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Effect of Green Shipping Practices on Marine Tourism in Nigeria

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ABSTRACT

The study examined the effect of green shipping practices on marine tourism in Nigeria focusing on marine tourism (MARITO) which served as the regressand or measure. The dimensions or the predictor variables of green shipping practices analyzed included energy-efficient vessels (ENEGEV), decarbonization of maritime transport (DEMATR), and technological innovation (TECHIN) and they served as the regressors. The data utilized for the study were time series data sourced from the Nigerian Ports Authority (NPA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Shippers' Council (NSC), Nigerian Navy and Marine Police (NNMP), National Inland Waterways Authority (NIWA) and Federal Ministry of Marine and Blue Economy (FMMBE) between the period of 1990 to 2024. The analytical techniques employed were Phillip-Perron unit root test and bounds cointegration test and the model was estimated using Autoregressive Distributed Lag (ARDL) model. The unit root test revealed that the variables have mixed order of integration I(0) and I(1). This led to the application of ARDL bounds test to confirm cointegration. The result indicated the presence of a long run relationship amongst the dependent and independent variables examined in the respective models. The ARDL results showed that energy-efficient vessels contributed significantly to marine tourism only in the long run while decarbonization of maritime transport and technological innovation have significant positive effects on marine tourism both in the short and long run. In addition, the result revealed that energy-efficient vessel has significant positive effect on port digitalization in the short run. Thus, the study recommends among other things, that to enhance growth in Nigeria's marine tourism sector, government policy should be made to align with technological innovations by developing adaptive regulatory policies that evolve alongside technological change to ensure synergy rather than conflict. Also, to improve efficiency in Nigeria's marine tourism, regulatory frameworks should prioritize carbon reduction strategies, including stricter emission controls and incentives for low-carbon shipping practices.

Keywords: Green Shipping Practices, Energy-Efficient Vessels, Decarbonization of Maritime Transport, Technological Innovation, Marine Tourism

INTRODUCTION

The global maritime transportation sector plays a pivotal role in the movement of goods and resources, facilitating international trade and contributing significantly to the global economy. Despite its economic benefits, this sector is one of the major contributors to greenhouse gas (GHG) emissions, accounting for nearly 3% of global emissions (Yui-Yip et al, 2024). The need for green shipping practices in maritime transportation has therefore gained considerable attention in recent years. Historically, shipping has relied on fossil fuels such as heavy fuel oil, which, while efficient for propulsion, has led to significant environmental challenges. Researchers and policymakers alike are now exploring innovative solutions to address these challenges, seeking to balance economic growth with environmental stewardship (Bofan et al, 2024).

Early discussions on green shipping practices centered on reducing energy consumption through operational improvements. Researchers in the 1990s and early 2000s explored methods such as slow steaming, improved vessel design, and enhanced routing systems to optimize fuel usage. These efforts showed promising results in reducing energy consumption but were insufficient to address the broader issue of carbon emissions (Mander, 2017). The recognition that operational efficiencies alone could not meet global climate goals led to an increased focus on alternative fuels and technologies. One area of research has been the development and adoption of alternative marine fuels. Liquefied natural gas (LNG) emerged as a potential transitional fuel, offering reduced sulfur oxide and nitrogen oxide emissions compared to conventional fuels (Livanious & Papadopoulos, 2022). Recent advancements in battery technologies have further expanded the possibilities for hybrid and fully electric vessels, particularly for short-sea shipping and ferries. Researchers continue to address challenges such as energy density, battery lifespan, and charging infrastructure to enhance the feasibility of these systems (Giovanni et al, 2024).

However, apart from the fact that the empirical evidence based on these studies is mixed and often contradictory, because of differences in political, economic, and geographical structure, the results cannot be applicable for Nigeria. More so, there is a dearth of (limited) literature in Nigeria and few studies like (Jacob & Umoh, 2022; Ali, 2023; Elisha, 2019) only looked at the marine tourism from the angle of opportunity, challenges, and effective management. These authors failed to establish erudite scholarly findings in their work. Additionally, the relationship between the blue economy and sustainable development remains largely sectoral due to the concept of "blue economy; sustainable development" remaining ambiguous and open-ended. This demonstrates the need for additional research to investigate these connections using a more programmatic approach.

Nigeria as a country enjoys vast maritime resources which include ocean, lakes and rivers which have potential in marine tourism among others. Nigerian Government recognizes these marine ecosystems as its natural capital and protects and maintains them accordingly. It has been reported that 95 per cent of Nigerian trade, by volume, and more than 70 per cent of its value moves around aboard ships and is handled by seaports nationwide (Elegbede et al., 2023).

In spite of a few attempts, there is limited knowledge on the scope and scale of green shipping practices and marine tourism development in Nigeria, as literature across the wider maritime industry, including shipping, port, and maritime logistics businesses indicate so (Osuji & Agbakwru, 2024; Bofan et al, 2024; Nwokolo & Ahia, 2023). In addition, there is limited attempt to apply quantitative and secondary/time series data and tools to mine textual information embedded in journal databases to examine the effect of the variables of green shipping practices (technological innovations, energy-efficient vessels, and decarbonization of marine transport) and marine tourism (Enyioko & Amadi, 2025; UNEP (2024); Osuji & Agbakwru, 2024). Furthermore, there is a lack of understanding on what green shipping practice is expected to achieve in both short-run and long-run means and marine tourism development studies, with inconsistencies and conflicting views on the use of various concepts, models and measurements. This study sought and filled that gap that existed in the literature by investigating the effect green shipping practices on marine tourism in Nigeria.

Objectives of the Study

The following specific objectives were addressed in the study:

i. To evaluate the effect of energy-efficient vessels on marine tourism.

ii. To determine the effect of decarbonization of marine transport on marine tourism.

iii. To determine the effect of technological innovations on marine tourism

Research Questions

The following research questions were raised based on the objectives of the study:

i. To what extent do energy-efficient vessels affect marine tourism?

ii. To what extent does decarbonization of marine transport affect marine tourism?

iii. To what extent do technological innovations affect marine tourism?

Research Hypotheses

The following research hypotheses were tested in the study:

Ho1: Energy-efficient vessels have no significant effect on marine tourism.

Ho2: Decarbonization of marine transport has no significant effect on marine tourism.

Ho3: Technological innovations have no significant effect on marine tourism.

LITERATURE REVIEW

Theoretical Framework

Green shipping theories explore how to minimize the environmental impact of shipping while balancing economic and operational realities. They encompass a range of approaches. In this section, theories such as green theory and blue economy theory, have been used in this study.

Green Theory

Green Theory is a profound and evolving approach within literary and cultural studies that focuses on the relationship between humans and the environment (Wake & Malpas, 2013). Also known as ecocriticism, Green Theory examines how nature is portrayed in literature and the role of literature in advocating environmental protection. It encompasses physical phenomena such as plants, animals, and landscapes and a powerful force often called "Nature" (Marland, 2013).

Within Green Theory, culture is viewed as human activity concerning nature, including inhabitation, cultivation, business, and worship, and human culture is seen as part of the broader natural culture. The pastoral tradition in literature, celebrated for its idealized portrayal of rural life and nature, is critiqued within Green Theory for mystifying rural production relations (Coupe, 2013). At the same time, Kenneth Burke stressed the need to integrate ecological awareness with literary criticism, viewing human language as rooted in biological processes and nature (Nwokolo & Ahia, 2023).

Green Theory is instrumental in promoting environmental justice and sustainability, making it a cornerstone in literary and maritime studies. It offers profound insights into the complex relationships between humans and the natural world. It continues to evolve in addressing global issues, providing hope for a more balanced and harmonious future (Chang & Danao, 2017). Through the works of influential scholars and critical strands like ecofeminism, Green Theory challenges traditional notions and invites us to reconsider our relationship with nature, firmly establishing itself as a vital framework for shaping a more sustainable future for all, hence its application as a very anchor theory for the effect of green shipping practices on blue economy development (Chang & Danao, 2017).

Blue Economy Theory

The Blue Economy Theory advocates for sustainable use of ocean resources to drive economic growth, improve livelihoods, and create jobs while simultaneously preserving the health of marine ecosystems. It emphasizes decoupling socioeconomic development from environmental degradation, ensuring that ocean-related activities contribute to both prosperity and ecological well-being. This approach aligns with the United Nations Sustainable Development Goal (UNSDG) 14 (Youssef, 2023). The idea of the "blue economy theory" was conceived at the Rio+20 United Nations Conference on Sustainable Development, held in Rio de Janeiro in June 2012. This conference addressed two key themes: the further development and refinement of the Institutional Framework for Sustainable Development and the advancement of the "green economy" concept. The outcome of the meeting reaffirmed poverty eradication as its key challenge and focused on the green economy as a tool to achieve both poverty eradication and sustainable development (World Bank, 2022). The blue economy theory has been presented subsequently in many fora and is viewed as an alternative economic model for sustainable development that puts the oceans at the centre of this approach.

The oceans cover a large proportion of the earth's surface and make up more than 95 per cent of the biosphere. They provide much of the world's population with food and livelihoods and are a significant means of transport in global trade. The marine and coastal environments also constitute key resources for the important global tourism industry, supporting all aspects of the tourism development cycle, from infrastructure and the familiar "sun, sand and sea" formula to the diverse and expanding domain of eco-tourism (Hussein et al., 2017). The sea also offers vast potential for renewable "blue energy" production from wind, wave, tidal, thermal and biomass sources. The potential of the oceans to meet sustainable development needs is enormous, but only if the oceans can be maintained in and/ or restored to a healthy and productive state (Jakobsen et al., 2023). The blue economy embraces the same desired outcomes as the Rio+20 green economy initiative: "[achieving] improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2024).

Conceptual Review

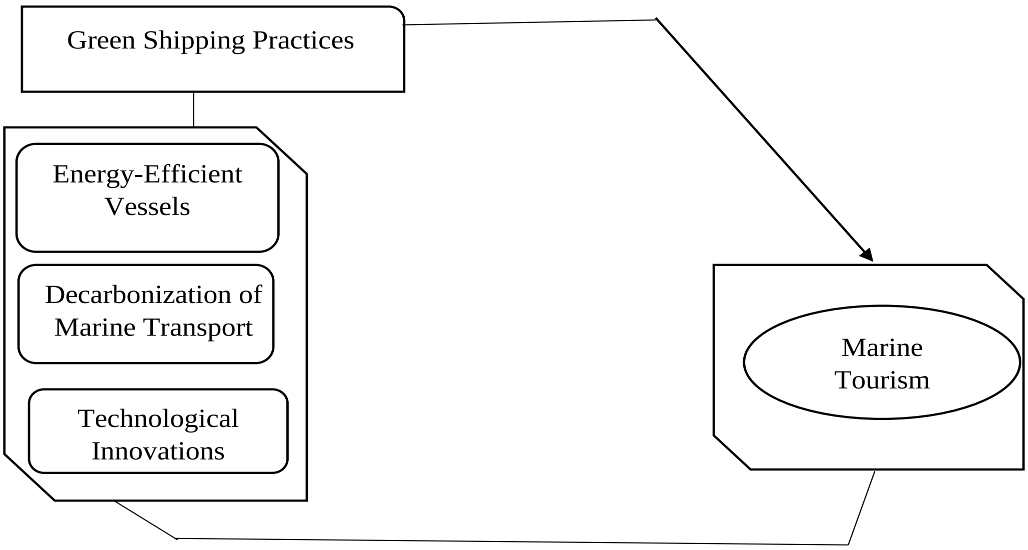

Figure 1: Conceptual Framework of the Effect of Green Shipping Practices on Marine Tourism in Nigeria

Sources: Elegbede et al.(2023a); Enyioko and Amadi (2025); Odiegwu and Zeb-Obipi (2023); Mi et al. (2024), Karagkouni and Boile (2024), UNCTAD (2024), Aja (2024), Rok et al. (2024) and Empirical Literature Survey, 2025.

Green Shipping Practices

Green shipping practices involve a range of strategies to minimize the environmental impact of shipping, including using alternative fuels, reducing emissions through operational efficiencies, optimizing routes, and minimizing waste through sustainable packaging and recycling. These practices aim to improve energy efficiency, reduce pollution, and protect marine ecosystems (Mi et al., 2024). The maritime industry has long been a cornerstone of global trade and economic activity, but its environmental footprint, particularly its greenhouse gas emissions, has increasingly come under scrutiny (Mikalai et al, 2024). The concept of "green shipping" has emerged as a response to growing environmental concerns, with researchers and industry stakeholders focusing on practices and technologies that mitigate the sector's impact on the environment.

Green shipping has taken center stage of many environmental discussions. Osuji and Agbakwru (2024) noted that green shipping involves the implementation of the principles of sustainable development in the shipping sector. It defines how shipping firms go about their environmental responsibility in the course of rendering their shipping services (Poi & Moko, 2023).

Port operations and their role in green shipping have been extensively studied as well. Shore power systems, also known as cold ironing, have been identified as a critical strategy for reducing emissions from ships while at berth (Glavinovic et al, 2023). These systems allow ships to connect to the local electrical grid, eliminating the need to run auxiliary engines for power. Case studies from ports in Europe and North America have demonstrated significant reductions in air pollutants and greenhouse gas emissions. The integration of renewable energy sources into port operations, such as wind and solar, has further enhanced the environmental performance of these systems.

Green shipping has emerged as a critical area of focus within the maritime industry, driven by the need to reduce environmental impacts, enhance energy efficiency, and address growing concerns over climate change (Kee-Hung et al, 2011). Several studies have investigated various aspects of green shipping, exploring its potential to contribute to a sustainable maritime sector. This conceptual review examines the relevant literature on topics closely related to green shipping practices, technologies, and strategies, with a particular emphasis on research that informs the objectives outlined.

The concept of green shipping has been widely explored through investigations into innovative practices and technological advancements aimed at minimizing the environmental footprint of maritime transportation (Mi et al, 2024). A significant body of research has delved into alternative fuel options, such as liquefied natural gas (LNG), hydrogen, ammonia, and biofuels, as viable substitutes for traditional fossil fuels.

Studies have examined the impact of hull design optimization, air lubrication systems, and waste heat recovery technologies on energy efficiency (Yuan et al, 2021; Akomolafe et al., 2022; Atedhor,, 2023). For instance, advancements in hull design, such as the use of bulbous bows and optimized hull coatings, have been shown to reduce drag and improve fuel efficiency by up to 10%. Additionally, the implementation of air lubrication systems, which create a layer of air bubbles along the hull's surface, has demonstrated energy savings of up to 8%.

The concept of green ports has gained traction, with studies exploring the integration of renewable energy sources, electrification of port equipment, and the use of automated systems to enhance operational efficiency VDC (Kolich & Kirtovic, 2021). The transition to green shipping has also been examined through the lens of digitalization and smart technologies. The use of big data, the Internet of Things (IoT), and artificial intelligence (AI) has been explored to optimize ship operations, route planning, and fuel consumption. For instance, studies have demonstrated the potential of AI-driven weather routing systems to reduce fuel consumption by 5% to 10% by identifying the most efficient routes based on real-time weather data. Additionally, digital twins, which create virtual replicas of ships and their systems, have been investigated for their potential to improve maintenance practices and operational efficiency.

Energy-Efficient Vessels

The concept of energy-efficient vessels involves minimizing energy consumption and emissions while maintaining or improving ship performance. This includes reducing fuel consumption, improving fuel efficiency, and lowering greenhouse gas emissions. It's achieved through a combination of design improvements, operational practices, and technological advancements (Hassan et al., 2023).

Energy-efficient vessels prioritize minimizing energy consumption and emissions while maximizing operational efficiency. This involves incorporating technologies and practices that reduce fuel consumption, lower greenhouse gas emissions, and improve overall operational performance. Key aspects include optimizing hull design, utilizing efficient propulsion systems, implementing advanced energy management strategies, and promoting operational practices that minimize energy waste (IMO, 2024).

Energy efficiency indicators for sea-going ships intended for international voyages are used for a decade and are provided by the International Maritime Organization (IMO). They can be divided into design and operational ones. Firstly, a design indicator labelled as energy efficiency design index (EEDI) became mandatory for new ships over 400 GT built between 2013 and 2015, under the MARPOL Annex VI. EEDI criterion has been strengthened over the years, namely in 2015, 2020, and expected to be strengthened in 2025. In 2023, existing ships faced the IMO's regulatory examination through the compulsory requirements of the energy efficiency existing ship index (EEXI) (El-Omda et al., 2025).

Energy efficiency can bridge the gap. A range of innovative, practical, and effective technologies are available today which can increase the energy efficiency of vessels, decrease net energy input and fuel demand, and drive significant reductions in emissions. At the same time, implementing these measures can potentially reduce emission costs related to regulations like EU ETS and FuelEU Maritime while improving ship efficiency (Kolich. & Kurtovic, 2021).

Energy efficiency scholars distinguish between technological and operational energy efficiency measures (Ganeshu et al., 2023). Technological measures such as Flettner rotors, propellor boss cap fins, and main engine de-ratings require capital outlays by shipowners. Operational measures do not require major investment but focus on improved voyage execution, including speed reduction, weather routing, trim optimization, auto-pilot optimization, engine optimization, reduced ballasting, port-call optimization, and just-in-time arrival in port (IMO, 2018). The current review focuses on the literature on operational measures, considering energy efficiency in voyage planning and execution in the different shipping sectors because their trading patterns differ.

Decarbonization of Marine Transport

Maritime decarbonization is the process of reducing greenhouse gas (GHG) emissions from the global maritime sector, with an overall goal of placing the sector on a pathway that limits global temperature rise to 1.5-degrees Celsius. The tool can analyze the costs and emissions reduction impacts for three main carbon reduction strategies: electrification, RNG, and green hydrogen (Akujor et al., 2022).

Decarbonizing marine transport involves transitioning the shipping industry to reduce its greenhouse gas emissions and move towards a net-zero future. This is a global effort driven by the International Maritime Organization (IMO), with the goal of achieving net-zero emissions by or around 2050. The transition involves several strategies, including using alternative fuels, improving vessel efficiency, and adopting new technologies (IMO, 2021).

Maritime decarbonization is the process of reducing greenhouse gas (GHG) emissions from the global maritime sector, with an overall goal of placing the sector on a pathway that limits global temperature rise to 1.5-degrees Celsius. The maritime industry is at the onset of a once-in-a century energy transition as it looks for ways to decarbonize rapidly through electrification and low-carbon fuels, optimization tools, and efficiency technologies (Luis et al., 2023).

The effectiveness of decarbonization strategies and technologies in reducing greenhouse gas (GHG) emissions from maritime transportation is a growing area of focus due to its significant implications for global climate change mitigation (Thalis et al, 2020). Evaluating these approaches is essential for identifying the best pathways to achieving substantial reductions in GHG emissions while maintaining operational efficiency and economic viability. This literature review examines how researchers have assessed the effectiveness of various decarbonization strategies and technologies in reducing emissions, highlighting key insights and metrics used to measure their impact within the maritime sector.

Decarbonization strategies in the maritime industry have been extensively evaluated, with a focus on their effectiveness in reducing greenhouse gas emissions. The IMO's Initial Strategy on the Reduction of Greenhouse Gas Emissions from Ships, which aims to reduce emissions by at least 50% by 2050 compared to 2008 levels, has provided a framework for research in this area. Studies have analyzed various approaches, including operational measures, market-based mechanisms, and technological solutions (Serra & Fancello, 2020).

Technological Innovations

Technology innovation is defined as the creation and application of new or improved technologies, tools, systems, and processes that bring about significant advancements or breakthroughs in various fields (Olaniyi et al., 2024). It involves harnessing knowledge, expertise, and resources to develop innovative solutions that solve problems, improve efficiency, drive progress, and deliver value (El-Omda, et al., 2025).

Technological innovation refers to the implementation of new technologies or the significant improvement of existing technologies, resulting in advances in efficiency, productivity and competitiveness (Atedhor, 2023). This concept covers various activities, from the development of new products and processes, to the acquisition of more advanced management systems or the improvement of technological infrastructure (Barbu et al., 2022).

Through technological innovation, it becomes possible for businesses to adapt more quickly to market changes, meet public demands effectively and stand out in an increasingly competitive environment. In addition, technological innovation can reduce operating costs, increase the quality of products and services and open up new business opportunities, thus contributing to the creation of value and the longevity of companies (Bofan et al., 2024).

Technology innovation is a major driver of economic growth and competitiveness. It fosters the development of new industries, job creation, and increased productivity. Countries and organizations that prioritize technology innovation can gain a competitive advantage, attract investment, and stimulate economic development (Kolios, 2024). Technology innovation drives improvements in efficiency and productivity. By introducing new technologies, automation, and streamlined processes, organizations can optimize operations, reduce costs, and increase output. This leads to improved efficiency, higher profitability, and the ability to deliver products and services more effectively (Jakobsen et al., 2023).

Technology innovation empowers individuals and enhances user experiences. It provides tools, platforms, and services that enable individuals to access information, connect with others, express themselves, and participate in societal activities. Innovations like social media, mobile applications, and online platforms have transformed the way people communicate, collaborate, and engage with the world (Jakobsen et al., 2023). Technology innovation is crucial for achieving sustainable development goals. It enables the development of clean technologies, renewable energy solutions, and environmentally friendly practices. By leveraging technology, societies can transition to more sustainable and resource-efficient systems, mitigating the impact on the environment and fostering long-term sustainability (Kabeyi & Olanrewaju, 2023).

Marine Tourism

Marine tourism involves recreational activities and travel focused on the marine environment, including coastal areas and offshore waters. It encompasses various forms like scuba diving, surfing, marine wildlife tourism, nautical tourism, and more. Essentially, it's tourism that is centered around the ocean and its resources *(*Nusraningrum et al., 2023). Marine tourism includes those recreational activities which involve travel away from one's place of residence and which have as their host or focus the marine environment. Such environments include waters that are both saline and tide affected (Ozili, 2024).

Marine tourism involves travel experiences focused on ocean and coastal environments, including activities like diving, snorkeling, and whale watching, promoting both recreation and conservation. This form of tourism plays a significant role in the economy, often boosting local communities while highlighting the need for sustainable practices to protect marine ecosystems. Understanding marine tourism helps in appreciating the balance between enjoying and preserving our vital marine resources. (Nusraningrum et al., 2023).

Marine tourism is defined as the sector of the tourism industry that is based on tourists and visitors taking part in active and passive leisure and holiday pursuits or journeys on (or in) coastal waters, their shorelines and their immediate hinterlands (Giwa 2018)). Marine tourism activities can be grouped into three categories, namely: • boating and cruising - which includes yachting, cruising and ferrying; • sports and recreation – which includes marine activities, such as diving, swimming and sailing; and the leisure category – consisting of eco-marine tourism such as visits to marine protected areas (MPAs), and adventure and viewing tourism; for example, whale-watching and shark diving respectively (Gavalas et al., 2022).

Marine tourism refers to travel and recreational activities undertaken in coastal and marine environments, encompassing a wide range of leisure pursuits and experiences. These activities include recreational boating, scuba diving, snorkeling, whale watching, fishing tours, and cruise tourism (Akomolafe et al., 2022). Each of these activities not only attracts tourists seeking unique marine experiences but also contributes significantly to local economies and environmental conservation efforts. Activities Marine tourism activities can be categorized into several types. Recreational boating and water sports, such as sailing, yachting, jet skiing, and windsurfing, are popular among tourists seeking leisure and adventure in coastal waters (Giwa 2018). Scuba diving and snorkeling appeal to marine enthusiasts interested in exploring underwater ecosystems, coral reefs, and marine wildlife habitats. Cruise tourism offers comprehensive experiences of coastal destinations, combining leisure activities with cultural and historical tours (Dzhengiz & Niesten, 2020). Fishing tourism, including fishing tours and charters, attracts anglers interested in sport fishing, contributing to local economies through tourism expenditures and licensing fees (Ali, 2023).

Effect of Energy-Efficient Vessels on Marine Tourism

Ahmed et al. (2020) posit that green shipping contributes to sustainable tourism by reducing carbon emissions, minimizing pollution, and conserving marine ecosystems. It promotes energy-efficient practices and the use of sustainable fuels, enhancing the environmental appeal of destinations. Ali (2023) studied sustainable blue economy and its impact on economic growth in Africa. Case study: Zanzibar State and found that mode of transport to be much more energy-efficient than other modes and, consequently, to produce less Co_2 per passenger carried. Furthermore, according to the European Transport Safety Council, coastal shipping is relatively safer than other modes of transport, such as road and rail transport. Jinggai et al. (2024) conducted a study on shore power for reduction of shipping emission in port: A bibliometric analysis. The study revealed that using coastal shipping increases corporate social responsibility from which various benefits for transportation are derived, such as reduced air pollution and highway noise, mitigated highway congestion, and improved road safety. Furthermore, coastal shipping is an economical transport mode due to its efficient energy consumption and lower infrastructure expenditures.

Kolios (2024) studied retrofitting technologies for eco-friendly ship structures: A risk analysis perspective. revealed that efforts have been made to address the implications of these benefits of technological innovations and maritime transport decarbonization, but the majority were focused on freight rather passenger transport. Most studies have placed the competitiveness, effectiveness and efficiency of coastal shipping in freight transport within the realm of multimodal logistics supply chains. Akujor et al. (2022) did a study on decarbonization of the transport sector in Nigeria. The study used simple regression and found that various components and strategies have been developed to improve the efficiency of technological innovations and maritime transport decarbonization, including port infrastructure, administrative infrastructure, port time, support policies, and funding from governments.

Ho_1: Energy-efficient vessels have no significant effect on marine tourism.

Effect Of Decarbonization of Marine Transport on Marine Tourism

Yin et al. (2022) conducted a study on shore power management for green shipping under international river transportation with the help of an expository study, the paper suggested a theoretical intermodal competition model to compare sustainable and road transport and concluded that the EU needs to concentrate on port and transport system efficiency to promote technological innovations and maritime transport decarbonization. By applying factor analysis, Omai et al. (2018) investigated the effect of supply chain practices on sustainable supply chain performance in Kenyan textile and apparel industry. The study revealed that specific supply chain strategies integrate technological innovations and maritime transport decarbonization into multimodal transport chains.

Wenhai et al. (2019) examined the successful blue economy examples with an emphasis on international perspectives. The study revealed that the development of technological innovations and maritime transport decarbonization needed to be put into practice in the logistics sector and that there was a need for continued care and maintenance by logistics personnel. Anthony et al. (2021) proposed a framework for determining responsibility for ferry safety goals. Barone et al. (2024) developed an adaptive systems approach to determine vulnerability management actions through analysis of the Sewol ferry disaster. Carter et al. (2024) suggested a disaster management framework for the passenger shipping industry based on insights from the literature. In addition to research into the benefits derived from social, environmental, and economic perspectives, the competitiveness of coastal shipping has also been addressed in comparison to road transport by numerous previous studies. Ho_2: Decarbonization of marine transport has no significant effect on marine tourism.

Effect of Technological Innovations on Marine Tourism -

Stark et al. (2022) insist that green shipping practices, such as reducing carbon emissions and waste, are increasingly important for both environmental sustainability and the success of marine tourism. Empirical studies show a positive correlation between green shipping initiatives and improved environmental performance in the maritime industry, and also highlight the potential for these practices to enhance the appeal and sustainability of marine tourism. Song, (2024) maintains that green shipping practices, encompassing environmentally friendly shipping technologies and operational strategies, can positively influence marine tourism by reducing pollution and enhancing the appeal of coastal areas. Conversely, marine tourism itself can be a driver for green shipping initiatives, as increased environmental awareness among tourists and the demand for sustainable practices can influence shipping companies and port operations. Aminul et al. (2024) conducted a study on accelerating the green hydrogen revolution: A comprehensive analysis of technological advancements and policy interventions. The study used correlation analysis and found that technological innovations and maritime transport decarbonization is promoted as an alternative to road freight transport in Greece by comparing the private and social costs, such as road accidents, environmental impacts, and other undesirable externalities. Notwithstanding the fact that coastal shipping is of critical importance for the transport of people and goods, lack of safety precautions leading to ferry disasters can be economically devastating (Yin et al., 2019). Ho_3: Technological innovations have no significant effect on marine tourism.

MATERIALS AND METHODS

Research Design

Research design is the blueprint that guides the researcher in acquiring and generating necessary data for the study; so, this study adopted the ex-post facto research design which requires the usage of historical data to forecast future trends employing regression techniques.

Method of Data Collection

Secondary sources of data were used as the main data collection sources in which accuracy, availability, adequacy, authority, scope, suitability and sources of data were considered for relevance. The relevant data for this study were collected from the annual reports and accounts of Nigerian Ports Authority, NIMASA, Shippers Council, Nigeria Inland Waterways Authority (NIWA), Federal Ministry of Blue Economy and National Bureau of Statistics Annual Statistical Bulletins of the various years in question from their official website. The data collected were from the period of 1990-2024.

Model Specification

This research work adopted the model of Odiegwu and Enyioko (2022a); Felício et al. (2021).; Odiegwu & Zeb-Obipi (2023) with slight modifications (for example; marine tourism, port digitalization, sustainable fisheries and ecological sustainability). The researchers expressed blue economy development (BED) indicators as a function of green shipping practices (GSP). Based on that, the model of the study is stated thus:

$$Y = b_o + b_1x_1 + b_2x_2 + b_3x_3 + e$$

$$MARITO = ß_0 + ß_1\ ENEGEV + ß_2\ DEMATR + ß_3\ TECHIN + U_t$$

Where:

MARITO = f(ENEGEV, DEMATR, TECHIN)

Where;

MARITO= Marine tourism

ENEGEV= Energy-efficient vessels

DEMATR= Decarbonization of marine transport

TECHIN=Technological innovations

A priori Expectation - The a priori expectations adopted the findings of Felício et al. (2021); Odiegwu and Zeb-Obipi (2023) and Nguyen et al. (2025), which all stated a positive significant effect of independent variables on dependent variables/parameters/indicators.

Techniques of Data Analyses - The data generated/collected was subjected to analysis. The analytical tool used was Eviews 12. Several data analyses techniques were employed for the purposes of analyzing the collected data set and drawing conclusions based on them.

Test for Stationarity - In carrying out this research work, it was important to test the stationarity properties of the time series.

Test for Serial Correlation - In a time, series or panel data model, this is correlation between the errors in different time periods. A series is said to be serially correlated where the data are correlated across time and the errors arise from adjacent time periods.

RESULTS

Presentation of Data

Time series annual data on marine tourism (MARITO), energy-efficient vessels (ENEGEV), decarbonization of maritime transport (DEMATR) and technological innovations (TECHIN) for Nigeria covering the period from 1990 to 2024 used for this study are presented Table 1 below:

Table 1: Time series annual data on marine tourism, energy-efficient vessels, decarbonization of maritime transport and technological innovations from 1990 to 2024

Year	MARITO (Tourism Receipts (in Million $)	ENEGEV (No. of Energy – Efficient Vessels (Approx.)	DEMATR (No. of Decarboni-zation incentives count)	TECHIN (No. Notable Innovations)
1990	380	1	1	2
1991	420	1	1	2
1992	475	1	2	2
1993	460	1	1	2
1994	495	1	2	2
1995	510	1	2	3
1996	530	1	2	3
1997	560	1	2	3
1998	590	2	3	3
1999	610	3	3	3
2000	780	4	4	5
2001	850	4	3	5
2002	910	4	4	5
2003	980	5	4	5
2004	1150	5	5	5
2005	1320	5	6	8

2006	1450	5	6	8
2007	1620	5	7	8
2008	1780	5	7	8
2009	1660	5	8	8
2010	1950	10	9	15
2011	2200	10	10	15
2012	2380	10	11	20
2013	2550	10	12	20
2014	2780	10	13	20
2015	2400	20	15	30
2016	2100	20	16	30
2017	2320	20	18	30
2018	2650	20	20	40
2019	2800	20	22	40
2020	2450	30	24	50
2021	2920	30	28	50
2022	2450	30	30	55
2023	2650	40	32	55
2024	2800	50	35	60
Sources: Nigerian Ports Authority (NPA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Shipper's Council (NSC), Nigerian Navy and Marine Police (NNMP), National Inland Waterways Authority (NIWA), Federal Ministry of Marine and Blue Economy (FMMBE).				

Descriptive Statistics

A descriptive analysis of the series was carried out to gain more information on each of the variables. The Table 2 below summarized and organized the characteristics of a total of 35 observations of the dependent variables and independent variables.

Table 2: Descriptive Statistics of the Variables

	MARITO	ENEGEV	DEMATR	TECHIN
Mean	1569.429	11.14286	10.51429	17.71429
Median	1620.000	5.000000	7.000000	8.000000
Maximum	2920.000	50.00000	35.00000	60.00000
Minimum	380.0000	1.000000	1.000000	2.000000
Std. Dev.	900.1787	12.36490	9.852952	18.57191
Skewness	0.043441	1.482447	1.080320	1.043935
Kurtosis	1.413885	4.529590	3.023671	2.675297
Jarque-Bera	3.679828	16.23159	6.808844	6.510920
Probability	0.158831	0.000299	0.033226	0.038563
Observations	35	35	35	35

Source: Author's computation using E-views software, 2025

The descriptive statistics from Table 2 revealed that marine tourism (MARITO) averaged 1569.429, the minimum value of MARITO during the period is 380.000 while the maximum value stood at 2920.000 with an associated standard deviation of 900.1787 indicating that the observations for MARITO clustered around the mean value given the standard deviation is lower than the mean value. In the same manner, the mean, minimum, maximum and standard deviation energy-efficient vessels (ENEGEV), decarbonization of marine transport (DEMATR) and technological innovations (TECHIN) are 478558.0, 24.85714, 6.200000 11.14286 and 17.71429 respectively. The standard deviations showed that the observations for each of the variables are centered around their respective mean values with the exception of ENEGEV and TECHIN whose standard deviations appeared to be greater than their mean values, implying that the data are dispersed around the mean. Furthermore, the kurtosis which measures the peak-ness or flatness of the distribution of the series revealed that MARITO and TECHIN are platykurtic since their kurtosis values are less than 3 showing they have broad curves and thick tails.

Data Analysis (Unit Root Test)

Unit root tests is crucial in time series analysis to determine if a series is stationary or contains a unit root. A unit root indicates the series is non-stationary, potentially leading to spurious regressions, where relationships between variables appear significant when in fact they are not. Testing for a unit root is a fundamental step to ensure the validity and reliability of econometric models and avoid misleading results. Hence, this study employed the Phillips-Perron (1988) unit root test to examine the order of integration of the variables. The result of the Phillips-Perron test of stationarity at level and first difference are presented in Table 3:

Table 3: Unit Root Test Results

Variables	PP at Level	Critical value 5%	PP at 1st Diff.	Critical value 5%	Order of Integration
$LMARITO_t$	-1.660667	-2.951125	-6.011499	-2.954021	1(1)
$LENEGEV_t$	0.483834	-2.951125	-6.511759	-2.954021	1(1)
$LDAMATR_t$	-8.628040	-2.951125	-	-	1(0)
$LTECHIN_t$	0.886557	-2.951125	-11.26185	-2.954021	1(1)

Source: Authors computation from Eviews 12

From the Phillip-Perron unit root test results in Table 3, it was discovered that decarbonization of marine transport DEMATR was stationary at level that is integrated of order zero I(0). However, other variables (marine tourism MARITO, energy efficient vessels ENEGEV and technological innovations TECHIN) became stationary at first difference that is integrated of order one I(1). Given the mixed order of integration of the series I(0) and I(1), the autoregressive distributed lag (ARDL) model was employed.

Model Estimation

Following the evidence of mixed order of integration and the presence of long run relationship amongst the variables examined, the autoregressive distributed lag (ARDL) model was estimated to analyze the behaviour of the variables in the long run and short run and the speed of adjustment to long run equilibrium in models (MARITO). The results are presented in Tables 4-5.

Estimation of The ARDL Model for Marine Tourism Model

Table 4: ARDL Estimates for Marine Tourism (MARITO) Model

Dependent Variable: LOGMARITO				
Variable	**Coefficient**	**Std. Error**	**t − Stats**	**Prob.**
Short Run Estimates				
D(LENEGEV)	-0.1021	0.0699	-1.4612	0.1821
D(LDEMATR)	0.4642	0.1581	2.9349	0.0189
D(LTECHIN)	0.4029	0.1172	3.4378	0.0089
CointEq(-1)	-0.9624	0.1482	-6.4943	0.0002

Variable	**Coefficient**	**Std. Error**	**t – Stats**	**Prob.**
Long Run Estimates				
LENEGEV	0.2424	0.1286	1.8846	0.0962
LDEMATR	1.9419	0.2447	7.9341	0.0000
LTECHIN	1.4865	0.2328	6.3850	0.0002
C	5.9519	0.1353	43.980	0.0000
R-Squared	0.8538	Durbin-Watson Stat.	2.2433	

Source: Author's compilation from output of E-Views 12, 2025

Short Run Results

The short run results from Table 4. revealed that energy-efficient vessel has a negative effect on marine tourism in Nigeria. This implies that a percent increase in energy-efficient vessel (ENEGEV) will lead to a decrease in marine tourism (MARITO) by 0.1021 percent. This outcome is not in conformity with the a priori expectation of the study. Also, the negative effect of energy-efficient vessel on marine tourism in Nigeria was found not to be statistically significant at 0.05 level with an associated probability value of 0.1821.

The estimated coefficient of decarbonization of maritime transport (DEMATR) showed it has a positive and significant effect on marine tourism (MARITO) in Nigeria at 0.05 level suggesting that a percent increase in decarbonization of maritime transport will boost marine tourism by 0.4642 percent.

Long Run Results

The long run results revealed that energy-efficient vessel has a positive and insignificant effect on marine tourism in Nigeria, implying that one percent increase in energy-efficient vessel increases marine tourism in Nigeria by 0.2424 percent which is contrary to the short run outcome. Also, the result conforms to a priori expectation of the study. For decarbonization of maritime transport, its coefficient appeared positively signed and exert a highly significant effect on marine tourism in Nigeria given the corresponding probability value of 0.0000. The result indicates that a percent increase in decarbonization of maritime transport will lead to a rise in marine tourism by 1.9419 percent, this outcome is consistent with theoretical expectation. Also, the long run estimate revealed that technological innovation has a positive and statistically significant relationship with Nigeria's marine tourism suggesting that a percent increase in technological innovation will increase marine tourism by 1.4865 percent. This result shows that the relationship between technological innovation and marine tourism conforms to a priori expectation of the study. Furthermore, the R-squared value of 0.8538 signifies that 85 percent of the variation in marine tourism is explained by the independent variables examined in the model (ENEGEV, DEMATR and TECHIN).

Table 5: Inspection of CLRM Assumptions (Marine Tourism (MARITO) Model)

Tests	**CLRM Problem**	**Test Stats.**	**Prob.**	**Decision**
Breusch-GodfreyLM	Serial Correlation	1.0733	0.3002	Serial independence
Breusch-Pagan-Godfrey	Heteroscedasticity	17.308	0.6329	Constant Variance
Jarque Bera	Normality Test	2.3942	0.3020	normally Distributed
Ramsey RESET	Model Specification	0.1753	0.6879	Model is not mis-specified
CUSUM	Stability	-	-	Model is Stable

Source: Author's compilation from output of E-Views 12, 2025

As presented in Table 5, the Breusch-Godfrey Serial correlation LM test result shows there is complete absence of autocorrelation in the estimated residual. The test illustrated that, the chi-square statistics value is 1.0733 with a probability value of 0.3002 for MARITO model, 0.1116 with a probability value of 0.7384. The heteroscedasticity analysis based on the Breusch-Pagan-Godfrey method showed that there is no existence of heteroscedasticity in the residuals as the null hypothesis is accepted. The chi-square value 17.308 and probability value of 0.6329 for MARITO model, 22.860 and probability value of 0.3514. The Jarque-Bera Normality test results indicate that their residuals are normally distributed. Thus, the null hypothesis is not rejected as the Jarque Bera test statistic values in the examined models exceed 0.05 significance level. The Ramsey's reset test result shows that there is no functional or specification error, given the F-Statistic of 0.1753 and a probability value of 0.6879 for MARITO model. Finally, the stability test conducted using the cumulative sum (CUSUM) revealed that the parameters are stable over the period 1990 - 2024.

DISCUSSION

The ARDL model's short- and long-run analysis covering the period between 1990 - 2024 offer crucial insights into how the components of green shipping practices; energy efficient vessels (ENEGEV), decarbonization of maritime transportation (DEMATR) and technological innovations (TECHIN) affect development of blue economy in Nigeria measured by marine tourism (MARITO). The empirical results were discussed to ascertain if the specified objectives of the study were achieved and also link the findings with the theoretical expectations. The findings were equally discussed in line with the stated hypotheses to ascertain if the null hypotheses are to be rejected or not.

Effect of Energy-Efficient Vessels on Marine Tourism in Nigeria

The estimated ARDL model results showed that energy-efficient vessels (ENEGEV) have an insignificant negative effect on marine tourism (MARITO) in Nigeria in the short run. It explained that one percent increase energy-efficient vessels will reduce marine tourism by 0.1021 percent in short run suggesting that transition to energy-efficient vessels may take longer to translate into visible outcomes in marine tourism performance in the short run due to increased initial costs and potential disruption as the upfront expenses of retrofitting or building new energy-efficient ships can be substantial leading to higher tour cost or limiting access to certain destinations for some tourist potentially reducing demand for marine tourism. Contrariwise, Energy-efficient vessels exhibited a positive long-run effect on marine tourism indicating that one percent increase in energy-efficient vessels will boost marine tourism by 0.2424 percent. This finding is consistent with a priori expectation of the study and aligns with Ajayi (2024) who noted that while energy-efficient vessels improve sustainability in the long term, its direct impact on tourism demand is often delayed, as infrastructure must reach visible scale before influencing tourism behavior. However, the positive effect of energy-efficient vessels was found to be statistically insignificant at 0.05 significance level given the probability value of 0.0962. Hence, the study fails to reject the null hypothesis since the probability value exceeds 0.05. Based on the long run result, the study submits that energy-efficient vessel has insignificant positive effect on marine tourism in Nigeria.

Effect of Decarbonization of Marine Transport on Marine Tourism in Nigeria

Also, these findings conform to the theoretical expectation and in tandem with the studies of Ali (2023) and Stark et al. (2022) which highlight that reduction of carbon emissions improves marine environmental quality, making coastal areas more attractive to tourists. In addition, the positive effect of decarbonization of maritime transport on marine tourism was found to be statistically significant at 0.05 level both in the short run and long run given the corresponding probability values of 0.0189 and 0.0000 respectively. Hence, the study rejects the null hypothesis since the probability value is less than 0.05. In effect, the findings indicate that changes in decarbonization of marine transport determine the extent of increase or decrease in marine tourism in Nigeria. Based on the short run and long run results, the study submits that decarboinization of marine transport has positive and significant effect on marine tourism in Nigeria.

Furthermore, the short run and long run estimated coefficient of technological innovations (TECHIN) revealed it has positive effect on marine tourism in Nigeria implying that a one percent rise in technological innovation increases marine tourism by percent 0.4029 and 1.4865 percent in the short run and long run respectively. This result is consistent with a priori expectation of the study and in agreement with UNCTAD (2021) which asserts that digital and green innovations in port operations and maritime services attract more marine tourists and increase sector competitiveness. Also supported by Adeleke et al. (2019) who found that smart maritime infrastructure enhances eco-tourism development. In addition, the positive effect of technological innovations on marine tourism was found to be statistically significant both in the short run and long run given the associated probability values of 0.0089 and 0.0002 respectively.

Effect of Technological Innovations on Marine Tourism in Nigeria

The adoption of biofuels, hydrogen, ammonia, wind-assisted propulsion, and optimized hull designs can further reduce emissions and operational costs. Cleaner ships improve air and water quality, helping to protect coastal ecosystems that underpin marine tourism such as beaches, coral diving, and wildlife spotting Hence, the study rejects the null hypothesis and submits that technological innovation has significant positive effect on marine tourism both in the short run and long run. The finding of this study aligns strongly with works of Popoola and Olajuyigbe (2023); Poi and Moko (2023); Odiegwu and Enyioko (2022b) and Emeka et al. (2024) as they maintained that Nigeria's ports are exploring LNG-powered vessels that can cut CO_2 emissions by up to 25% compared to traditional heavy fuels.

Yui-yip et al. (2024) submits that the impacts green shipping practice on tourism include cleaner ports and ocean environments enhance visitor satisfaction, attracting eco-cruise lines as cruise lines increasingly prefer ports with shore power (cold-ironing**)** and waste treatment aligned with MARPOL standards. Nigeria's potential cruise port in Lagos is planned to include these features, positioning it for eco-conscious tourism growth. Green shipping practices can significantly elevate marine tourism in Nigeria by enhancing environmental quality, attracting sustainable cruise traffic, improving port efficiency.

CONCLUSION

The findings underscore the pivotal role of green shipping practices in advancing Nigeria's blue economy agenda. Among the practices**,** decarbonization of maritime transport emerges as the most influential**,** delivering immediate and sustained environmental benefits across the five models examined. Technological innovation and energy-efficient vessels also significantly contribute positively to the development of blue economy in Nigeria. Green shipping practices in Nigeria are not just an environmental imperative but a strategic enabler for marine tourism.

RECOMMENDATIONS

Based on the empirical findings, the following policy recommendations are proposed:

i. To improve efficiency in Nigeria's marine tourism, regulatory frameworks should prioritize carbon reduction strategies, including stricter emission controls and incentives for low-carbon shipping practices.

ii. Decarbonization in maritime transport should be promoted through adopting alternative fuels and investing in renewable energy infrastructure to attract marine tourism

iii. To enhance growth in Nigeria's marine tourism sector, government policy should be made to align with technological innovations by developing adaptive regulatory policies that evolve alongside technological change to ensure synergy rather than conflict.

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