}_{n+1} = \mathrm{y} \,|\, Y_{\mathrm{n},} = y_{\mathrm{n},}) \tag{2}$$

The Markov switching model focuses on the mean behaviour of variables. The estimated model consists of a two-state Markov switching model and the four non-switching AR terms, as well as with a single switching mean regressor C. We assumed that the error variance is common across the regimes. Therefore, the only probability regressor is the constant C since time-invariant regime transition probabilities is being considered.

The model is specified as shown in equation 3;

Regime Switching Model

$$x_t = \beta_0(1 - s_t) + \beta_1 S_t + \varepsilon_{t,} \varepsilon_t \sim \mathrm{N}(0, \sigma^2) \qquad \text{3a}$$

Transition Probabilities

$$\begin{aligned} \Pr(\mathrm{s}_t - 1 \,|\, s_{\mathrm{t}-1} = 1) = p \\ \Pr(\mathrm{s}_t - 0 \,|\, s_{\mathrm{t}-1} = 0) = q \end{aligned} \qquad \text{3b}$$

Steady state probability

$$E(s_t - 1 \mid s_{t-1} = 1) = p \qquad 3c$$

$$E(s_t = 0) = (1 - p) / (2 - p - q)$$

Expected duration

$$1/(1-p) \text{ or } 1/(1-q) \qquad 3d$$

Equation 3a to 3d shows the simple Markovian regime switching model specification. It helps to determine the probability that the current state belongs to either 1 or 0 since we interested in only two states and two possibilities. It is the probability of staying in the current stay or switching to another regime, in other words, moving from the current state--one *(p)* or zero *(q)* another regime. Here, the mean is shifting overtime with the two state regimes. We model CO2 emissions overtime with the GDP growth rate as the exogenous variable. When equation 3b is estimated, which is a random variable, equation 3c, indicate the computation of the expected values. It suggests the probability of the current state is one, unconditionally or probability of the next state as zero. It is required as part of the initialization of the problem. Expected duration indicates how long a variable remains in a state overtime.

4. Discussion of Results

The Regime switching approach was employed for this study. The result of the analysis is discussed in this section. Table 1 shoes the descriptive characteristics of the variables.

Table 1: Descriptive Statistics for Nigeria (NIG)and South Africa (SA)

	NIG_CO2	*NIG_GDPG*	*SA_CO2*	*SA__GDPG*
Mean	11.72	4.278	12.765	2.126
Median	11.49	4.212	12.847	2.542
Maximum	19.86	15.329	13.013	5.603
Minimum	11.19	-2.035	12.383	-6.342
Std. Dev.	1.44	3.898	0.216	2.460
Skewness	5.50	0.479	-0.528	-1.264
Kurtosis	31.53	3.495	1.745	5.399
Jarque-Bera	1324.583	1.648	3.812	17.223
Probability	0.0000	0.438	0.148	0.0001
Sum	398.48	145.464	434.022	72.2928
Sum Sq. Dev.	68.96	501.478	1.545	199.791
Observations	34	34	34	34

Note: NIG_CO2 = Nigeria's CO2 emissions. SA_CO2 = South Africa CO2 emissions. NIG_GDPG = GDP growth rate for Nigeria. SA__GDPG = GDP growth rate for South Africa.

The mean of CO_2 emissions is slightly higher than Nigeria with a meager different of 0.98 percent. The converse is the case in terms of GDP growth rate. The rate of economic growth on average over the period under consideration is 42.8 and 2.13 for Nigeria and South Africa respectively.

The result from the estimated Two Regime-Switching Model Estimates for both Nigeria and South Africa is presented in Table 2 and 3. The results shows that changes in output growth from one regime to another affects or leads to changes in CO_2 emissions differently. A negative effect is observed in the second regime where the economic states longer whenever there is a policy changes. This implies that increase in output production can be a possible rise in co2 emission rate in Nigeria. This could be as a result of increased dependency on the oil sector where there are huge emissions from fossil fuel consumption.

However, a different outcome was observed for South Africa. In both regimes, GDP growth rate does not necessarily lead to increase in CO_2 emissions. This result is surprising despite the fact that the country uses coal largely in electricity production. The coefficient estimates were largely the same for both regimes though not statistically significant in the first regime, but was statistically significant in the second regime.

Table 2: Two Regime-Switching Model Estimates—Nigeria

		Regime 1		
Variable	Coefficient	Std. Error	z-Statistic	Prob.
NIG_GDPG	0.475	39.566	0.012	0.990
C	17.925	157.128	0.114	0.909
		Regime 2		
NIG_GDPG	-0.004	0.005	-0.710	0.477
C	11.564	0.106	108.930	0.000
		Common		
AR(1)	0.844	0.231	3.644	0.000
AR(2)	-0.311	0.318	-0.977	0.328
AR(3)	0.254	0.272	0.934	0.350
AR(4)	0.008	0.207	0.039	0.968
LOG(SIGMA)	-2.646	0.162	-16.270	0.000

Note: Dependent Variable: SA_CO2. Method: Markov Switching Regression (BFGS / Marquardt steps). Sample (adjusted): 1994 2023. Included observations: 30 after adjustments. Number of states: 2. Initial probabilities obtained from ergodic solution. Standard errors & covariance computed using observed Hessian.

Table 3: Two Regime-Switching Model Estimates—South Africa

		Regime 1		
Variable	*Coefficient*	*Std. Error*	*z-Statistic*	*Prob.*
SA__GDPG	0.012	0.008	1.392	0.163
C	12.920	0.158	81.292	0.000
		Regime 2		
SA__GDPG	0.010	0.003	3.031	0.002
C	13.055	0.153	85.094	0.000
		Common		
AR(1)	1.040	0.238	4.368	0.000
AR(2)	-0.154	0.374	-0.412	0.679
AR(3)	-0.309	0.326	-0.948	0.342
AR(4)	0.342	0.203	1.689	0.091
LOG(SIGMA)	-3.517	0.163	-21.580	0.000

Note: Dependent Variable: SA_CO2. Method: Markov Switching Regression (BFGS / Marquardt steps). Sample (adjusted): 1994 2023. Included observations: 30 after adjustments. Number of states: 2. Initial probabilities obtained from ergodic solution. Standard errors & covariance computed using observed Hessian.

Essentially, of more interest is the transition probability. Table 3 shows the transition probability matrix and the expected durations for South Africa. There is considerable average state dependence in the transition probabilities for South Africa with a relatively average probability of remaining in the origin regime of 0.48 for the low output state, 0.93 for the high output state). The corresponding expected durations in a regime are approximately 1.9 and 14.8 years, respectively.

Table 3: Transition summary: Constant Markov transition probabilities and expected durations

From/to State	1	2
1	0.481	0.518
2	0.067	0.932
Constant expected durations:	1.930	14.805

Note: Constant transition probabilities: P(i, k) = P(s(t) = k | s(t-1) = i). (row = i / column = j).

When macroeconomic variables and policies changes it results in changes in economic outputs. The goal of this paper is to estimate the effects of regime changes. Determine how long a regime exists and what are the parameters estimates which is associated with each regime systems.

Markov-transition models estimates the means and variances which is associated with each regime. Table shows the estimated transition probabilities of changes in regimes for Nigeria and South Africa. The probability of transiting from state 1 to state 1 in Nigeria is 0.029. This low probability suggests that state 2 is not persistent. However, with the probability of 0.97, it transits to state 2 and once in state 2, it stays there. With the probability of 0.032, the processes revert from state 2 to state 1 in the following year. The process continues in the next period to state 2 with the probability of 0.97 in year 2. This suggests that impact policies or regulations has more impact not in the immediate year, but the preceding year and tends to stay longer before policy changes. This is primary will be due to time lags and policy somersault. There is considerable average state dependence in the transition probabilities for Nigeria with a relatively average probability of remaining in the origin regime of 0.02 for the low output state, 0.97 for the high output state. The corresponding expected durations in a regime for Nigeria are approximately 1.0 and 31.5 years.

Table 4: Nigeria-Transition summary: Constant Markov transition probabilities and expected durations

From/to State	*State 1*	*State 2*
State 1	0.029	0.970
State 2	0.031	0.968
Constant expected durations:	1.030	31.510

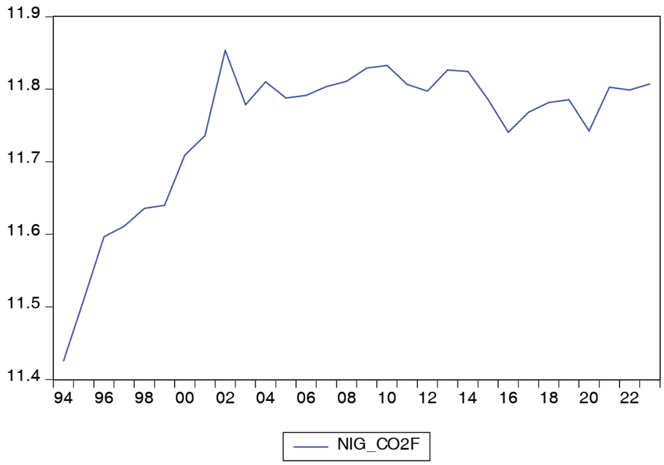
Note: Constant transition probabilities: P(i, k) = P(s(t) = k | s(t-1) = i). (row = i / column = j).

Finally, the display of the filtered and full sample estimates of the probabilities of being in the two regimes is presented in Figures 3 and 4 for Nigeria and South Africa respectively. The predicted regime probability of mean Absolute error of 0.51 suggests a gradual reduction in $CO2$ emissions but slowly for Nigeria. However, for South Africa, the predicted regime probability of mean Absolute error of 0.06 indicates a plateau rise over time, but minimal rise into the future.

5. Policy Implications and Conclusion

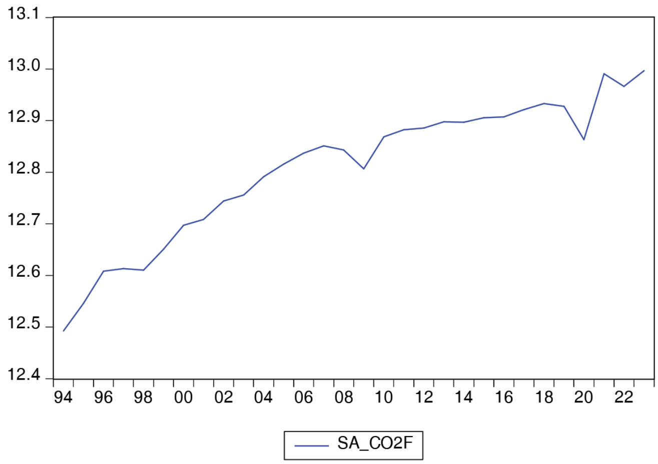
This paper employed a two-regime approach to identify hidden regimes in macroeconomic time series. The results from the two-regime process showed increased regime persistence under regime 2 classification.

The impacts of growth in economic activities in Nigeria and South Africa affect the $CO2$ emissions differently. While changes in output production tend to contributes more to $CO2$ emissions in Nigeria, the converse is the case for South Africa. Further,



Forecast: NIG_CO2F	
Actual: NIG_CO2	
Forecast sample: 1990 2023	
Adjusted sample: 1994 2023	
Included observations: 30	
Root Mean Squared Error	1.497964
Mean Absolute Error	0.512456
Mean Abs. Percent Error	3.480788
Theil Inequality Coefficient	0.063428
Bias Proportion	0.000279
Variance Proportion	0.883586
Covariance Proportion	0.116136
Theil U2 Coefficient	0.995040
Symmetric MAPE	3.795817

Figure 4: Nigeria CO2 Forecast with GDP growth



Forecast: SA_CO2F	
Actual: SA_CO2	
Forecast sample: 1990 2023	
Adjusted sample: 1994 2023	
Included observations: 30	
Root Mean Squared Error	0.080664
Mean Absolute Error	0.068703
Mean Abs. Percent Error	0.536091
Theil Inequality Coefficient	0.003148
Bias Proportion	0.006622
Variance Proportion	0.307758
Covariance Proportion	0.685620
Theil U2 Coefficient	1.322127
Symmetric MAPE	0.535907

Figure 5: South Africa CO2 Forecast with GDP growth

the transition probability of output effects on emissions and stayed longer in second regime in both countries, although the transition from one regime to another is faster in South African when compared to Nigeria. This is an indication of faster rate of policy effectiveness in the former than the later. The results also show that the impacts of emissions arising from output production is not in the immediate. There is usually a gap period before the effects is felt. The period is shorter in South Africa than Nigeria.

Based on the findings, two major recommendations are made. One, the switch to renewable energy is important for both countries in production activities to mitigate the long-term effects of CO2 emissions. Two, policy transmission mechanism needs be strengthen in Nigeria for policy effectiveness. If South Africa sustained the present drive towards renewable energy drive and policy articulation, mitigation efforts would likely be achieved quicker than other economies in Africa.

In conclusion, energy transition is paramount to the attainment of the 2030 agenda for sustainable development. Both Nigeria and South Africa intrinsically are pivotal in taking action to combat climate change and its impact on Africa continent.

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