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THE NEXUS BETWEEN COASTAL INFRASTRUCTURE DEVELOPMENT AND SUSTAINABLE ECONOMIC GROWTH IN NIGERIA

Saheed Aliu, Aladejana Ph.D*
Department of Economics,
Olusegun Agagu University of Science and Technology (OAUSTECH),
Okitipupa, Ondo State, Nigeria.

Israel Olabode, Aroge Ph.D
Department of Project Management,
Olusegun Agagu University of Science and Technology (OAUSTECH),
Okitipupa, Ondo State, Nigeria. Email: io.aroge@oaustech.edu.ng
&
Titilayo Doris, Ibikunle Ph.D
Department of Entrepreneurship Management,
Olusegun Agagu University of Science and Technology, (OAUSTECH),
Okitipupa, Ondo State, Nigeria. Email: drealtitilayomiibikunle@gmail.co

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Abstract

This study examined the relationship between coastal infrastructure development and sustainable economic growth in Nigeria from 1990 to 2024 using the Dynamic Ordinary Least Squares (DOLS) approach. Data were obtained from the Central Bank of Nigeria (CBN), the National Bureau of Statistics (NBS), and the World Bank's World Development Indicators. Coastal infrastructure was proxied by port throughput, while sustainable economic growth was measured through indicators of economic performance, employment, and trade facilitation. The findings indicated that coastal infrastructure and trade openness positively influenced economic growth,

* **Address of corresponding Author**: Dr. Saheed Aliu, Aladejana, Department of Economics, Olusegun Agagu University of Science and Technology (OAUSTECH), Okitipupa, Ondo State, Nigeria. Email: aladejana26@gmail.com Phone: +2347039557346

whereas human capital had a negative effect. Energy use showed a positive but statistically insignificant impact, while carbon emissions significantly constrained growth. Importantly, the effect of coastal infrastructure depended on complementary factors, including institutional quality, effective human capital utilisation, and robust trade facilitation. The negative coefficient of human capital reflects structural inefficiencies such as underemployment, skill mismatches, and limited industrial absorption. Trade openness emerged as a key growth driver, highlighting the importance of export promotion, trade liberalisation, and global integration. Conversely, the adverse effect of carbon emissions underscores the need for environmental sustainability measures. The study concluded that achieving inclusive and resilient growth requires coordinated policies integrating coastal infrastructure, human capital, trade, energy efficiency, and environmental protection. Accordingly, the study recommended among others: strategic investments in ports and logistics, alignment of education and skills development with labour market needs, promotion of trade liberalisation and foreign investment, adoption of cleaner energy technologies, and institutional reforms to optimise human capital utilisation. Collectively, these measures can transform infrastructure and trade investments into sustainable, long-term economic development outcomes for Nigeria.

Keywords: Coastal infrastructure; Economic growth; Energy use; Human capital; Trade openness; Nigeria.

Résumé

Cette étude a examiné la relation entre le développement des infrastructures côtières et la croissance économique durable au Nigeria sur la période 1990-2024, en utilisant l'approche des moindres carrés ordinaires dynamiques (DOLS). Les données ont été recueillies auprès de la Banque centrale du Nigeria (CBN), du Bureau national des statistiques (NBS) et de la base de données « World Development Indicators » de la Banque mondiale. Le volume de trafic portuaire a servi d'indicateur pour les infrastructures côtières, tandis que la croissance économique durable a été évaluée à travers des indicateurs de performance économique, d'emploi et de facilitation des échanges. Les résultats indiquent que les infrastructures côtières et l'ouverture commerciale ont influencé positivement la croissance économique, alors que le capital humain a eu un effet négatif. La consommation d'énergie a affiché un impact positif mais statistiquement non significatif, tandis que les émissions de carbone ont freiné la croissance de manière significative. Il est important de noter que l'effet des infrastructures côtières dépendait de facteurs complémentaires, notamment la qualité des institutions, l'utilisation efficace du capital humain et une facilitation robuste des échanges. Le coefficient négatif associé au capital humain reflète des inefficacités structurelles telles que le sous-emploi, l'inadéquation des compétences et une capacité d'absorption industrielle limitée. L'ouverture commerciale s'est révélée être un moteur clé de la croissance, soulignant l'importance de la promotion des exportations, de la libéralisation des échanges et de l'intégration mondiale. À l'inverse, l'effet néfaste des émissions de carbone met en évidence la nécessité de mesures en faveur de la durabilité environnementale. L'étude conclut que la réalisation d'une croissance inclusive et résiliente nécessite des politiques coordonnées intégrant les infrastructures côtières, le capital humain, le commerce, l'efficacité énergétique et la protection de l'environnement. En conséquence, l'étude recommande notamment: des investissements stratégiques dans les ports et la logistique, l'alignement de l'éducation et du développement des compétences sur les besoins du marché du travail, la promotion de la libéralisation des échanges et des investissements étrangers, l'adoption de technologies énergétiques plus propres, ainsi que des réformes institutionnelles visant à optimiser l'utilisation du capital humain. Dans leur

ensemble, ces mesures peuvent transformer les investissements dans les infrastructures et le commerce en résultats de développement économique durable et à long terme pour le Nigeria.

Mots-clés: Capital humain ; Consommation d'énergie ; Croissance économique ; Infrastructures côtières; Ouverture commerciale ; Nigeria.

Background to the Study

In Sub-Saharan Africa (SSA), the development of coastal and maritime infrastructure is increasingly recognised as a critical driver of sustainable economic growth. The region's extensive coastlines offer substantial opportunities for trade expansion, enhanced logistics efficiency, and economic diversification (Konstantinus & Woxenius, 2022; Prasutiyon *et al*., 2025). However, despite this considerable potential, many SSA countries continue to grapple with persistent challenges, including inadequate port capacity, infrastructural inefficiencies, and weak hinterland connectivity. These constraints limit the extent to which maritime activities can translate into broad-based and sustainable economic growth (Chenikwi, 2016; Sahoo, 2024). Consequently, a key policy concern across the region is how improvements in coastal infrastructure can more effectively influence long-term economic performance, particularly within the context of the African Continental Free Trade Area (AfCFTA) and emerging transnational transport corridor initiatives (Olayemi & Nwokoye, 2026).

Within this regional landscape, Nigeria occupies a strategically significant position, given its approximately 853-kilometre Atlantic coastline and its status as one of the largest economies in Sub-Saharan Africa (SSA). Nigerian seaports play a pivotal role in facilitating external trade and supporting domestic economic activity, collectively handling over 100 million metric tonnes of cargo annually in recent years. Notably, cargo throughput increased from approximately 71.2 million tonnes in 2023 to around 103.3 million tonnes in 2024, reflecting renewed momentum in port operations, improvements in operational efficiency, and expanding trade volumes (Irejeh & Sile, 2024; Ndalu & Okene, 2024; Martins, 2024). Nevertheless, persistent port congestion, logistics bottlenecks, and uneven coastal connectivity underscore the coexistence of recent progress with long-standing structural weaknesses (Fuanbial, 2024). These conditions raise critical questions regarding the extent to which coastal infrastructure developments have translated into sustainable economic growth, beyond short-term increases in trade volumes.

Against this backdrop, the administration of President Bola Ahmed Tinubu has positioned coastal and maritime infrastructure at the heart of Nigeria's economic transformation agenda. Under the "Renewed Hope" framework, the Federal Government has prioritised large-scale infrastructure projects aimed at repositioning the coastal economy as a catalyst for growth and diversification. A flagship initiative in this regard is the Lagos–Calabar Coastal Highway, a planned 700-kilometre transport corridor designed to enhance connectivity across coastal states, stimulate trade and tourism, and unlock opportunities within the blue economy (Soile, 2025). The mobilisation of substantial financing for the project, including over US$1.1 billion for its initial phases, signals a deliberate shift towards infrastructure-led growth anchored on productive investment. This strategy is further reinforced by the establishment of the Federal Ministry of Marine and Blue Economy and the adoption of a National Policy on Marine and Blue Economy, both of which reflect an increasing policy emphasis on leveraging coastal infrastructure to achieve sustainable economic outcomes (Odusanya, 2025).

Despite these policy commitments and ongoing infrastructural initiatives, empirical evidence on the relationship between coastal infrastructure development and sustainable economic

growth in Nigeria remains limited and fragmented. Specifically, there is limited empirical evidence on the long-run influence of coastal infrastructure on sustainable economic growth. Therefore, this study seeks to examine the nexus between coastal infrastructure development and sustainable economic growth in Nigeria, with the aim of providing empirical evidence on this relationship and generating policy-relevant insights that can guide infrastructure investment priorities and support the effective implementation of Nigeria's blue economy and AfCFTA-driven development agenda.

Statement of the Research Problem

Although coastal infrastructure is widely acknowledged as a critical driver of economic development, many developing economies continue to struggle to convert such investments into sustained and inclusive growth (Ibrahim & Bello, 2023; Fuanbial, 2024). In Nigeria, the underutilisation of coastal resources, operational inefficiencies within port systems, and weak integration of transport and logistics networks have constrained the effective performance of maritime infrastructure (Adewale & Okafor, 2024; Ndalu & Okene, 2024). These structural deficiencies raise fundamental questions regarding the capacity of coastal infrastructure investments to deliver long-term developmental benefits, including industrial expansion, trade facilitation, employment creation, and inclusive economic growth. The empirical evidence on the specific contributions of coastal infrastructure components—such as ports, transport corridors, and maritime logistics systems—to national economic performance suggests significant limitations. Such limitations restrict policymakers' ability to prioritise infrastructure projects, allocate resources efficiently, and design strategies that maximise sustainable development outcomes. Consequently, without robust empirical insights into these linkages, coastal infrastructure investments risk generating predominantly short-term gains, thereby undermining Nigeria's potential to harness its coastal economy for broader and sustainable socio-economic development.

A review of the extant literature further indicates that a substantial portion of studies has concentrated on the blue economy nexus, particularly within developed countries like China and Japan, and select emerging economies including Fiji, Bangladesh, India, the Philippines, Sri Lanka, and other East Asian nations. In contrast, within Sub-Saharan Africa—including Nigeria—only a limited number of studies (Abdullahel, 2017; Amaechi, 2018; Hammed, 2018; Elisha, 2019; Sule, 2021; Jacob & Umoh, 2022; Ali, 2023; Aladejana *et al*., 2024; Nweke & Dhakir, 2025; Chakila *et al*., 2025; Tonye & Ligha, 2025; Agunsoye *et al*., 2025) have explored the relationship between the blue economy and sustainable development. Notably, much of this literature has primarily addressed opportunities, challenges, governance, and management frameworks, with comparatively less attention given to the role of infrastructure as a direct catalyst for sustained economic growth.

Despite the expansive conceptual scope of the blue economy, its empirical outcomes cannot be assumed to directly translate to coastal economy contexts. This distinction is particularly salient because the coastal economy represents a critical subset of the blue economy, encompassing ocean-based activities that are geographically concentrated within coastal zones and intrinsically linked to infrastructure, local livelihoods, and the socio-economic well-being of coastal communities. Accordingly, generalisations derived from the broader blue economy framework may fail to capture the context-specific developmental dynamics and infrastructure-related constraints that characterise coastal regions, particularly in developing economies such as Nigeria.

Against this backdrop, there remains a pronounced paucity of empirical literature explicitly investigating the nexus between coastal infrastructure development and sustainable economic growth in Nigeria. This gap underscores the need for systematic and contextually grounded research. Consequently, the present study seeks to examine the relationship between coastal infrastructure development and sustainable economic growth in Nigeria, providing empirical insights that can inform policy decisions and investment priorities.

Following the background to the study and the research problem, the paper is structured as follows: Section 2 reviews the theoretical and empirical literature on coastal infrastructure and sustainable economic growth; Section 3 presents the methodological framework and data sources; Section 4 discusses the empirical findings; and Section 5 concludes with key insights and policy implications.

Literature Review

Theoretical Framework

This study is anchored on the Endogenous Growth Theory, which posits that long-term economic growth is primarily driven by internal factors—such as investments in productive infrastructure, human capital accumulation, and technological advancement—rather than by exogenous influences alone (Ifoghere & Olele, 2024). Within this framework, coastal infrastructure—including ports, transport corridors, and maritime logistics systems—is conceptualised as productive public capital that enhances private sector efficiency, reduces transaction and trade costs, and stimulates sustained economic activity (Ugah *et al*., 2024). These investments facilitate trade integration, promote economies of scale, and strengthen linkages between coastal and hinterland economies, thereby generating positive productivity and income spillovers.

The framework is particularly pertinent to Sub-Saharan Africa and Nigeria, where persistent infrastructure deficits have constrained economic growth and limited the developmental impact of trade. By improving coastal connectivity and logistics, such investments are expected to enhance export competitiveness, support industrial diversification, and deepen integration into regional and global value chains, in alignment with the objectives of the African Continental Free Trade Area (AfCFTA) (Adeyemi & Okoro, 2021). Moreover, the theory incorporates sustainability considerations by recognising that efficiently planned and well-managed infrastructure investments can promote inclusive growth while sustaining long-term economic stability. Accordingly, within the context of Nigeria's blue economy agenda, the Endogenous Growth Theory provides a robust analytical framework for examining the long-run influence of coastal infrastructure on sustainable economic growth and development.

Empirical Review

Aladejana *et al*. (2024) examined the impact of the blue economy on sustainable development in Nigeria. Using annual time-series data from the CBN Statistical Bulletin and the World Bank Development Indicators (WBDI) spanning 1990 to 2021, the study employed ordinary least squares (OLS) estimation. Key variables included the Sustainable Development Index (SDI), blue economy (BLEG), gross capital formation (GCF), CO_2 emissions (GHE), and per capita income growth rate (PCGR). The findings revealed that an increase contribution of the blue economy to GDP significantly enhances SDI, thus highlighting its critical role in promoting sustainable development. In contrast, gross capital formation's share in GDP did not exhibit a statistically significant relationship with SDI, indicating limited predictive power in this context. Moreover, higher CO_2 emissions indicated negative association with SDI, reflecting environmental pressures,

while rapid per capita income growth correlated negatively with SDI, suggesting potential sustainability challenges amid economic expansion. Collectively, these results underscore the necessity of integrated sustainable development strategies that harmonise economic, social, and environmental dimensions. Consequently, incorporating blue economy initiatives into Nigeria's development planning is imperative, emphasising the adoption of holistic policies that balance economic growth with social equity and environmental sustainability.

Complementary studies provide additional insights into the blue economy's opportunities and constraints. Nwogu (2022) evaluated the challenges and investment opportunities within Nigeria's Blue Economy framework, highlighting strategies to promote sustainable practices aligned with international standards. Similarly, Ali (2023) examined Zanzibar's blue economy, demonstrating that the fishing sector contributes 2.6% to GDP, employed over 200,000 people, and attracted 68% of investment projects, which collectively accounted for substantial economic gains, including 30% of GDP and 80% of foreign earnings. Nevertheless, there is little or no similar study, as yet, in the context of Nigeria.

Expanding the discussion to maritime infrastructure, Sibali and Jainuddin (2024) analysed major Indonesian ports, revealing that improved port capacity and logistics efficiency significantly reduce trade costs, enhance flows, and boost competitiveness. However, persistent financing challenges and environmental concerns indicate that sustainable growth requires regulatory clarity, public–private partnerships, and eco-friendly technologies. Likewise, Gbban (2025) assessed Saudi Arabia's Jeddah Corniche waterfront, demonstrating that investments in desalination, wastewater treatment, and marine tourism could increase GDP by ~4%, generate 15,000 jobs, and stimulate 20% growth in tourism revenue over five years. These findings suggest that integrated coastal investment, aligned with sustainable development goals, enhances economic diversification and urban quality of life while necessitating complementary environmental and social policies.

Addressing climate-related risks, Adshead *et al*. (2024) employed high-resolution household data from Bangladesh's coastal zones, showing that floods, cyclones, and other hazards disproportionately threaten infrastructure services and progress toward Sustainable Development Goals (SDGs). The study also indicated that targeted adaptation strategies in high-risk areas could safeguard 50–85% of key SDG outcomes, underscoring the importance of climate-resilient infrastructure for sustainable coastal development.

From a regional and cross-country perspective, Zuo *et al*. (2023) constructed a natural–economic–social (NES) coastal sustainable development index for 41 countries along the Maritime Silk Road (2010–2020). Results revealed that economic and social dimensions exert greater influence than natural factors and highlighted spatial disparities, reinforcing the need for integrated policy frameworks combining infrastructure, economic planning, and social welfare. Similarly, Abdel-Kader (2024) developed a framework linking blue infrastructure to sustainable coastal economies in Rasheed Canter, Egypt, proposing a model that balances economic development with ecosystem services and social equity. Wibowo *et al*. (2024) further demonstrated that port development stimulates trade, employment, and workforce readiness, but environmental sustainability remains a critical concern, necessitating integrated educational and ecological policies.

Despite the valuable insights provided by the empirical studies reviewed, several gaps remain in the literature. Aladejana *et al*. (2024) highlighted the blue economy's contribution to sustainable development in Nigeria but focused primarily on macroeconomic indicators, largely overlooking coastal infrastructure as a mediating factor. Similarly, the studies reviewed above

emphasised governance, sector-specific outcomes, or investment trends, often relying on secondary or regional data. Empirical research in Sub-Saharan Africa, particularly Nigeria, remains limited, with few studies investigating how infrastructure drives sustainable economic growth. Moreover, the broad blue economy framework does not fully capture the context-specific dynamics of coastal economies, which rely on local infrastructure, spatial economic activities, and community livelihoods. Therefore, a significant gap persists in systematic research examining the role of coastal infrastructure in promoting sustainable economic growth in Nigeria.

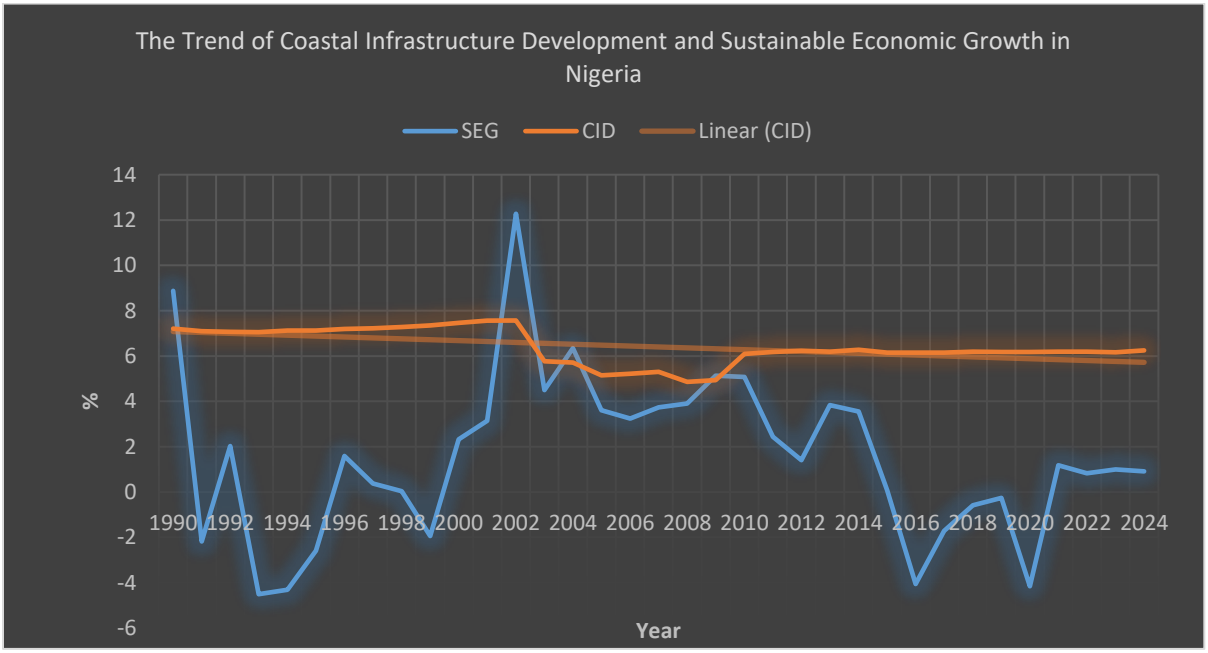

Fig. 1: Trend of Coaster Infrastructure Development and Sustainable Economic Growth in Nigeria.
Source: Author's calculation based on WBDI database.

The figure illustrates the joint movement of Sustainable Economic Growth (SEG) and Coastal Infrastructure Development (CID) in Nigeria from 1990 to 2024, revealing a stark contrast between highly volatile economic growth and relatively stable, albeit slightly declining, coastal infrastructure. SEG exhibits pronounced fluctuations, reflecting persistent structural and macroeconomic instability, with sharp contractions in the early 1990s, a peak around 2002, moderate growth in the mid-2000s, and fragility post-2015. These patterns underscore Nigeria's exposure to external shocks, structural rigidities, and policy uncertainties over the period.

In contrast, CID demonstrates relative stability, with gradual improvements observed in the late 1990s and early 2000s, minor declines in the mid-2000s, and moderate stabilisation after 2010. However, the linear trend indicates a marginal long-term decline, suggesting that coastal infrastructure expansion has not kept pace with the country's growing trade volumes and economic demands.

Collectively, these series highlight weak short-run synchronisation between SEG and CID: although coastal infrastructure provides essential baseline support for economic activity, its modest growth has been insufficient to stabilise or sustain economic expansion. The volatility in SEG reflects broader macroeconomic factors, including oil dependence, institutional constraints, and investment dynamics. Overall, the trends point to a structural gap between infrastructure

development and the requirements for sustainable growth, emphasising the urgent need for integrated policies that enhance port capacity, improve logistics efficiency, and secure long-term infrastructure financing to strengthen the contribution of coastal infrastructure to Nigeria's sustainable economic development.

Methodology

Data and Sources

This study utilises annual time-series data spanning 1990 to 2024 to investigate the relationship between coastal infrastructure development and sustainable economic growth in Nigeria. Data were drawn from authoritative sources, including the Central Bank of Nigeria (CBN), the National Bureau of Statistics (NBS), and the World Bank's World Development Indicators (WBDI). Coastal infrastructure is proxied by port throughput, while sustainable economic growth is measured using a composite of economic performance, employment generation, and trade facilitation indicators. Preliminary analyses indicate that all variables are integrated of order one, I(1), and the Johansen cointegration test confirms the existence of a stable long-run equilibrium among them.

Consequently, the study adopts the Dynamic Ordinary Least Squares (DOLS) estimation technique to obtain robust long-run parameter estimates. DOLS effectively addresses potential endogeneity and serial correlation by incorporating leads and lags of first differences, thereby producing efficient and unbiased coefficients suitable for policy-oriented macroeconomic analysis. This approach is consistent with the theoretical underpinnings of infrastructure-led growth and aligns with contemporary blue economy literature.

Conceptually, coastal infrastructure activities correspond to the OECD Ocean Economy framework, which distinguishes between established and emerging maritime sectors while recognising their interdependence within the broader blue economy. By integrating this framework with DOLS estimation, the study provides a rigorous and comprehensive assessment of the long-term effects of coastal infrastructure investment on Nigeria's sustainable economic performance. The resulting insights offer a solid analytical foundation to inform policy formulation, strategic infrastructure planning, and investment decisions within the country's evolving blue economy agenda.

Model Specification

Based on the theoretical review and empirical consideration, the following model was used in this work: Mathematically written as:

$$SEG_t = f(CID_t, X_t) \text{ ---------- (i)}$$

Where:

SEG_t= Sustainable Economic Growth

CID_t= Coastal Infrastructure Development

X_t= Vector of control variables

The baseline econometric model is specified as:

$$SEG_t = \beta_0 + \beta_1 CID_t + \beta_2 HC_t + \beta_3 TRD_t + \beta_4 ENE_t + \beta_5 CO2_t + \pi_t \text{ ---------- (ii)}$$

Where:

β_0 = is the intercept term

β_1= captures the long-run effect of coastal infrastructure development on sustainable economic growth.

β_2= is a vector of coefficients associated with the control variables

ε_t=is the white-noise error term.

Table1. Variable Definition and Measurement

Variable	Proxy	Expected Sign
SEG	Real GDP per capita	–
CID	Port infrastructure investment	(+)
HC	Human capital (secondary school enrolment or education expenditure)	(+)
TRD	Trade openness (exports + imports / GDP)	(+)
ENE	Energy infrastructure (electricity generation or access to electricity)	(+)
CO_2	Carbon emissions per capita (environmental sustainability control)	(−)

Source: Researcher's Compilation (2026)

Dynamic Ordinary Least Squares (DOLS) Model

To account for possible endogeneity and serial correlation, the DOLS technique augments the baseline model by including leads and lags of the first differences of the regressors. The DOLS specification is therefore expressed as:

$$SEG_t = \beta_0 + \beta_1 CID_t \beta_2 X_t + \sum_{j=-q}^{q} \gamma_j \Delta CID_{t-j} + \sum_{j=-q}^{q} \delta_j \Delta X_{t-j} + \pi_t \text{ ----------(iii)}$$

Where:

Δ denotes the first difference operator

q is the optimal number of leads and lags selected using information criteria

γ_j and δ_j capture short-run dynamics

Presentation and Analysis of Results

Descriptive Statistics

Table 1 Descriptive Statistics Result of the Estimated Variables

Description	SEG	CID	HC	TRD	ENE	CO_2
Mean	1.574	6.400	36.053	35.346	48.460	0.677
Median	1.404	6.195	35.112	34.460	49.900	0.640
Maximum	12.276	7.568	54.883	53.280	61.800	0.910
Minimum	-4.507	4.860	23.545	20.720	27.300	0.500
Std. Dev.	3.680	0.769	9.101	9.246	8.604	0.106
Skewness	0.521	-0.218	0.154	0.142	-0.370	0.312
Kurtosis	3.706	2.180	1.609	2.116	2.398	1.959
Jarque-B	2.312	1.258	2.958	1.258	1.329	2.150
Prob	0.315	0.533	0.228	0.533	0.515	0.341
Sum	55.095	224.014	1261.869	1237.113	1696.110	23.690
Sum Sq. Dev.	460.550	20.099	2815.884	2906.641	2517.109	0.379
Obs	**35**	**35**	**35**	**35**	**35**	**35**

Source: Researcher's compilation, 2026 from E-view-9.

Table 4.1 presents the descriptive statistics for Sustainable Economic Growth (SEG), Coastal Infrastructure Development (CID), Human Capital (HC), Trade Openness (TRD), Energy Use (ENE), and Carbon Emissions (CO_2), thereby providing preliminary insights into their central tendency, dispersion, and distributional characteristics. The mean values suggest moderately fluctuating economic performance for SEG (1.574) alongside gradual expansion in CID (6.400). Similarly, HC (36.053) and TRD (35.346) indicate consistent improvements in human capacity and trade openness, respectively, while ENE (48.460) reflects significant energy dependence and CO_2 (0.677) signals moderate environmental pressure.

The median values closely align with the means, and the ranges reveal greater variability in SEG relative to the comparatively stable CID, HC, TRD, ENE, and CO_2, highlighting gradual structural and environmental changes over the study period. Moreover, skewness and kurtosis statistics indicate mild asymmetry and predominantly platykurtic distributions. The Jarque–Bera test confirms no serious departures from normality, thereby supporting the reliability of subsequent econometric analyses.

Taken together, these findings suggest that the dataset exhibits adequate variability and stable distributional properties, providing a robust foundation for stationarity testing, cointegration analysis, and long-run modelling within the context of Nigeria's blue economy framework.

Augmented Dickey Fuller (ADF) Unit Root Test Results

Table 2. Results of Unit Root Test at Level and at First Differences using ADF (DOLS)

Variable	Test Statistic	5% critical Value	Test Statistic	5% critical Value	Remark
SEG	----------	----------	-9.696	-2.954	I(1)
CID	----------	----------	-5.365	-2.954	I(1)
HC	----------	----------	-7.455	-2.954	I(1)
ENE	----------	----------	-5.511	-2.964	I(1)
TRD	----------	----------	-5.591	-2.957	I(1)
CO_2	----------	----------	-6.028	-2.954	I(1)

Source: Research's Compilation, 2026 from E-view-9

Table 2 presents the Augmented Dickey-Fuller (ADF) unit root test results for Sustainable Economic Growth (SEG), Coastal Infrastructure Development (CID), Human Capital (HC), Trade Openness (TRD), Energy Use (ENE), and Carbon Emissions (CO_2), assessing their stationarity to ensure the reliability of subsequent econometric analyses. The findings indicate that all variables are non-stationary at their levels but attain stationarity after first differencing. Specifically, the first-differenced values for SEG (-9.696), CID (-5.365), HC (-7.455), ENE (-5.511), TRD (-5.591), and CO_2 (-6.028) reject the null hypothesis of a unit root, confirming that all series are integrated of order one, I(1). This consistent integration across variables justifies the application of cointegration techniques, such as the Johansen test, and long-run estimation methods like Dynamic Ordinary Least Squares (DOLS), facilitating the analysis of stable equilibrium relationships among the studied variables. Consequently, the ADF results establish a robust foundation for time-series analysis, ensuring that both cointegration testing and long-run estimation can produce valid, reliable, and policy-relevant insights into the dynamic interactions between coastal infrastructure, human capital, energy use, trade, carbon emissions, and sustainable economic growth in Nigeria.

Table 3. Correlation matrix between the explanatory variables

Variables	SEG	CID	HC	TRD	ENE	CO_2
SEG	1					
CID	-0.163	1				
HC	-0.030	-0.528	1			
TRD	0.339	0.159	-0.452	1		
ENE	-0.096	-0.552	0.855	-0.359	1	
CO_2	-0.017	0.704	-0.788	0.412	-0.758	1

Source: Research's Compilation, 2026 from E-view-9

Table 3 presents the pairwise correlations among Sustainable Economic Growth (SEG), Coastal Infrastructure Development (CID), Human Capital (HC), Trade Openness (TRD), Energy Use (ENE), and Carbon Emissions (CO_2), offering preliminary insights into the strength and direction of their interrelationships. SEG exhibits generally weak correlations with most variables, but demonstrates a moderate positive association with TRD, suggesting that trade openness plays a supportive role in promoting sustainable economic growth, whereas the immediate influence of other factors appears limited.

Conversely, stronger interrelationships are observed among the explanatory variables, particularly HC, ENE, and CO_2, indicating that improvements in human capital can enhance energy efficiency and mitigate environmental impact, while coastal infrastructure and trade openness may correspond with higher carbon emissions. Collectively, these patterns underscore that sustainable economic growth emerges from the interplay of multiple factors rather than any single determinant. Consequently, the observed relationships justify the application of cointegration techniques and long-run estimation methods, such as Dynamic Ordinary Least Squares (DOLS), to effectively capture both short- and long-term dynamics within Nigeria's evolving blue economy framework.

Results for Johansen Co-Integration Test

Table 4: Johansen Co-Integration Test tracing Max-Eingen & Max-Eigen Statistics

H_0	Trace Statistics	Critical value at 5% level	Prob.**	Max-Eingen Statistics	Critical value at 5% level	Prob.**
None *	160.575	95.754	0.000	69.751	40.078	0.000**
At most 1 *	90.824	69.819	0.000	55.024	33.877	0.000**
At most 2	35.800	47.856	0.407	15.211	27.584	0.731
At most 3	20.589	29.797	0.384	12.155	21.132	0.532
At most 4	8.434	15.495	0.420	8.239	14.265	0.355
At most 5	0.195	3.841	0.659	0.195	3.841	0.659

Trace test indicates 2 co-integrating eqn.(s) at the 0.05 level. Denotes rejection of the hypothesis at the 0.05 level** indicates statistically significant.

Source: Researcher's Compilation, (2026)

Table 4 presents the results of the Johansen cointegration test, employing both Trace and Maximum Eigenvalue statistics to investigate the long-run relationships among Sustainable Economic Growth (SEG), Coastal Infrastructure Development (CID), Human Capital (HC), Trade

Openness (TRD), Energy Use (ENE), and Carbon Emissions (CO_2). The findings reject the null hypotheses of no cointegration and of at most one cointegrating equation at the 5% significance level, whereas the null hypotheses of at most two or more cointegrating equations cannot be rejected. This outcome indicates the presence of two stable long-run relationships, suggesting that these variables move together over time despite individual stochastic trends. The established cointegration therefore provides a sound basis for applying long-run estimation techniques, such as Dynamic Ordinary Least Squares (DOLS), to robustly quantify the equilibrium effects of coastal infrastructure, human capital, trade openness, energy use, and carbon emissions on sustainable economic growth in Nigeria.

Dynamic Ordinary Least Squares (DOLS)

Table 5: Result of Dynamic Least Squares (DOLS) (Dependent Variable: SEG)

Variable	Coefficient	Std. Error	t-Statistic	Prob. **
C	17.632	9.816	1.796	0.100
CID	0.907	1.666	0.545	0.597
HC	-0.525	0.220	-2.384	0.036**
TRD	0.463	0.076	6.055	0.000**
ENE	0.353	0.234	1.507	0.160
CO_2	-54.741	16.922	-3.235	0.008**

R^2: 0.897; Adjusted R^2: 0.711; Durbin-Watson:1.45

Source: Researcher's Compilation, (2026)

Table 5 presents the results of the Dynamic Ordinary Least Squares (DOLS) estimation for the baseline model, with Sustainable Economic Growth (SEG) specified as the dependent variable. The coefficient of Coastal Infrastructure Development (CID) is positive (0.907), aligning with the a priori expectation that improvements in coastal infrastructure facilitate trade, stimulate industrial activity, and enhance logistics efficiency, thereby promoting economic growth ($\beta_1 > 0$). Nevertheless, the associated probability value (0.597) indicates that this relationship is not statistically significant at conventional levels. This suggests that variations in CID alone do not exert a strong or consistent influence on sustainable economic growth in Nigeria over the study period. This observation resonates with the empirical findings of Ndalu and Okene (2024), Anim and Ishioro (2025), and Huq-Sowrov (2025), who similarly reported positive but statistically insignificant effects of infrastructure-related variables on economic growth. By contrast, the results diverge from those of Irshad *et al.* (2023) and Wahab (2024), who documented statistically significant positive impacts of infrastructure on economic performance and trade outcomes.

Despite its statistical insignificance, the positive coefficient remains theoretically consistent. It implies that enhanced coastal infrastructure has the potential to stimulate economic activity, particularly when complemented by improvements in human capital, reliable energy supply, institutional quality, and effective trade facilitation. Accordingly, the result provides qualified support for the infrastructure-led growth hypothesis, indicating that CID's impact on sustainable economic growth in Nigeria is likely mediated through synergistic interactions with other macroeconomic and structural drivers rather than functioning as an isolated determinant.

In contrast, the coefficient of Human Capital (HC) is negative (−0.525) and statistically significant at the 5 per cent level ($p = 0.036$). This outcome contradicts the a priori expectation ($\beta_2 > 0$), which posits that improvements in education, skills acquisition, and workforce productivity should stimulate sustainable economic growth. The negative and significant coefficient suggests

that increases in human capital were associated with a decline in SEG during the study period. This counterintuitive result may reflect structural inefficiencies within the economy, including underemployment of skilled labour, mismatches between acquired competencies and labour market needs, limited industrial capacity, and weak absorption of human capital into productive sectors. In this regard, the finding aligns with the empirical evidence reported by Ogundari and Awokuse (2018), Pelinescu (2019), Lawanson (2020), Yakubu and Akanegbu (2022), and Adeniyi *et al*. (2023), who documented weak, insignificant, negative growth effects of human capital under contexts characterised by structural and institutional constraints. Conversely, it deviates from the studies of Hanushek and Woessmann (2020), Aslam and Rawal (2021), and Churchill and Yew (2022), who reported strong and statistically significant positive effects of human capital on economic growth. Notwithstanding its divergence from theoretical expectations, this finding underscores the imperative of aligning educational outcomes and training systems with the productive structure of the economy. It highlights that human capital development, in isolation, may not automatically translate into economic gains unless supported by complementary institutional, infrastructural, and policy frameworks that enable effective and productive utilisation.

Moreover, the coefficient of Trade Openness (TRD) is positive (0.463) and statistically significant at the 1 per cent level ($p = 0.000$), consistent with the a priori expectation ($\beta_3 > 0$). This finding confirms that deeper integration into international trade fosters sustainable economic growth through expanded market access, enhanced export competitiveness, technology diffusion, and increased capital inflows. The positive and statistically significant effect indicates that trade openness substantially contributed to SEG in Nigeria over the study period. This result corroborates the findings of Tahir and Azid (2020) and Adebayo and Odugbesan (2022), who reported significant positive effects of trade openness on economic growth in developing economies, while diverging from the evidence presented by Ulaşan (2019), Sakyi *et al.* (2020), and Were (2021), who suggested that the trade–growth relationship may be weak, insignificant, or conditional on structural and institutional factors. Importantly, the result highlights the pivotal role of trade liberalisation and external economic linkages in stimulating industrial performance, enhancing allocative efficiency, and promoting economic diversification, thereby reinforcing the need for policies that expand exports, reduce trade barriers, strengthen productive capacity, and deepen global economic integration to sustain long-term growth.

Similarly, the coefficient of Energy Use (ENE) is positive (0.353), with a probability value of 0.160, while Carbon Emissions (CO_2) exhibit a negative coefficient (−54.741) with a probability value of 0.008. These outcomes align with theoretical expectations, wherein energy use is anticipated to positively influence SEG ($\beta_4 > 0$), and carbon emissions are expected to exert a negative effect ($\beta_5 < 0$). Although the positive coefficient of ENE is consistent with theory, its statistical insignificance suggests that variations in energy consumption alone may not produce a strong or consistent impact on sustainable economic growth during the study period. Conversely, the negative and statistically significant coefficient of CO_2 confirms the detrimental effects of environmental degradation, indicating that rising carbon emissions substantially constrain sustainable growth in Nigeria. Consequently, while energy use can support economic activity, its effectiveness depends on efficiency, technological advancement, and sectoral allocation, whereas environmental pressures from carbon emissions significantly hinder sustainable economic progress. These findings underscore the importance of policies that promote energy efficiency, cleaner technologies, and integration of environmental sustainability into broader economic development strategies.

Overall, the model exhibits strong explanatory power, with an R^2 of 0.897, indicating that approximately 89.7 per cent of the variation in SEG is jointly explained by CID, HC, TRD, ENE, and CO_2. Additionally, the adjusted R^2 of 0.711, which accounts for the number of explanatory variables and sample size, confirms that the model maintains substantial explanatory capacity after correcting for potential over fitting. Furthermore, the Durbin–Watson statistic of 1.449 suggests mild positive autocorrelation in the residuals, which remains within acceptable bounds for time-series analysis, indicating generally reliable estimates. Collectively, these diagnostic indicators demonstrate that the DOLS specification provides a robust and informative framework for analysing the determinants of sustainable economic growth in Nigeria, effectively capturing the combined influence of infrastructure development, human capital, trade openness, energy use, and environmental factors. Consequently, the model's strong explanatory performance and satisfactory residual behaviour enhance confidence in the empirical findings and reinforce the credibility of the resulting policy recommendations.

Table 6: Summary of Diagnostic Tests

Test	Test Statistic / Value	Probability (p-value)	Decision (5% Level)	Interpretation
Wald Test (Joint Significance)	F = 1343.021; χ^2 = 6715.106	0.0000	Reject H_0	Variables are jointly significant.
Breusch-Godfrey Serial Correlation LM Test	F = 0.916; Obs*R^2 = 2.649	0.4154 (F); 0.2660 (χ^2)	Fail to reject H_0	No serial correlation; residuals are independent.
Heteroskedasticity Test (Breusch-Pagan-Godfrey)	F = 1.038; Obs*R^2 = 9.530	0.4414 (F); 0.3899 (χ^2)	Fail to reject H_0	Residuals have constant variance.
Heteroskedasticity Test (Harvey)	F = 1.122; Obs*R^2 = 10.066	0.3873 (F); 0.3452 (χ^2)	Fail to reject H_0	No heteroskedasticity detected.
Ramsey RESET Test	t = 0.0225, df = 22; F = 0.001	0.9823	Fail to reject H_0	Model is correctly specified.
Residual Normality (Jarque-Bera Test)	JB = 13.704; Skew = -1.194; Kurt = 5.138	0.0011	Reject H_0	Residuals are non-normal (negative skew, leptokurtic).
Residual Mean	Mean = -5.27e-16	—	—	Residuals centred at zero; no bias.

Source: Research's Compilation, 2026

Summary, Conclusion and policy Implication

This study examined the relationship between coastal infrastructure development and sustainable economic growth in Nigeria over the period 1990–2024. The analysis employed the Dynamic Ordinary Least Squares (DOLS) approach. Data were drawn from the Central Bank of Nigeria (CBN), the National Bureau of Statistics (NBS), and the World Bank's World Development Indicators. The results indicate that both coastal infrastructure development and trade openness positively influence sustainable economic growth, whereas human capital exhibited a negative effect. Energy use demonstrated a positive but statistically insignificant impact, while carbon emissions significantly constrained growth. Notably, coastal infrastructure development alone did not exert a statistically significant effect, suggesting that its contribution to economic growth is contingent upon complementary factors such as institutional quality, effective utilisation of human capital, and robust trade facilitation mechanisms. Similarly, the negative coefficient of human capital reflects structural inefficiencies—such as underemployment, skill mismatches, and limited industrial absorption—that hinder its productive contribution to economic growth.

The study further revealed that trade openness remains a key driver of sustainable economic growth, emphasising the importance of export promotion, trade liberalisation, and deeper integration into the global economy. Conversely, carbon emissions were found to impede economic progress, underscoring the critical need for environmental sustainability measures. While coastal infrastructure development exhibits a positive influence, its effectiveness is maximised only when integrated with human capital development, energy efficiency, and strong institutional support, thereby achieving meaningful long-term growth outcomes.

These findings carry several important policy implications. First, strategic investment in ports, logistics, and maritime infrastructure should be prioritised to enhance trade and industrial performance. Second, education and skills development programmes must be aligned with labour market requirements to improve the productive utilisation of human capital. Third, policies that promote trade liberalisation, export diversification, and foreign investment should be strengthened to fully harness the benefits of global economic integration. Fourth, energy efficiency and the adoption of cleaner technologies should be encouraged, alongside regulatory measures to mitigate carbon emissions. Overall, the evidence underscores the necessity of a coordinated policy framework that integrates infrastructure development, human capital, trade, energy, and environmental sustainability to achieve inclusive, resilient, and sustainable economic growth in Nigeria.

Recommendations

Based on the findings, the study recommends that the Nigerian government pursue coordinated investments in coastal infrastructure, human capital development, trade facilitation, and clean energy technologies to maximise their combined and synergistic effects on sustainable economic growth. In addition, institutional reforms that strengthen governance, reinforce regulatory frameworks, and ensure the efficient utilisation of skilled labour should be prioritised, thereby transforming infrastructure and trade investments into inclusive, resilient, and long-term economic development outcomes.

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