International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

Maritime Sector Growth, Environmental Regulation and CO_2 Emission Nexus: Evidence from Nigeria

Obasi Catherine Chimma[1]
*AruweiPorwekobowei[2]
[12]Nigeria Maritime University, Okerenkoko, Delta State, Nigeria
*Corresponding Author: Aruwei Porwekobowei

Date of Submission: 05-02-2025 Date of Acceptance: 15-02-2025

Abstract
This study investigates maritime sector growth, environmental regulation and CO_2 emission nexus in Nigeria. The study used secondary time series data from 1990 to 2023 sourced from the Central Bank of Nigeria statistical bulletin and the World Development Indicator. The data for the study was analysed by Vector autoregression (VAR) model, after employing some preliminary data analysis such as descriptive statistics, ADF unit root test and cointegration test. Findings from the study showed that in the VAR model estimates the single most important determinant of each variable is its one-period lagged value. The Impulse Response Function result showed that there is a positive and stable relationship between the maritime sector growth and CO_2 emission both in the long run and short run. Environmental regulation have an asymmetric effect on CO_2 emission both in the long run and short run.The variance decomposition results showed that the predominant sources of CO_2 emission variation are largely due to its own shocks and maritime sector growth innovations. The study therefore recommends that the government should make stiffer and more enforceable environmental rules to reduce CO_2 emission from the maritime industry, lower emissions by supporting the maritime industry's adoption of sustainable practices and greener technology like alternative fuels and energy-efficient ships, create policies to strike a balance between environmental sustainability and the expansion of the maritime industry so as to prevent disproportionate rise of CO_2 emission.

Keywords: Maritime Sector Growth, Environmental Regulation, CO_2 Emission, VAR, Cointegration

I. Introduction

The rise in commercial activities and business demand have made seaborne trade experience an amazing growth to provide about 80% of world goods in 2019. It increased from 7,857 million tonnes (Mt) in 2009 to 11,005 Mt in 2018, the laden volume of international marine traffic has therefore seen ten years of continuous increase until the COVID-19 epidemic struck (UNCTAD, 2020). Developing economics especially show this predominance (UNCTAD, 2020). The COVID-19 epidemic caused about 4% decline in international seaborne trade in 2020; yet, as the world economy started to recover in 2021, the upward trajectory returned (UNCTAD, 2022). In return for amazing volume growths, the environmental effects of intense maritime transportation started to be underlined, particularly the climate effects from exhaust Greenhouse Gases (GHG) (IMO, 2021; Ytreberg et al., 2021).

Although marine transport is among the most effective means of transport for goods, in 2018 it produced 1,076 Mt of GHG emissions, of which 1,056 Mt were CO_2 emissions, therefore making around 3% of all anthropogenic CO_2 emissions. But by 2025, the rate is expected to grow to 17%, suggesting that, absent intervention, worldwide shipping CO_2 emissions are trending in the other direction (ISEMAR, 2020). This is so since oil accounted for more than 99% of overall energy needs historically (IEA, 2023), so the maritime sector is more fossilised than other sectors. From 977 million tonnes in 2012 to 1076 million tonnes in 2018, the fourth IMO GHG research indicated that the overall marine GHG emissions, both domestic and international, comprising CO_2, CH_4 and N_2O, expressed in CO_2 equivalent emissions (CO_2e) have increased by 9.6%. Of these around 98% are CO_2 emissions (IMO, 2020).

In Nigeria for instance, the land use change and forestry, Energy, waste, agricultural, and industrial operations sector contributed 38.2%, 32.6%, 14.0, 13.0% and 2.1% correspondingly to GHG emissions in Nigeria (IEA, 2023). Burning coal, oil, and natural gas among other fuels drives the great majority of CO2 emissions in the energy industry. This constant implies that trade and movement of products and services in the maritime sector adds to CO_2 emissions. Moreover, 80% of Nigerian carbon emissions directly result from burning fossil fuels (Ogundipe, Okwara and Ogundipe, 2020). Given Nigeria's reliance on ports and shipping for trade, oil exports and importation of goods, the maritime industry is a vital part of its economy (Aruwei and Eko-Raphaels, 2022). More so, with Nigeria been the fourth biggest economy and significant involvement in world trade, the maritime industry is of great importance (Bloomberg, 2024). Industrial activity includes shipping aggravates the major environmental issues the nation faces: air pollution, oil spills, and deforestation (IEA, 2023). This study looks at how environmental rules, CO_2 emissions, and Nigeria's maritime industry growth interact. It emphasises the economic value of the industry, its environmental effect, and the part laws help to reduce emissions. Complementing worldwide SDGs and Nigeria's development objectives, the results provide policy insights for juggling economic growth with sustainability. Furthermore used in the study are sophisticated econometric methods vector autoregression (VAR) models to examine the relationship among CO_2 emissions, environmental policies, and maritime sector growth. Thus, offering a strong methodological approach with ideas that may be repeated in many situations. The study offers localised data that might guide national plans for environmentally friendly maritime growth.

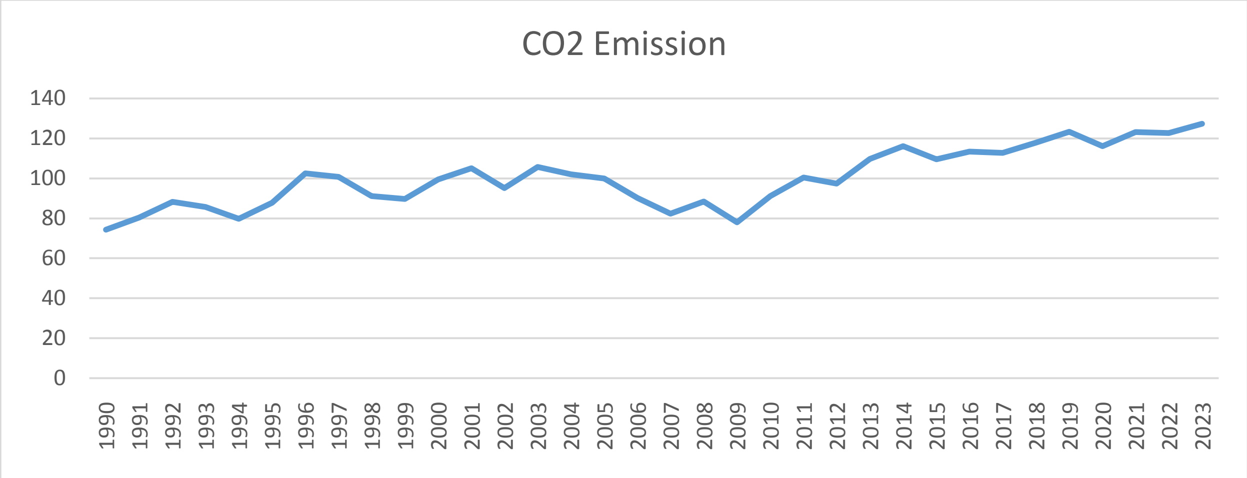
It is therefore imperative to investigate what this mean for a developing country like Nigeria that is trying to diversify its economy by exploring the blue economy? It is therefore important to examine the link between maritime Sector Growth, environmental regulation and CO_2 Emission from Nigeria.The rest of the study is structured as follows; the second section focus on the literature review, the third section addresses the estimation methodologies. The fourth section is concerned with the results and discussion of the findings and the final section presents the conclusion.

CO_2 Emission:

Mostly byproducts of energy generation and consumption, carbon dioxide emissions contribute the most of the greenhouse gases linked to global warming. Main causes of anthropogenic carbon dioxide emissions are cement production and burning of fossil fuels. For the same level of energy consumption, different fossil fuels emit different amounts of carbon dioxide; coal releases almost twice as much as natural gas and oil releases roughly 50 percent more (WDI, 2025). The average emission rate of a particular pollutant from a given source expressed relative to the intensity of a given activity is known as emission intensity. Comparatively evaluating the environmental impact of various fuels or activities also relies on emission intensities (WDI, 2025). Often used instead are the related words emission factor and carbon intensity. A nation's carbon dioxide emissions tell only one greenhouse gas story. Gases like methane and nitrous oxide should be considered if one wants a more whole picture of how a nation shapes climate change. In agricultural economy especially, this is quite vital. Carbon dioxide's environmental consequences pique great attention. Comprising the most of the greenhouse gases causing global warming and climate change, carbon dioxide (CO2) By means of carbon dioxide (or CO2) equivalents, all other greenhouse gases (methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) could be compared and their individual and total contributions to global warming (WDI, 2025) could be ascertain.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

Figure 1: CO2 Emission

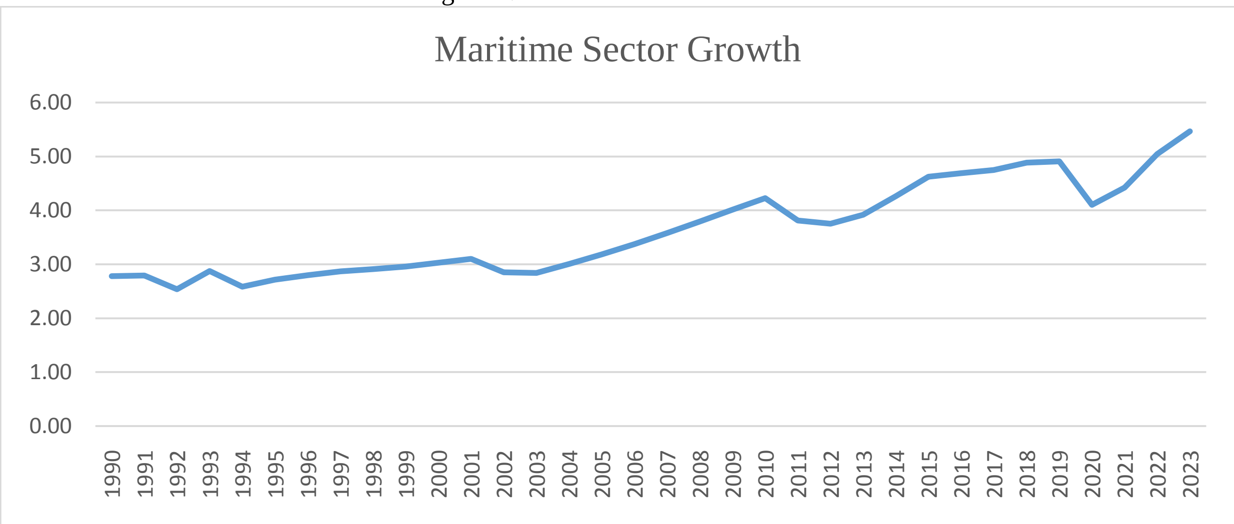


Source: Data from WDI, graphed by Author

Maritime Sector:

The maritime sector is all industry and activity connected to sea-based trade, transportation, and resources. It covers shipping, ports, shipbuilding, marine engineering, fishing, offshore energy (coal, gas, and renewables), and maritime tourism. Globally, trade depends on this industry since over eighty percent of commodities are shipped by sea. In environmental sustainability, resource exploitation and economic development it is also an important sector.

Figure 2: Maritime Sector Growth



Source: Data from WDI, graphed by Author

II. Literature Review

2.1 Theoretical review

The Environmental Kuznets Curve theory provides the theoretical framework to clarify the link among energy, economic growth, and carbon emissions. According to the EKC theory, economic expansion affects the surroundings at every level of development. The theory holds that while the energy consumption and economic activities in the first stage of economic development endanger the environment, the will will be a turnover when a particular degree of development is reached (Gyimah and Yao, 2022). This theory has been applied in several studies to explain the impact on economic growth and energy use on carbon emissions (Tachega, et al. 2021; Nyantakyi, et al. 2023). Given the industrial revolution period we live in, many nations-especially those in developing nations-are implementing policies to accommodate the worldwide increase of development. Many nations find themselves in a position to exploit environmentally damaging energy sources under this scenario. Investigating how the kind of energy use supports economic development and environmental quality is relevant given the global struggle against climate change.

2.2 Empirical review

Obani et al., (2025) with data from 2005 to 2023 evaluated with the Granger causality and ordinary least square (OLS) technique, examined the effect of environmental rules on foreign direct investment in Nigeria. The results revealed that although foreign direct investment does not environmental regulation, environmental regulation grange causes. FDI and carbon emissions have a bi-directional causality. Although FDI does not grander cause GDP, GDP grander cause is seen to be FDI. Furthermore negatively and statistically insignificantly is environmental regulation's effect on FDI. One finds a negative, minor correlation between FDI and carbon emissions. GDP and FDI have a negative and significant association. With data from 38 SSA countries between 2002 and 2022, Oumarou and Nourou (2024) evaluated the effects of trade openness on carbon dioxide (CO_2) emissions in Sub-Saharan Africa (SSA) estimated with the Generalised Method of Moments (GMM) system and the double ordinary least squares method. The primary findings revealed that trade openness in SSA helps to explain increasing CO2 emissions there. Moreover, the results revealed that environmental quality is mostly driven by the consumption of renewable energy, thereby presumably lowering CO2 emissions. Conversely, population rise, human capital, and the quality of institutions raise CO2 emissions. Moreover, the interplay of openness with institutional excellence reduces CO2 emissions. Using the ordinary least squares regression approach to estimate the data between 1990 and 2023, Obani et al., (2024) examined the impact of renewable energy on economic growth especially it empirically evaluated the link between solar power and GDP. Their results revealed that usage of renewable energy-a substitute for solar power-has a negligible and favourable effect on economic growth. Economic growth is favourably and significantly influenced by carbon emissions. Direct foreign investment has a major and favourable impact on economic development. Though it is not statistically significant, trade balance also shown a favourable effect on economic development. Furthermore, whereas carbon emission and GDP have bidirectional causality, solar power consumption has no statistically significant causal effect on GDP. Using data from 1990 to 2019 projected with Simultaneous equations approach, Bouchoucha (2024) investigated 40 African countries. Trade openness has a positive and significant effect on CO2 emissions, hence CO2 emissions have a positive correlation with infant mortality and under-five mortality whereas CO2 emissions have a negative association with life expectancy.

Using data from 2003 to 2017 projected with the Bayesian technique, Pham & Nguyen (2024) averaged 64 developing nations. There was no evidence of a statistically significant impact of trade openness on environmental pollution in emerging nations. Still, the data contradict the polluted paradise theory. Apart from trade openness, the findings revealed that capital abundance, financial openness, and renewable energy use are main factors influencing environmental quality, thereby seeming to lower CO2 emissions. Over a span of 150 years projected with rigorous cointegration approaches, Barkat et al. (2024) used 20 Organisation for Economic Cooperation and Development (OECD) countries. Trade liberalisation and CO2 emissions revealed a positive direct effect; income growth mediated a negative influence in the indirect effect. These different effects help to establish the environmental Kuznets curve theory. Trade opening is clearly a cause of environmental damage in BRICS countries, according to Chhabra et al. (2023), who used data from 1991–2019 and projected with the modern method of dynamic common correlative effects verifying the pollution paradise hypothesis. Goswami et al. (2023) projected with the ARDL model and the random forest model data from 1981–2021. The ARDL model turned out that variables were co-integrated. Short-term correlations between CO2 emissions and economic development and trade openness are found; energy consumption and urbanisation were positively correlated. Long term, CO2 emissions are favourably connected with urbanisation and business opening as well as with energy consumption; economic development and CO2 emissions are likewise favourably correlated.

Omri and Saadaoui (2023) investigated France using data from 1980–2020 projected with the NARDL (Non-linear Autoregressive Distributed Lag). Rising emissions are coming from unrestricted trade and fossil fuels. The study validates the inverted U-curve relating carbon emissions to economic development. Using Granger's non-causality estimate of the mean group of correlated

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

effects, Ghaderi et al. (2023) examined the Environmental Kuznets Curve Hypothesis in the MENA Region from 1995–2018. Main causes of CO2 emissions are trade openness and energy usage. Ogundipe, (2020) looked at the impact of fossil fuel consumption on environmental quality in Nigeria. The results also revealed that although first-generation estimators confirmed the Environmental Kuznets curve (EKC) hypothesis, there is no inverted U-shaped association between economic progress and CO2 emissions. The paper applies the Johansen co-integration technique using secondary data from 1970 to 2017. Their findings showed that direct consequence of fossil fuel combustion accounts for almost eighty percent of carbon emissions in Nigeria. They also discovered that pollution was a growing function of income; increases in pollution follow the increasing density of communities during the course of the study. According to Sulaiman et al. (2011), present and future engines will be compelled to adopt new technologies in the future based on their study on air emission from ship driving force for next generation marine technical and regulatory change. Furthermore, they thought that future technologies will be a main driver of a sequence of research projects aiming at resolving present environmental and energy issues. Such research will produce data that will be used to enforce pertinent rules on climate change control and compliance. Launched recently towards global warming, climate change and ozone depletion control in the maritime industry, the developing technology discussed could help meet the current demand by IMO for the implementation of Energy Efficiency Design Index (EEDI), Ship Energy Efficient Management Plan (SEEMP) and Ship Energy Efficiency Operational Indicator (SEEOI).

III. Methodology

3.1 Data for the study

The study employs time series data from 1990 to 2023, sourced from the World Development Indicator (WDI) and the CBN statistical bulletin. Table 1 summarizes the information on the variables utilized in the study.

Table 1: Description of Variables

Variables	Description	Unit of Measurement	Source
CO_2	CO_2 Emission	CO_2 Emission ($MtCO_2e$)	WDI
MSG	Maritime contribution to Gross Domestic Product	Maritime GDP (constant 2010 prices)	CBN
ENVR	Environmental Regulation	Environmental Sustainability rating (1=low to 6=high)	WDI

Source: Author's compilation, 2025

3.2 Model of the study

The model of the study is specified by adopting that of Obani et al (2025) and Oumarou and Nourou (2024) with some modification. The fuctional form of the model is given as equation (1);

$$CO_2 = f(MSG, ENVR) \quad (1)$$

The study utilized the Vector Autoregressive (VAR) Model to analyse the data of the study. A VAR is an n-equation, n-variable linear model where each equation specifies a variable as a function of lagged values of all the n – variables in the model. Thus the VAR model considers all variables to be endogenous and captures the rich dynamics in multiple time series. Assuming there are n-variables of interest, say, $y_1, y_2, ..., y_n$; thus the vector of variables in the VAR is $(y_1, y_2, ..., y_n)$.

This implies that all the variables are endogenous. The VAR model is represented in its compact form as follows:

$$V_t = \alpha + \sum_{i=1}^{p} A_i V_{t-1} + \varepsilon_t \quad (2)$$

Where;

V_t isthe vector of CO_2Emission, Maritime sector growth and Environmental Regulation. $\alpha$is the intercepts of autonomous variables. $A_i$is the matrix of coefficients of all the variables in the model. $V_{t-1}$is the vector of the lagged variables and ε_t is the vector of the stochastic error terms.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

IV. Results and Discussion of Findings

Table 2: Descriptive Statistics

	CO2	ENVR	MSG
Mean	100.2622	2.470588	3.630177
Median	100.2112	3.000000	3.476799
Maximum	127.3461	3.500000	5.463231
Minimum	74.38070	0.000000	2.538185
Std. Dev.	14.60043	1.408530	0.847494
Skewness	0.126290	-1.160937	0.479670
Kurtosis	2.002427	2.479776	1.938457
Jarque-Bera	1.500178	8.020785	2.900211
Probability	0.472324	0.018126	0.234546
Observations	34	34	34

Source: Author's computation, 2025

The descriptive statistics is presented in table 2. From the information presented, the average CO_2 emission (CO2) for the study period stood at 100mt, environmental regulation (ENVR) was 2.47 percent and maritime sector growth (MSG) was 3.63 billion naira. Environmental regulation and maritime sector growth are positively skewed while CO_2 emission is negatively skewed based on their skewness values. Their kurtosis values showed that all the variables are platykurtic distribution. Their Jarque-Bera probability value shows that only CO2 and MSG are normally distributed.

Table 3: ADF unit root test

Unit Root Test at Levels			
Variable	**ADF Test Statistic**	**P-Value**	**Remark**
CO2	-1.480758	0.5307	Non-Stationary
ENVR	-1.854951	0.3487	Non-Stationary
MSG	0.207992	0.9690	Non-Stationary
Unit Root Test at First Difference			
Variable	**ADF Test Statistic**	**P-Value**	**Remark**
CO2	-6.373444	0.0000	Stationary
ENVR	-5.660836	0.0000	Stationary
MSG	-4.342348	0.0018	Stationary

Source: Author's computation, 2025

The result of the Augmented Dickey-Fuller Test is presented in table 3, from the result we observed that all the variables are stationary at first difference I(1). Therefore, we proceed to conduct the Johansen cointegration test to check for the existence of a long run relationship among the variables.

Table 4: Cointegration test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.235714	14.35612	29.79707	0.8200
At most 1	0.164497	5.754106	15.49471	0.7244
At most 2	9.49E-05	0.003037	3.841465	0.9544

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.235714	8.602016	21.13162	0.8631
At most 1	0.164497	5.751069	14.26460	0.6454
At most 2	9.49E-05	0.003037	3.841465	0.9544

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Author’s computation, 2025

From the results of the multivariate cointegration test presented in Table 4, the Johansen’s cointegration technique revealed that both the trace statistic and maximum Eigen value statistic confirm no existence of a cointegrating equations among the variables. Since the variables are not cointegrated, the existence of a stable long run relationship between the variable can only be confirmed Vector Autoregressive (VAR) model.

Table 5: Vector Autoregression Estimates

Sample (adjusted): 3 34
Included observations: 32 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	CO2	ENVR	MSG
CO2(-1)	0.681655	-0.000465	-0.002184
	(0.20299)	(0.01446)	(0.00763)
	[3.35800]	[-0.03215]	[-0.28628]
CO2(-2)	0.006536	0.016040	0.007551
	(0.20402)	(0.01453)	(0.00767)
	[0.03204]	[1.10361]	[0.98482]
ENVR(-1)	-0.399718	0.775217	-0.011972
	(2.81602)	(0.20061)	(0.10584)
	[-0.14194]	[3.86423]	[-0.11312]
ENVR(-2)	0.482437	0.025243	0.052089
	(2.72539)	(0.19416)	(0.10243)
	[0.17702]	[0.13001]	[0.50853]
MSG(-1)	-2.274957	-0.036832	1.023000
	(5.41815)	(0.38599)	(0.20363)
	[-0.41988]	[-0.09542]	[5.02370]
MSG(-2)	6.953218	-0.014193	-0.137585
	(5.50988)	(0.39253)	(0.20708)
	[1.26195]	[-0.03616]	[-0.66440]
C	16.22141	-0.740028	-0.135551
	(11.5609)	(0.82360)	(0.43450)

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

	[1.40313]	[-0.89853]	[-0.31197]
R-squared	0.760874	0.863385	0.910030
Adj. R-squared	0.703484	0.830597	0.888438
F-statistic	13.25790	26.33262	42.14529
Akaike AIC	7.063263	1.779867	0.500901
Schwarz SC	7.383893	2.100497	0.821531

Source: Author's computation, 2025

In Table 5 the Vector Autoregression Estimates are presented. All the coefficient estimates areelasticities. A careful study of the results shows that the single most importantdeterminant of each variable is its one-period lagged value. The elasticity of CO_2 emission with respect to its lagged value is 0.68; the elasticity of environmental regulation with respect to its lagged value is 0.78 and the elasticity of maritime sector growth with respect toits lagged value is 1.02. These results coincide with those of IRF and Variance Decomposition analyses. The variables of the model also have a high explanatory value depicted by the R-squared value of 0.760874 which shows a 76% explanatory power.

Table 6: Diagnostics of the Vector Autoregression Estimates
VAR Residual Serial Correlation LM Tests
Null hypothesis: No serial Correlation n at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	4.766780	9	0.8541	0.517426	(9, 48.8)	0.8548
2	7.628200	9	0.5720	0.851440	(9, 48.8)	0.5736

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	4.766780	9	0.8541	0.517426	(9, 48.8)	0.8548
2	14.76325	18	0.6782	0.804623	(18, 48.6)	0.6854

*Edgeworth expansion corrected likelihood ratio statistic.
Source: Author's computation, 2025

VAR Residual Heteroskedasticity Tests (Levels and Squares)
Joint test:

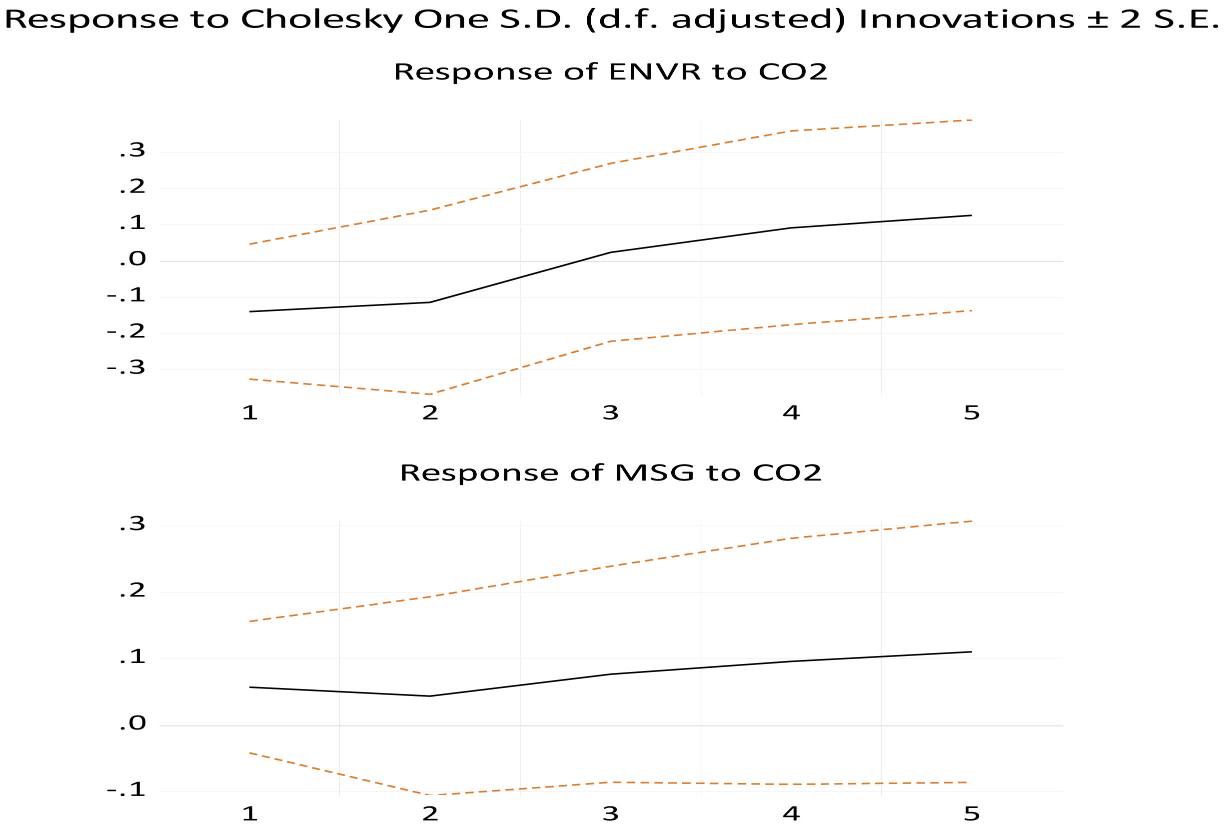
Chi-sq	Df	Prob.
69.49009	72	0.5619

Source: Author's computation, 2025

The model errors are free from serial correlation based on the VAR Residual Serial Correlation LM Tests result. The VAR Residual Heteroskedasticity Tests shows that the errors are homoskedastic.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

Figure 3: Impulse Response Function



Source: Author's computation, 2025

The impulse response function of environmental regulation and maritime sector growth to the one standard deviation innovations of CO_2 emission. The Impulse Response Function result showed that there is no initial response from the maritime sector growth to CO_2 emission but it gradually increased over the study period and maintaining a positive effect both in the long run and short run. Environmental regulation in the short run exhibit a negative impact, it reached a steady state and start to rise. Thus, it has an asymmetric effect on CO_2 emission both in the long run and short run.

Table 7: Variance Decomposition

(i)Variance Decomposition of CO2:				
Period	S.E.	CO2	ENVR	MSG
1	7.518549	100.0000	0.000000	0.000000
2	9.081792	99.46617	0.053381	0.480454
3	9.869800	98.79641	0.046333	1.157257
4	10.41300	95.31941	0.042641	4.637952
5	10.95060	89.98365	0.043241	9.973106

(ii)Variance Decomposition of ENVR:				
Period	S.E.	CO2	ENVR	MSG
1	0.535623	6.831839	93.16816	0.000000
2	0.678685	7.083315	92.89413	0.022551
3	0.752738	5.858245	94.03830	0.103453

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 5, Issue 1, Jan.-Feb., 2025, pp: 567-578 ISSN: 3048-6874
www.ijhssm.org

4	0.801795	6.462520	93.18337	0.354113
5	0.837861	8.180499	91.35774	0.461757

(iii)Variance Decomposition of MSG:				
Period	S.E.	CO2	ENVR	MSG
1	0.282576	4.106490	0.002436	95.89107
2	0.402398	3.211644	0.015212	96.77314
3	0.481810	4.779814	0.142930	95.07726
4	0.536584	7.067765	0.518348	92.41389
5	0.579955	9.688499	1.074356	89.23714
Cholesky Ordering: CO2 ENVR MSG				

Source: Author's computation, 2025

The forecast error variance decomposition was employed to further examine the short run dynamic properties of maritime sector growth, environmental regulation and CO_2 emission in Nigeria. The results for the three variables are presented in Table 4. An examination of the variance decomposition of CO_2 emission in Table4(i)shows that the lion's share of the variation experienced by CO_2 emission is attributed to its own shock. The contribution of own shock is 100% in the first period and declines slightly to 89.9% at the end of the 5-period horizon. The other 2 variables contributed marginally to it. The highest been maritime sector growth, which contributes 9.97% in the fifth period.

In Table 4(ii) environmental regulation exhibited a strong endogenous impact on its own shocks. The contribution of own shock is 93.1% in the first period but declines to 91.3% in the fifth period. The contribution of the other variables shows a strong exogenous influence with environmental regulation accounting. CO_2 emission have the highest among them contributing 8.1%, showing that environmental regulation as essentially driven by CO_2 emission.

In Table 4(iii) we observed that CO_2 emission have a strong exogenous impact on maritime sector growth both in the short run and long run. In the fifth period, CO_2 emission accounted for 9.6% of variation in maritime sector growth in the long run. Thus, displaying similar results as the impulse response function.

V. Conclusion

This study investigates maritime sector growth, environmental regulation and CO_2 emission nexus in Nigeria from 1990 to 2023. The study concludes that the single most importantdeterminant of each variable is its one-period lagged value. The Impulse Response Function and forecast error variance decomposition showed that the maritime sector growth and CO_2 emission exhibit a positive effect both in the long run and short run. Environmental regulation have an asymmetric effect on CO_2 emission both in the long run and short run.

Based on the findings the government should put in place stiffer and more enforceable environmental rules will help to reduce CO2 emissions from the maritime industry, so guaranteeing their efficacy in the long run as well as in the present. To lower emissions, support the marine industry's adoption of sustainable practices and greener technology like alternative fuels and energy-efficient ships. Create policies to strike a balance between environmental sustainability and the expansion of the maritime industry so as to prevent disproportionate rise of CO2 emissions. Encourage innovation to decouple sector development from environmental damage by supporting research into sustainable maritime practices and emissions reduction solutions.

References

[1]. Aruwei, P. &Eko-Raphaels, M., U. (2022). Impact of Port Congestion on Nigeria Economic Growth: An ARDL Approach. International Journal of Innovative Finance and Economics Research 10(1):29-35.

[2]. Barkat K., Mouyad A., Al Kwifi O.S. &Shaif J. (2024). Does trade openness mitigate environmental damage in Organisation for Economic Co-operation and Development (OECD) countries? Implications for achieving sustainable development, Natural Resources Forum,https://doi.org/10.1111/1477-8947.12412.

[3]. Bloomberg, (2024). Nigeria's Economy once africa's biggest slips to fourth place. https://www.bloomberg.com/news/articles/2024-04-18/

[4]. Bouchoucha N. (2024). Does Trade Openness and Environmental Quality Matter for Health Status? Evidencefrom African Countries. Journal of Knowledge in Economics, 15, 5729-5745. https://doi.org/10.1007/s13132-023-01197-w.

[5]. Chhabra M., Giri A.K. & Kumar A. (2023). Do trade openness and institutional quality contribute to carbonemission reduction? Evidence from BRICS countries. Environmental Scieence and Pollution Research,50986-51002. https://doi.org/10.1007/s11356-023-25789-w.

[6]. Ghaderi Z., Saboori B. &Khoshkam M. (2023). Revisiting the Environmental Kuznets Curve Hypothesis in theMENA Region: The Roles of International Tourist Arrivals, Energy Consumption and Trade Openness.Sustainability, 15, 2553. https://doi.org/10.3390/ su15032553.

[7]. Goswami A., Kapoor H.S., Jangir R.K., Ngigi C.N., Nowrouzi-Kia B. &Chattu V.K. (2023). Impact of Economic Growth, Trade Openness, Urbanization and Energy Consumption on Carbon Emissions: A Study of India. Sustainability, 15, 9025. https://doi.org/10.3390/ su15119025.

[8]. Gyimah, J. & Yao, X. (2022). Globalisation and renewable energy impact on carbon emissions in Ghana. International Journal of Global Warming, 28(2), 113–21.

[9]. IMO, (2020). Fourth IMO GHG Study 2020; International Maritime Organization (IMO): London, UK, 2020.

[10]. IMO. (2021). Fourth IMO GHG gas study 2020.

[11]. ISEMAR. (2020). Global Sulphur Cap 2020: Etat des lieux. (Summary Note ISEMAR No. 216).

[12]. Nyantakyi, G., Gyimah, J., Sarpong, F., A. &Sarfo, P., A. (2023). Powering Sustainable growth in West Africa: exploring the role of environmental tax, economic development, and financial development in shaping renewable energy consumption patterns. Environ SciPollut Res Int. 2023. https://doi.org/10.1007/s11356023-30034-5PMID: 37770735

[13]. Obani, I. P., Obani, Z., I. &Akroh, T., O. (2024). Renewable Energy and Economic Growth: An Empirical Analysisof the Relationship between Solar Power and GDP. International Journal of Humanities Social Science and Management (IJHSSM), 4(6), 389-396.

[14]. Obani, I. P., Obani, Z., I. &Akroh, T., O. (2025). The Impact of Environmental Regulations on Foreign Direct Investment:Evidence from an Emerging Economy. International Journal of Advanced Multidisciplinary Research and Studies 5(1), 471-475.

[15]. Ogundipe, A. A., Okwara, C.&Ogundipe, O., M. (2020). CO2 Emissions and Environmental Implications in Nigeria. International Journal of Energy Economics and Policy, Econjournals, 10(3), 317-324.

[16]. Omri E. &Saadaoui H. (2023). An empirical investigation of the relationships between nuclear energy, economic growth, trade openness, fossil fuels, and carbon emissions in France: fresh evidence using asymmetriccointegration. Environmental Science and Pollution Research, 13224-13245. https://doi.org/10.1007/s11356-022-22958-1.

[17]. Oumarou, M. &Nourou, M. (2024). The effects of trade openness on CO2 emissions in Sub-Saharan Africa: fresh evidence from new measure. Journal of Environmental Science and Economics, 69-98. https://doi.org/10.56556/jescae.v3i3.988

[18]. Pham D. T. T. & Nguyen H. T. (2024). Effects of trade openness on environmental quality: evidence fromdeveloping countries. Journal of Applied Economics, 27(1).doi:10.1080/15140326.2024.2339610

[19]. Sulaiman, O., Saharuddin, A. H., Saman A., A, K. & Nik, W., B. W. (2011).Air emission from ship driving force for next generationmarine technological and policy change: A review. African Journal of Business Management, 5(33), 12664-12683. DOI:10.5897/AJBM10.1633

[20]. Tachega, M. A., Yao, X., Liu, Y., Ahmed, D., Ackaah, W. &Gabir, M. (2021). Income Heterogeneity and the Environmental Kuznets Curve Turning Points: Evidence from Africa. Sustainability, 13(10).

[21]. Toumi, S. &Toumi, H. (2019). Asymmetric causality among renewable energy consumption, CO2 emissions and economic growth in KSA: Evidence from a non-linear ARDL model. Environmental Science and Pollution Research, 26, 16145-16156.

[22]. UNCTAD. (2020). Review of maritime transport 2019. United Nations.

[23]. UNCTAD. (2022). Review of maritime transport 2022. United Nations.

[24]. WDI (2025). https://www.climatewatchdata.org/ghg-emissions
[25]. Ytreberg, E., Åström, S., &Fridell, E. (2021). Valuating environmental impacts from ship emissions-the marine perspective. Journal of Environmental Management, 282, 111958. https://doi.org/10.1016/j.jenvman.2021.111958