

Empirical Assessment Of Blue Economy Drivers And SDG Outcomes In IORA Nations



Rajalaxmi Mohanty^{1*}, Dr. Sanjaya Kumar Lenka²

^{1*}Research Scholar (Economics), School of Economics & Commerce, KIIT (Deemed to be) University, Bhubaneswar, India, Email ID: rajlaxmimohanty.kiit@gmail.com, ORCID ID: <https://orcid.org/0009-0008-4792-1217>, Mob No: +91-9090338969

²Assistant Professor II (Economics), School of Economics & Commerce, KIIT (Deemed to be) University, Bhubaneswar, India, Email ID: sanjaya.iitindore19@gmail.com, ORCID ID: <https://orcid.org/0000-0001-9353-6872>, Mob No: +91-9993527709

Abstract

This study looks at how the drivers of the Blue Economy affect sustainable development in six economies of the Indian Ocean Rim Association (IORA): India, Indonesia, Australia, South Africa, Mauritius, and Kenya, between 2010 and 2024. The study utilizes a balanced panel dataset of 90 country-year observations for the testing of the relationship between Blue Economy indicators and Sustainable Development Goals (SDG) performance and is estimated using Fixed Effects, Random Effects, Panel-Corrected Standard Errors and Generalized Method of Moments methods. The results indicate that aquaculture production is positively and statistically significantly associated with SDG outcomes, pointing to the food security, employment generation, and development of sustainable enterprises in coastal areas, as well as to livelihood generation. Total fisheries production and agriculture–forestry–fishing activities, on the other hand, exhibit negative impacts, indicating that the production of fish and other resources, which demands high input and weak regulation, may negatively affect the sustainability. Marine Protected Areas also show short-term trade-offs, reflecting possible adjustment costs for coastal communities dependent on marine extraction. Merchandise exports positively influence SDG performance, while tariff barriers and weak regulatory implementation constrain sustainable progress. The study contributes to Blue Economy and sustainable entrepreneurship literature by showing that responsible aquaculture, innovation-oriented marine enterprises, institutional strengthening, and sustainable trade policies are essential for achieving inclusive and environmentally responsible development in IORA economies.

Keywords: Blue Economy; Sustainable Entrepreneurship; Aquaculture Production; SDG Performance; IORA Economies

1. Introduction

The United Nations Conference on Sustainable Development, which took place in Rio de Janeiro in 2012, is credited with giving creation to the relatively new notion of the "Ocean Economy" or the "Blue Economy" (Santos, 2025). The core concept of this idea is the separation of environmental degradation from socio-economic development, which has been seen as a great challenge in global development for centuries (Smith-Godfrey, 2016). Adopting sustainable development initiatives and cooperation in the Indian Ocean and Indo-Pacific region through the lens of Blue Economy resources supports the region's Blue Economy efforts and cooperation (Chansoria, 2018). The Indian Ocean will be a major geopolitical and economic player in the twenty first century (Khan, 2019). The Ocean Economy and Maritime Economy has been studied for a long time, mainly in an economic sense, on activities related to the sea, including fish catches, transportation by sea and the marine sector (Benevolo, 1999). The concepts of Blue Economy (BE) and Blue Growth (BG) are widely used in policy and scientific literature to denote the potential benefits for humans of aquatic and marine areas. The Blue Economy can be interpreted in many ways;

however, these different interpretations can lead to an imprecise definition that opens the door for varied perspectives, priorities and policy philosophies (Childs & Hicks, 2019).

Recognizing the ocean as a new economic frontier, covering over two-thirds of the Earth's surface, has resulted in significant investments, spurring development in existing sectors and the emergence of new activities across a wide range of marine-based industries (Jouffray et al., 2020). Coastal communities have depended on the water for fish, shellfish, marine animals, reptiles, seaweed and sea birds for thousands of years (Jackson et al., 2001). Shipments are a key enabler of raw materials, consumer goods and energy transport, and support the global economy and jobs both at sea and on land (McKinley et al., 2019). In addition to its macroeconomic functions, the Blue Economy also offers the potential for sustainable entrepreneurship through aquaculture companies, fisheries cooperatives, marine tourism businesses, blue biotechnology companies, renewable ocean-energy companies and small and medium-sized enterprises (SMEs) in coastal areas. These enterprise-based activities are fundamental to inclusive growth as they link to employment

creation, innovation, local employment security and environmental protection.

The Blue Economy holds great promise for ocean sustainability, but there are some challenges to consider when implementing it. A lack of agreed goals is a big hurdle for Blue Growth. For certain scholars and policy makers, Blue Growth is about maximizing the economic value of marine and aquatic resources (Boonstra et al., 2018). While an extractive reading of Blue Growth has the potential to threaten long-term sustainability if it does not also include responsible business practices, ecosystem safeguarding and inclusive governance. Coastal communities are affected by the Blue Economy and good ocean resource management. Even if the term ocean economics is used, the concept of Blue Growth is still in its infancy and historical comparisons can be used to guide planning and implementation. (Potgieter, 2018) The shipbuilding industry contributes much to coastal value of many areas (Sdoukopoulos et al., 2019). The concept of Blue Growth goes back to the concept of sustainable development. With greater international collaboration and expanded research on the Blue Economy, however, new definitions are now coming to light. Interdisciplinary and multidisciplinary research is important to grasp the issues related to Blue Economy, but integration of different disciplines is still a challenge (Wenhai, 2019). Such a fair and fair transition is essential for the Blue Economy in the context of the scale and complexity of the climate crisis. Low-income and vulnerable coastal communities have long been marginalized when it comes to access to benefits, who bears the costs, and who is involved in decision-making, and this is exacerbated by the climate crisis (Axon & Collier, 2022). This thereby calls for sustainable development of Blue Economy, which should combine innovative livelihood transformation, social inclusion, entrepreneurship support and environmental governance.

The concept of Blue Economy shows great potential in the Indian Ocean Region (IOR). The IOR is a region with a huge and growing population; some estimates predict that by 2050 almost half of the world's population will reside in littoral or coastal Indian Ocean states. The marine areas of the IOR are abundant in biodiversity, fisheries, shipping lanes, marine biotechnology, renewable energy resources and seabed minerals. The IOR, with its natural resources and geopolitical positioning, is a region of vast economic and development potential (Doyle, 2018). The sustainable development approach is very common in management literature related to the Blue Economy. Keen et al. (2018) developed a conceptual framework for assessing sustainable marine management practices, and Sarker et al. (2018) presented a Blue Growth model that focused on the cooperative approach to further develop Blue Growth and achieve Sustainable Development Goals

(SDGs). The development of ocean energy, including biofuels and renewable energy, has the potential to meet global energy demands. Oceans are also a source of a range of new and potentially useful industrial products such as medicines, antibiotics, antifreeze materials and antifouling coatings (FAO, 2020). Sectors are intrinsically linked to the development of innovation-led enterprises, offering opportunities for commercializing research, introducing green technology and sustainable business models in marine-dependent economies.

A transition towards ocean-based development is needed, especially in the area of clean and green energy from wind, waves and tides, to meet the Sustainable Development Goals. This transition is fueled by factors such as the scarcity of land-based resources and advancements in maritime technology that have paved the way for novel explorations in the sea. The Blue Economy of the Indian Ocean countries is well deserved, and these countries are key players in the formulation of the national maritime strategies (Asif, 2023). Sustainable entrepreneurship is in this context a key tool that enables Blue Economy potential to be translated into actual development results. Entrepreneurs, aquaculture producers, fisheries based small and medium enterprises, marine logistics companies and eco-tourism-based companies can achieve SDG's when they are in supportive institutional, technological and environmental environment.

Cooperative regimes, member-based groups, institutions and frameworks are created among governments with shared or strategic interests in maritime areas in order to harness the economic potential of oceans and seas. At the same time, increasing worries regarding the unsustainable exploitation of marine resources, especially the effect of it on climate change, have strengthened the cooperation efforts. The IORA is a prominent institution that advocates for sustainable development, regional cooperation and trade in the Indian Ocean region (Ogutu, 2021). The Blue Economy seeks to outline and define all companies and activities related to the ocean, and to advance sustainable development while fostering economic vitality. This method takes into account the economic and potential ecosystem service value of an industry (Spalding, 2016). The study of the Blue Economy in the Indian Ocean Rim is crucial to improve the development and contribution of the region to global sustainability (Mukhopadhyay et al., 2020). In 2014, the Blue Economy was officially recognised by the Indian Ocean Rim Association as a priority sector and agreed to support the development of the sector based on the principles of being socially inclusive, commercially successful and environmentally responsible. The IORA Working Group on the Blue Economy (WG-BE) actively promotes collaboration among

stakeholders in key sectors including fisheries and aquaculture, seaports and maritime logistics, renewable ocean energy, marine biotechnology, tourism, and research and innovation (Sarangi, 2022). It establishes a formal regional mechanism that can also have a guiding role in shaping policy, strengthen institutional capacity, synchronize legal frameworks and promote technology transfer across different capacities states (Rahman, 2021). This collaboration becomes especially crucial when it comes to building up blue entrepreneurship ecosystems, involving SMEs, fostering green financial access and facilitating competitiveness through innovation in marine sectors.

The primary aim of the study is to examine the impact of the factors driving the Blue Economy on sustainable development in a few of the IORA economies. Specifically the study examines the relationship between aquaculture production, total fisheries production, agriculture–forestry–fishing production, and the marine protected areas, other macroeconomic factors, and SDG performance. It also identifies the key dimensions of the Blue Economy that could be used to affect sustainable development outcomes. The study uses econometric approaches to deal with endogeneity and unobserved heterogeneity to maintain analysis rigor. This study assumes that the activities of the Sustainable Blue Economy do positively influence the longterm development of the IORA region, particularly with the presence of innovation, integration of trade, institutional quality and responsible resource governance. In addition, the effects of complementary factors like foreign direct investment, trade openness, merchandise exports and government institutions are hypothesized to affect the nature and impact of the relationship between the Blue Economy and sustainability.

This study also falls under the general context of sustainable entrepreneurship and sustainable innovation literature. Although there are several studies that focus on the Blue Economy from environmental, geopolitical and macroeconomic viewpoints, limited studies link the Blue Economy drivers to enterprise sustainable development in IORA economies. This research attempts to fill that void by not only understanding the development through the lens of a policy and resource-management problem, but also as an entrepreneurship and innovation pathway. The study especially brings evidence for information purposes for aquaculture business, fishermen-based SMEs, marine resource-based business and decision makers in promoting sustainable and inclusive growth in the Blue Economy.

The second part of this study examines the development and sustainability of the Blue Economy in selected member states of the Indian Ocean Rim Association, highlighting how the use of marine and coastal resources can ensure inclusive

growth, contribute to environmental protection, social welfare, and enterprise development. It looks at several key indicators—total fisheries production, aquaculture production, value added in agriculture, forestry and fisheries, marine protected areas, trade openness, foreign direct investment, merchandise exports, regulatory quality, and tariff rates—and considers economic, governance and ecological drivers. The study presents a comparative analysis of the national performances, identifies regional disparities, good practices and the contribution IORA's cooperative mechanisms can make to resilient ocean-based development. The findings will provide policy makers, entrepreneurs, SMEs and other stakeholders with evidence-based recommendations to improve collaboration, tackle institutional gaps, boost sustainable innovation and drive SDG progress with a solid Blue Economy strategy.

The rest of the article is organized as follows: Section 2 examines the relevant literature and develops the study hypotheses. Section 3 covers the conceptual framework, process of selecting the variables and theoretical connections between the variables of the Blue Economy and sustainable development. The data sources, methodology, and econometric models are presented in Section 4. The empirical results are summarized and the link between the Blue Economy and sustainable development is discussed in Section 5. Finally, the conclusion, implications, limitations and policy recommendations are given in Section 6.

2. Literature Review

The Blue Economy (BE) concept has been growing and developing as a transformative model for sustainable ocean governance, which is an integrated approach that combines sustainable economic development, environmental protection, and social development (Doyle, 2018; Spalding, 2016). In 2018, Doyle pointed out the strategic importance of the Indian Ocean Region (IOR), which is expected to become a global power by 2050 and the significance of the Indian Ocean Rim Association (IORA) in promoting cooperation in the region. The study highlighted the linkages between marine security, climate change and illegal fishing and the importance of adaptive governance to ensure inclusive growth and regional stability. Likewise, Spalding (2016) introduced the concept of the “new blue economy”, placing ecosystem services into the national accounts and encouraging sustainable industries, including marine renewables, blue biotechnology and blue carbon. Such an approach is based on mutual harmonization of criteria, spatial planning and precautionary governance as a mitigation of environmental risks. The framework is significant to sustainable entrepreneurship as it illustrates how resources from the ocean can be converted into sustainable business opportunities,

such as aquaculture businesses, SMEs based on fisheries, marine tourism businesses, renewable ocean energy businesses and blue biotechnology startups.

A business and innovation approach was used by Borgianni et al. (2012) to show how the Blue Ocean Strategy™ tools can be used to create New Value Propositions (NVPs) in the maritime domain. They found that there are traits in a value-carrying system that can be identified as being beneficial and are not associated with the need for resources or harm to the environment: robustness, controllability, ease of use. The study highlighted the importance of conducting additional case studies and industrial testing for systematic approaches to innovation in marine industries. The following stream of literature has direct relevance to blue entrepreneurship as it underscores the potential for companies to establish new market spaces through the design of sustainable products, using “green” processes in the operation of companies, and through innovation and value creation in marine sectors. The Blue Economy is, therefore, a policy approach and a pathway to business development which mobilises enterprises to become more competitive, with a lower environmental footprint.

Mohanty and Lenka (2026) investigated the impact of the blue economy on sustainable development in BRICS nations from 2006 to 2024. Using PCA and panel econometric techniques, the study found that aquaculture, marine conservation, and ocean-based innovation positively contribute to sustainable development, highlighting the importance of ocean-centric policies for sustainable growth. The socio-economic impacts of BE sectors are quantified by empirical studies. Martínez-Vázquez et al. (2023) analysed the correlation between BE sectors and PCI (per capita income) in European countries for the period 2010 to 2018 using panel data technique and Granger causality tests. They concluded that coastal tourism and population density were affected by PCI and that port activities, greenhouse gas emissions, maritime transport and living/non-living resources were the drivers of PCI growth. People, ship transport, marine life and marine energy were highlighted as key drivers. The study underscores the significance of sustainable management of the ocean, green port infrastructure and investments in marine renewable energy for economic development, job creation and global challenges like climate change. The conclusions support the theory that the Blue Economy sectors can create jobs and regional income, but their participation in sustainable development is contingent on managing responsibly, innovating technologies and adapting at the enterprise level. This is particularly important for the IORA economies as the livelihoods in the coastal areas are closely tied to fisheries, aquaculture, marine

transport, tourism and small-scale resource-based enterprises.

BE literature also includes much geopolitical and strategic analysis. Asif (2023b) discussed the socio-economic and strategic significance of the Indian Ocean for global trade, energy transportation and sustainable development. The study has studied geopolitical aspirations of the great powers like Belt and Road Initiative of China, Indian navy expansion and the strategic interests of the U.S. and Russia and highlighted Pakistan's potential with the help of CPEC & Gwadar Port. First, it was suggested that the research should promote alternative approaches from militarized competition to cooperation in governance, sustainable use of maritime resources and improved maritime security, to fully harness the potential of the Blue Economy. While geopolitical stability is critical, the entrepreneurship aspect of the Blue Economy also needs to be addressed, as regional cooperation can help enable cross-border trade, technology transfer, investment flows, and access to markets for marine-based businesses and SMEs. Hence, strategic cooperation in the Indian Ocean should relate to sustainable development of enterprises and inclusive economic participation.

From the regional and institutional viewpoints, IORA's values and contributions to sustainable BE development are highlighted. Llewellyn et al. (2016) identified traditional industries including fisheries, offshore oil and gas, shipping and tourism, as well as emerging marine biotechnology, renewable energy and digital infrastructure industries. The study highlighted the need for regionally integrated planning, strong governance and marine policies due to the transboundary nature of oceans. Skills sharing, public-private partnership and local capacity building are key principles of sustainable development and IORA will be playing a central role in the longer-term BE initiatives, providing economic sustainability and employment generation opportunities. These arguments resonate with the literature on sustainable entrepreneurship which highlights the need for institutional support, skill building, PwP and innovation ecosystems for transforming natural-resource potential into sustainable business performance. Such mechanisms can support blue start-ups, coastal SMEs, fisheries cooperatives, aquaculture producers and marine services enterprises in the context of IORA economies.

National and regional governance and management frameworks have been analysed. Plink et al. (2021) suggested the Integrated Management Model for improving maritime governance in Russia that involves federal, regional and municipal levels of governance as well as functional subsystems including Integrated Coastal Zone Management (ICZM), Marine Spatial Planning (MSP), Marine Macroregion Management and Ocean Governance. The model was based on good practices in the Baltic

Sea region, and with a focus on ecosystem-based planning, engaging stakeholders and cooperation between countries. It called for shifting from strategic planning to strategic management to bring together environmental, economic and social goals and called for renewable energy, resource efficiency and coordinated coastal development. Such governance structures are vital for a Blue Economy development approach that embraces entrepreneurship, as they provide certainty, regulatory clarity, marine ecosystem protection and conditions for sustainable investment. Good governance can also be used to incentivize companies to invest in cleaner technologies, meet environmental regulations, and engage in sustainable value chains.

Lastly, the role of legal and policy options in sustainable use of the resources in the Indian Ocean has been discussed. Techera (2018) reviewed the governance frameworks of the fisheries sector and other key areas related to sustainable fisheries, food security, and climate adaptation, which are under threat from over-fishing, pollution, sea-level rise, and ocean acidification—threats that impact not only the viability of fisheries but the livelihoods of more than 800 million people in the region. Even though international conventions and agreements have been ratified, regional governance is still poorly coordinated and there is a lack of enforcement. National responses differ – some countries, like Seychelles and the Maldives, have taken progressive steps, but others are having difficulties implementing these strategies. Techera advocated for multi-level, integrated governance with legal reforms, scientific support, and community participation, highlighting the role of IORA and regional programs like Large Marine Ecosystems (LMEs) in fostering cooperation, resilience, and sustainable fisheries management. This is especially relevant for small businesses and businesses in coastal areas as poor governance can lead to a deterioration of the resources, with reduced business security and sustainability of livelihoods over time. On the other hand, robust legislation can foster good fishery practices, certified aquaculture, sustainable tourism and environmentally friendly sea transport.

More recent literature also indicates the potential of the Blue Economy as platform of sustainable entrepreneurship and inclusive innovation. The Marine based sectors have the potential to create new business models related to sustainable aquaculture, fish processing, eco-tourism, blue biotechnology, renewable ocean energy, waste-to-value activities, and marine logistics. The sectors are crucial for developing and emerging economies for their employment and food security potential, export diversification and coastal community livelihoods. But institutional quality, access to finance, infrastructure, regulation of the

environment, uptake of technology and market integration are important factors determining the success of enterprise models. Thus, the link between Blue Economy drivers and SDG outcomes must be analysed from an environmental or macroeconomic perspective, as well as from an enterprise-development perspective.

Overall, the literature shows that the Blue Economy is a multi-dimensional concept that combines economic, environmental, governance, strategic and entrepreneurial dimensions. Research has emphasised the need to develop the sector sustainably, with innovative business models, effective governance frameworks and regional cooperation, including via IORA. Together, these findings highlight the strategic, economic, ecological and enterprise-development benefits of the Blue Economy for sustainable development, the Indian Ocean region's stability, inclusive growth and coastal entrepreneurship. However, the bulk of the existing literature is either on ocean governance, resource management, geopolitical strategy or macroeconomic growth, with comparatively less empirical research examining how the drivers of the Blue Economy affect the performance of SDG objectives from the perspective of sustainable entrepreneurship, innovation and enterprise-based development in the economies of the IORA region.

This study contributes to the literature by examining the role of the drivers of the Blue Economy in sustainable development in selected IORA economies. This research is different from that which only measures economic growth because the SDG Index is used as the dependent variable to measure wider social, economic and environmental outcomes. The study also translates the concept of aquaculture, fisheries, marine protection, trade openness, regulatory quality and the macroeconomic variables into factors that influence the operating environment for blue entrepreneurship, coastal SMEs and sustainable marine business models. Given the literature review, the following hypotheses are set:

H1a: Sustainable aquaculture production positively contributes to the SDG performance in selected IORA economies through the support of food security, livelihood generation and blue enterprise development.

H2a: Higher total fisheries production may negatively affect long-term SDG performance when it is associated with overfishing, biodiversity loss, and unsustainable resource extraction.

H3a: Greater reliance on agricultural, forestry and fishing-based activities could have a negative impact on sustainable development if they are resource-intensive, and poorly regulated.

H4a: Marine protected areas play a role in biodiversity conservation and in providing ecosystem services but may have varying impacts on SDG performance over the short-term depending on

livelihood dependency, governance effectiveness, and support to coastal communities.

H5a: When underpinned by sustainable production standards, market access and environmentally responsible enterprise practices, trade openness and merchandise exports positively affect SDG performance.

H6a: Regulatory quality intensifies the connection between Blue Economy development and SDG outcomes through the creation of an enabling environment for the sustainable development and governance of resources, entrepreneurship and innovation.

3. Variables Selection

3.1 Dependent Variable

a) SDG Index: A measure that reflects the degree of progress a country has made towards the 17 United Nations Sustainable Development Goals (SDGs). It was crafted by Sustainable Development Solutions Network (SDSN) and Bertelsmann Stiftung. The index includes a comprehensive assessment of sustainable development performance, covering economic and social, environmental and institutional aspects and normalizing them on a 0-100 scale. Each goal is given the same weight, and the SDG Index is calculated as an average of the normalized scores for the major dimensions of sustainable development. The SDG Index score is higher the better the performance of the countries in reaching sustainable development outcomes. The SDG Index in this study is considered the dependent variable since it reflects the overall sustainability impacts of the Blue Economy activities that can positively affect inclusive growth, environmental protection, social welfare, and sustainable enterprise development in IORA economies.

3.2 Independent Variables

a) Aquaculture Production: Aquaculture Production is the number of aquatic species produced by aquaculture in a country in a certain year, in metric ton. It involves fish, crustaceans, mollusk and aquaculture. The introduction of aquaculture as a key variable of the Blue Economy is justified by its relevance as a food security, employment, coastal living and sustainable entrepreneurship source. Responsible aquaculture can contribute to the development of blue enterprises in IORA economies through enabling access for small and medium-scale aquaculture, fish processing companies, fish value chain, and innovation-based production systems. Hence, aquaculture production should have an impact on SDG performance about economic inclusion, nutrition, livelihood diversification and sustainable marine resource use.

b) Total Fisheries Production: It is the overall number of aquatic species collected or produced each year by a country in metric ton. It encompasses

capture fisheries and aquaculture (mariculture) as well as other fish-farming operations for subsistence, commercial, industrial and recreational purposes. The variable is featured to measure the contribution of fisheries production to sustainable development. Fisheries production can play a role in the coastal economies in terms of income generation, exports, food security, and employment. But overfishing, loss of biodiversity, degradation of ecosystems and long-term livelihood insecurity are potential outcomes of excess or uncoordinated fisheries production. Therefore, the impact of overall fisheries production on SDG performance could be conditional on how production is achieved, that is, by sustainable practices, responsible governance, and implementation at the enterprise level, based on environmental standards.

c) Agriculture, Forestry, and Fishing: Agriculture, Forestry, and Fishing is the percentage contribution of agriculture, forestry, and fishing sectors to the gross domestic product (GDP) of a country in a specific year. This variable reflects a country's economic reliance on primary sector industries. It is relevant to the current study as the sectors are closely connected with the issues of rural livelihoods, entrepreneurship in the coastal regions, natural resource utilization and environmental sustainability. Support for agriculture, forestry, and fishing for employment and income generation is possible, but too much reliance on these sectors can be a sign of structural vulnerability, low level of diversification, poor technological upgrading and stress on the ecosystem. Hence, this variable is a useful indicator to analyse whether the current economic structures found in IORA economies are enabling or constraining sustainable development.

d) Marine Protected Areas: Marine Protected Areas (MPAs) show the level of protection and conservation of marine and territorial waters in a country over a particular period. This variable is indicative of the level of marine conservation and marine environmental governance. MPAs play a vital role in biodiversity conservation, replenishment of fish stocks, ecosystem services and ocean sustainability. Their short-term impacts, however, on local livelihoods and coastal businesses can be different, especially in the fishing and coastal resource-extraction-dependent communities. Hence, this variable is incorporated to determine if the marine governance for conservation achieves SDG outcomes in addition to the importance of inclusive policies to ensure that the marine-based SMEs, fisheries cooperatives and entrepreneurs impacted by marine governance for conservation are supported.

3.3 Control Variables

In addition to the primary explanatory variables, a set of control variables are also added to incorporate institutional and macroeconomic issues

that could affect sustainable development. These variables allow better understanding of the impact of the Blue Economy indicators on the SDG Index while adjusting for other economic, trade, financial and governance conditions in IORA economies.

The level of integration with international markets is called Trade Openness (TRD). It is added due to its potential to affect sustainable development through increased market access, export diversification, improving technologies transfer, and promotion of development of blue economy enterprises. But if environmental standards are not robust, the growth of trade can be accompanied by growing demands for resources and pressures on the environment.

The macroeconomic stability is reflected in the inflation (INF). Moderate and moderate inflation can be conducive to investment, business planning, and long-term economic growth while high inflation can lead to lower purchasing power, increased uncertainty and decreased business sustainability.

Merchandise Exports (ME) are the country's value of exports. This variable is incorporated due to the importance of export performance in the income generation, industrial development, foreign exchange earnings, and competitiveness of marine based industries including fisheries, aquaculture products, processed seafood, marine logistics, and other SMEs.

Growth in GDP (Gross Domestic Product) is indicative of the rate of economic growth. It is used to regulate for the overall economic growth context where Blue Economy activities are carried out. Sustainability investments, infrastructure, innovation, and support for enterprises may require more fiscal strength, but it is not always necessarily better growth that is more resource intensive that leads to better SDG outcomes.

Foreign Direct Investment (FDI) is the amount of money that comes from a foreign country. FDI can help sustainable development by providing capital, technology, managerial know-how and market access. For Blue Economy sectors, FDI can help realize aquaculture modernization, port development, marine renewable energy and blue innovation. Its sustainability impact, however, is contingent on foreign investment being sustainable in terms of environmental considerations, good business practice and inclusive local development.

Regulatory Quality (RQ): The perceived ability of a government to develop and/or implement sound policies and regulations that support the private sector development is measured by EST. This variable is added to encompass institutional effectiveness and policy enforcement. A robust regulatory quality can facilitate sustainable entrepreneurship by ensuring responsible consumption of resources in Blue Economy sectors, improving compliance and reducing uncertainty, while fostering innovation. Firms with access to the

sea, such as SMEs, and investors who need clear rules, transparent governance, and policy stability are especially interested in this.

Tariff Rate (TR): It is the degree of restriction of trade in an economy. It is included because tariff barriers may have an impact on access to imported technologies, to production inputs, green equipment, and on international markets. Reducing tariff barriers can foster sustainable innovation and competitiveness, by providing access to modern aquaculture technology, environmental monitoring technologies, renewable energy technologies, and efficient processing technology for Blue Economy enterprises. On the other hand, high tariff rates can hinder the uptake of technologies and consequently stifle the development of sustainable marine business.

These control variables allow for the inclusion of differences in structure, institutions and policy across the selected IORA economies. Their inclusion allows to avoid the risk of potential macroeconomic bias, governance bias, trade integration bias, and investment flows bias in the estimated impact of the Blue Economy indicators on the performance of SDGs. Such an approach enriches the empirical analysis and aids in understanding the relationship between activities related to the Blue Economy and sustainable entrepreneurship and innovation and development outcomes.

4. Empirical Framework

In this study, the researcher used a panel data set for 2010-2024 which covers 15 years of observations to identify the driver affecting sustainable development in six countries in the Indian Ocean Rim Association (IORA), namely India, Indonesia, Australia, South Africa, Mauritius, and Kenya. The empirical model is specified in equation (1) as the SDG Index to be a function of blue economy and the control variables.

$$SDG_{it} = \alpha + \beta_1 AP_{it} + \beta_2 TFP_{it} + \beta_3 AFF_{it} + \beta_4 MPA_{it} + \beta_5 GDP_{it} + \beta_6 INF_{it} + \beta_7 TRD_{it} + \beta_8 FDI_{it} + \beta_9 ME_{it} + \beta_{10} RQ_{it} + \beta_{11} TR_{it} + \mu_{it} \quad \text{--- eq (1)}$$

Within the empirical model, SDG_{it} denotes the Sustainable Development Goals Index for country "i" at time "t". The main independent variables comprise Aquaculture Production (AP), Total Fisheries Production (TFP), Agriculture-Forestry-Fishing value added (AFF), and Marine Protected Areas (MPA). To address macro-economic and institutional differences, the model also features several control variables: Gross Domestic Product (GDP) as a measure of economic growth; Inflation (INF) as a proxy for macro-economic stability; Trade Openness (TRD), Foreign Direct Investment (FDI), and Merchandise Exports (ME) to measure external economic integration; Regulatory Quality Estimation (RQ). The institutional capacity was measured using the level of institutional capacity

(ICSD) and the trade policy restrictiveness was measured using the Tariff Rate (TR). Fixed Effects (FE) models and Random Effects (RE) models are employed and Hausman specification test is used to adjudicate which one to use. Panel-Corrected Standard Errors (PCSE) are used to correct heteroskedasticity and contemporaneous correlation. Moreover, the Generalized Method of Moments (GMM) estimator is used to deal with potential endogeneity, simultaneity bias and reverse causality and thus to guarantee the robustness and consistency of the estimated coefficients.

4. Research Methodology

4.1 Research Design

This study is quantitatively designed with panel data approach for studying the effect of the Blue Economy on sustainable development. The study spans 15 years (2010-2024) and incorporates six Indian Ocean Rim Association (IORA) member states: India, Indonesia, Australia, South Africa, Mauritius and Kenya. A panel data approach is suitable, which can reflect differences among countries and time variations in Blue Economy activities and sustainable development outcomes.

The countries chosen are spread across a spectrum of economic development, marine-resource dependence, institutional capacity and Blue Economy potential in the IORA region. Thus, the research design is appropriate for analysing the relationship between marine economic activities, conservation, trade integration, governance conditions and SDG performance in various national contexts.

4.2 Study Area and Sample Selection

The study is restricted to six IORA economies – namely India, Indonesia, Australia, South Africa, Mauritius and Kenya. The countries were chosen for their close ties with the Indian Ocean region and their high marine, coastal, fisheries, aquaculture, trade and Blue Economy potential.

The sample consists of developed and developing economies, thus reflecting economic structure and institutional quality, resource dependence, and sustainable development performance variations. Such diversity adds to the comparative relevance of the study and enhances the range of understanding about the operation of the Blue Economy drivers in different IORA settings.

4.3 Data Sources and Period of Study

Secondary data is used in this analysis and has been gathered annually by the World Bank World Development Indicators, Worldwide Governance Indicators, and the Sustainable Development Report/SDG Index database, as well as OECD National Accounts (if applicable). The data set is a balanced panel of six selected countries across IORA that covers the period 2010-2024.

Thus, the final data set will consist of 90 country-year observations, which are 6 countries observed for 15 years. The balanced panel design enables the panel to compare the cross-country variation and the time-invariant variation in the drivers of the Blue Economy, the macroeconomic conditions, the institutional quality, and the outcomes of sustainable development.

4.4 Variable Description

The dependent variable of this study is Sustainable Development Goals Index (SDG Index) which is an index used to measure the progress of each country to achieve Sustainable Development Goals (SDGs) set by the United Nations (UN). The independent variables are mainly Aquaculture Production (AP), Total Fisheries Production (TFP), Agriculture–Forestry–Fishing (AFF) and Marine Protected Areas (MPA). The variables selected are the key factors of the Blue Economy related to marine production, marine dependence and conservation.

The control variables include Gross Domestic Product Growth (GDP), Inflation (INF), Trade Openness (TRD), Foreign Direct Investment (FDI), Merchandise Exports (ME), Regulatory Quality (RQ). The following abbreviations are used: EST, or Estimate; and TR, or Tariff Rate. These variables are added to account for macroeconomic, trade, investment and institutional conditions that affect more broadly the sustainable development outcomes.

4.5 Analytical Framework

To clarify the structural link between the drivers of Blue Economy and Sustainable Development, descriptive statistics, correlation analysis, Fixed Effects, Random Effects, Panel-Corrected Standard Errors and Generalized Method of Moments estimations are used. This is a multi-method analysis to make sure that the results are not reliant on one estimation method. It also increases the reliability of the results due to problems of unobserved heterogeneity, heteroskedasticity, serial correlation, contemporaneous correlation and endogeneity.

4.6 Descriptive Statistics

Descriptive statistics are used initially to observe the central tendency, distribution dispersion, the minimum value and the maximum value of the study variables. Some of these variables are Sustainable Development Goals Index (SDG), Aquaculture Production (AP), Total Fisheries Production (TFP), Agriculture–Forestry–Fishing (AFF), Marine Protected Areas (MPA), Gross Domestic Product Growth (GDP), Inflation (INF), Trade Openness (TRD), Foreign Direct Investment (FDI), Merchandise Exports (ME), Regulatory Quality (RQ). There are two types of tariff: Excessive Stock Transfer (EST); and Tariff Rate (TR).

This preliminary analysis gives the general idea on cross-country variation and time trends of Blue Economy activities, macroeconomic conditions, institutional quality and sustainable development performance. It also serves to pinpoint the degree of disparities in marine economic activities, conservation and policy context among selected IORA economies.

4.7 Correlation Analysis

The direction and strength of the relationships between variables studied are evaluated using correlation analysis. This step is valuable to find out if there are potential multicollinearities before estimation of regression. It is particularly important to consider the relationship between Aquaculture Production and Total Fisheries Production because both variables are associated with marine output. As such, a correlation analysis can offer an initial clue of the need for further diagnostic tests such as variance inflation factor analysis and alternative model specifications.

4.8 Model Specification

The empirical model estimates the SDG Index as a function of Blue Economy indicators and control variables. The general model is specified as follows:

$$SDG_{it} = \beta_0 + \beta_1 AP_{it} + \beta_2 TFP_{it} + \beta_3 AFF_{it} + \beta_4 MPA_{it} + \beta_5 GDP_{it} + \beta_6 INF_{it} + \beta_7 TRD_{it} + \beta_8 FDI_{it} + \beta_9 ME_{it} + \beta_{10} RQ. EST_{it} + \beta_{11} TR_{it} + \mu_i + \varepsilon_{it}$$

where SDG_{it} represents the Sustainable Development Goals Index of country i in year t ; AP denotes Aquaculture Production; TFP denotes Total Fisheries Production; AFF represents Agriculture–Forestry–Fishing; MPA represents Marine Protected Areas; GDP , INF , TRD , FDI , ME , $RQ. EST$, and TR represent the control variables; μ_i captures country-specific effects; and ε_{it} is the error term.

This type of model is useful to understand from the lens of sustainable entrepreneurship, the impact of marine-based production, conservation, trade integration, flows of investment, quality of regulations and tariff structures on SDG outcomes in IORA economies. Therefore, the model is not only useful to measure environmental and macroeconomic performance, but also to gain insight into the broader enabling conditions of blue business, coastal SMEs, aquaculture business, fisheries cooperatives and innovation-driven marine sectors.

4.9 Econometric Estimation Techniques

Econometric modelling is done using Fixed Effects (FE) and Random Effects (RE) specifications to take into consideration that there is unobserved country level heterogeneity in the economies chosen for the IORA. A Fixed Effects model allows for the inclusion of time-constant country factors (geographical, historical institutions, resource endowments and structural differences). The Random Effects model

makes the assumption that the country specific effects are not related to the explanatory variables.

A Hausman specification test is employed to select the most suitable between FE & RE. The chosen method is appropriate for the current study as factors other than the observable ones, but specific to a country, can have an impact on the performance of the Blue Economy and on SDGs' outcomes in the long term.

The Panel-Corrected Standard Errors (PCSEs) estimator is used to correct econometric problems that are frequently found in panel data such as heteroskedasticity, serial correlation and contemporaneous correlation. The PCSE approach makes coefficient estimates more reliable as it adjusts the standard errors for the case of non-independence of the disturbances across countries and/or over time. This is also especially true in cross-country sustainability studies where countries could encounter similar shocks because of climate change, trade, regional policy adjustments, and/or global economic downturns.

Moreover, the Generalized Method of Moments (GMM) method is applied to solve the endogeneity, simultaneity bias and reverse causality problems between the indicators of the Blue Economy and sustainable development outcomes. For instance, the performance of SDG activities can affect SDG outcomes, but countries that perform better on SDG may have better institutional capacity, have invested more, and have better policies for supporting sustainable aquaculture, marine conservation and blue innovation. This is where the GMM estimator comes in, because they can consider the dynamic relationship and ensure consistency of the estimates with the help of internal instruments.

4.10 Diagnostic and Robustness Checks

Appropriate diagnostic and robustness checks are conducted to ensure the reliability of the empirical findings. The Hausman test is used to choose between the Fixed Effects and Random Effects models. To check for any possible multicollinearity among explanatory variables, the correlation analysis is performed. Moreover, the correction for heteroskedasticity, serial correlation and contemporaneous correlation is done by the estimation of PCSE, whereas the presence of endogeneity and dynamic panel bias is taken care of by the GMM estimation method.

These diagnostic and robustness procedures increase the credibility of the results and the estimated relationship between the drivers of the Blue Economy and the performance of the SDGs is not affected by common econometric issues.

4.11 Methodological Relevance to Sustainable Entrepreneurship

This approach applies to the scope of sustainable entrepreneurship since Blue Economy industries

are tied to marine-based businesses, coastal SMEs, aquaculture producers, fisheries cooperatives, eco-tourism companies, marine logistics companies and innovation-based ocean industries. The study analyses the correlation between the Blue Economy indicators and SDG outcomes and offers empirical evidence on the contribution of different marine-based economic activities, governance structures, trade openness and investment to sustainable enterprise development in IORA economies.

Therefore, it is essential to highlight that the methodological framework is aligned with the overall aim of fostering sustainable entrepreneurship, inclusive growth, environmental responsibility and sustainable development in the

long term by helping to facilitate the development of the Blue Economy.

5. Results and Discussion

5.1 Descriptive Statistics

Table 1 presents the descriptive statistics of the variables used in the study. The table reports the number of observations, mean, standard deviation, minimum, and maximum values for the dependent variable, independent variables, and control variables.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
SDG	90	63.94667	7.233135	51.7	76
AP	90	3,448,215	5,472,126	4.86	1.61e+07
TFP	90	5,584,443	8,176,936	6,864	2.32e+07
AFF	90	9.689746	7.38437	1.926849	22.70273
MPA	90	10.10222	15.50906	0	45.4
GDP	90	3.763007	3.336166	-14.54654	9.689592
INF	90	4.539124	2.840315	-0.6631576	15.26429
TRD	90	55.52903	23.74487	27.23782	119.5001
FDI	90	2.197552	1.510938	-0.0053685	9.660265
ME	90	1.51e+11	1.33e+11	1.79e+09	4.53e+11
RQ. EST	90	0.3969699	0.8122878	-0.5171906	1.989518
TR	90	6.692222	4.281233	0.89	19.25

The descriptive statistics provide information about the main variables of the 6 countries selected for IORA for the period of 15 years. The mean value of SDG Index is 63.95 thus sustainable development performance among the selected economies is moderate. The range between the minimum value (51.7) and the maximum value (76), however, indicates that there are significant differences in SDG performance between the sampled countries. This variation is due to the economic structure, social development, environmental governance and the level of institutional capacity.

The standard deviations of the Aquaculture Production and Total Fisheries Production indicate a significant amount of variation. This indicates that the potential for marine production is very unevenly distributed in the economies of the IORA countries. Greater aquaculture systems, fisheries infrastructure and supply chain, as well as export capacity will lead to higher aquaculture production, while lesser aquaculture systems, fisheries infrastructure, marine supply chain, and export capacity will lead to lower aquaculture production on smaller island and less industrialized economies. The variation from this also represents unequal opportunities for aquaculture business, fisheries-based SMEs, seafood processing business, and

coastal livelihoods from a sustainable entrepreneurship point of view.

The average value of Agriculture–Forestry–Fishing (AFF) sector in the selected countries is 9.69%, demonstrating that primary resource-based industries are still economically significant in the selected countries. The broad spread of the AFF values indicates that there are still countries that are more reliant on agriculture, forestry and fishing than other countries. Dependence can help rural people make a living but may also put strain on ecosystems unless rural production is sustained by sustainable technology, environmental regulation and responsible enterprise.

MPAs demonstrate an average value of 10.10%, highlighting the unevenness of coverage of the marine and territorial conservation in the sampled economies. That number is meant to be viewed as an indicator of conservation, rather than a share of GDP. The relatively large size of the SD for MPA indicates that conservation efforts in the selected IORA countries are not equal, which could be attributed to varying degrees of commitment to policies, institutional capacity, priorities for marine biodiversity, and strategies for managing coastal resources.

The macroeconomic indicators include GDP growth, which is on an average 3.76%, and inflation which is

4.54%. The mean value of trade openness is 55.53%, indicating the selected economies are moderately open. The level of Foreign Direct Investment (FDI) averages 2.20% and Merchandise Exports (ME) have a significant spread, suggesting there are significant variations in export capacity and export structure. Regulatory Quality (RQ). The average score for institutional performance is 0.39 (EST), and the average score for Tariff Rate (TR) is 6.69%, reflecting some trade restrictiveness.

The descriptive statistics show that there is significant cross-country variation in all the indicators of Blue Economy activity, trade integration, institutional quality, conservation coverage, and SDG performance. This provides a

good reason to use the econometric methods typically employed in panel data analysis, which allows the selected countries to vary not only in their marine-resource endowments, but also in their policy climates, market structures and sustainable development trajectories.

5.2 Correlation Analysis

Table 2 presents the correlation matrix among the study variables. Correlation analysis is used to examine the direction and strength of linear relationships among variables and to identify possible multicollinearity concerns before regression estimation.

Table 2. Correlation Analysis

Variable	SDG	AP	TFP	AFF	MPA	GDP	INF	TRD	FDI	ME	RQ.ES T	TR
SDG	1.000 0											
AP	- 0.428 0	1.000 0										
TFP	- 0.478 8	0.994 9	1.000 0									
AFF	- 0.756 3	0.399 1	0.424 0	1.000 0								
MPA	0.090 1	- 0.318 6	- 0.335 8	- 0.577 5	1.000 0							
GDP	- 0.408 8	0.259 6	0.286 0	0.426 4	- 0.273 8	1.000 0						
INF	- 0.209 8	- 0.039 8	- 0.008 0	0.350 9	- 0.259 5	0.223 3	1.000 0					
TRD	0.704 8	- 0.327 5	- 0.339 8	- 0.503 3	- 0.253 2	- 0.065 2	- 0.129 1	1.000 0				
FDI	0.314 3	- 0.168 2	- 0.183 7	- 0.454 1	0.288 8	0.020 8	- 0.133 7	0.440 4	1.000 0			
ME	- 0.560 4	0.466 6	0.503 5	0.056 1	0.381 0	0.199 5	- 0.052 0	- 0.452 3	- 0.011 8	1.000 0		
RQ.ES T	0.441 2	- 0.343 0	- 0.380 1	- 0.749 8	0.752 7	- 0.292 2	- 0.449 5	0.305 2	0.521 1	0.125 8	1.000 0	

TR	-0.5781	0.0716	0.0992	0.8222	-0.4506	0.2702	0.3937	-0.5551	-0.5812	-0.0725	-0.8061	1.0000
----	---------	--------	--------	--------	---------	--------	--------	---------	---------	---------	---------	--------

The correlation coefficients show several important relationships among the study variables. To provide a clearer visual interpretation of the correlation matrix, Figure 1 presents the correlation heatmap of

the study variables. The heatmap highlights the direction and strength of associations among Blue Economy indicators, macroeconomic controls, institutional variables, and SDG performance.

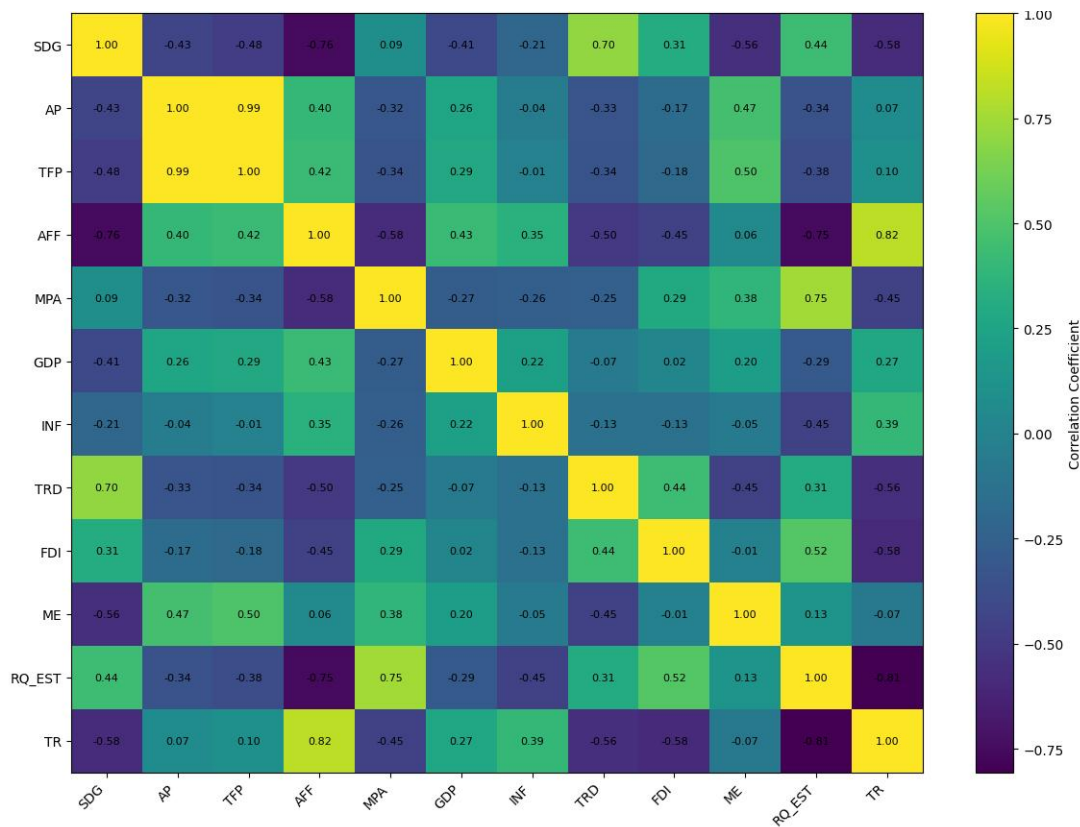


Figure 1. Correlation Heatmap of Study Variables

There is a negative correlation between the SDG Index and Aquaculture Production (AP), Total Fisheries Production (TFP) with coefficients of -0.4280 and -0.4788, respectively. These negative bivariate correlations mean that in some countries higher production in the marine sector could be linked to a lower score for SDG, but they do not imply causation. Hence, the need to perform regression-based analysis to account for other macro-economic, institutional and Blue Economy variables.

The correlation between AP and TFP is very high (AP = 0.9949), meaning that there is a very strong positive relationship between AP and TFP. This indicates a potential problem of multicollinearity, in particular since production from aquaculture is a significant part of the total fisheries production. Thus, caution needs to be taken when interpreting this relationship in regression analysis. To increase the reliability of the results, the study should incorporate diagnostic tests like Variance Inflation Factor (VIF) and if required, different model

specifications with AP and TFP alone should be employed.

The SDG Index is positively correlated with Trade Openness (TRD) with a coefficient of 0.7048. This suggests that countries which are more integrated into the international market can achieve better sustainable development outcomes, perhaps because of their higher rates of income, technology transfer, exports, and institutional relations. Yet the effects on sustainability are positive or negative depending on the environmental quality of trade, the effectiveness of regulation and the willingness of enterprises to meet sustainability standards.

The coefficient of correlation of Agriculture-Forestry-Fishing (AFF) is -0.7563 which is strong negative correlation with SDG. This implies that those countries that rely heavily on primary resource-based sectors might experience poor sustainable development results, particularly if they engage in extracting primary resources in an environmentally destructive manner, with little technology uptake and with low value addition.

Entrepreneurship wise, it emphasises the need to shift away from traditional resource-based activities to more sustainable and innovation-oriented business models.

Regulatory Quality (RQ) is correlated with a weak positive correlation with SDG and the Mastered is a positive correlation between EST and SDG and MPA, (all data are presented in the same format). This indicates that better institutional conditions can foster outcomes in conservation and sustainable development. The balance between conservation and development can however be different depending on the nature of the policies for marine protection, the measures taken for livelihoods, and the involvement of coastal communities and SMEs. Tariff Rate (TR) has a negative correlation with SDG and Regulatory Quality, suggesting that higher trade barriers could be related to lower sustainable development performance and lower institutional effectiveness. This can happen due to increased potential barriers to green technologies, sustainable

production inputs and access to international markets for Blue Economy businesses.

In general, the results of the correlation analysis indicate meaningful initial relationships between the indicators of the Blue Economy, the macroeconomic situation, institutional quality and the SDG performance. But because of the possibility of multicollinearity and the failure of correlation analysis to give causal inference, multivariate panel regression models are necessary for more reliable inference.

5.3 Panel Regression Results

The panel regression results are reported in Table 3 (Fixed Effects (FE), Random Effects (RE), Panel-Corrected Standard Errors (PCSEs), and Generalized Method of Moments (GMM) estimations). The SDG Index is the dependent variable. The models are used to explore the effect of the Blue Economy indicators and the control variables on the sustainable development performance of the selected IORA economies.

Table 3. Model Specifications

Variable	FE Model	RE Model	PCSEs	GMM
AP	0.0000*** (0.000)	0.0000*** (0.000)	0.0000*** (0.001)	0.0000*** (0.000)
TFP	0.0000*** (0.000)	0.0000*** (0.000)	-3.0346*** (0.002)	-5.0031*** (0.000)
AFF	-0.8013*** (0.000)	-0.8952*** (0.000)	-0.8952*** (0.000)	-0.8877*** (0.000)
MPA	-0.1378*** (0.008)	-0.2490*** (0.000)	-0.2490*** (0.046)	-0.3944*** (0.000)
GDP	0.0688 (0.456)	-0.01113 (0.884)	-0.0111 (0.869)	-0.0082 (0.936)
INF	0.1847*** (0.015)	0.1839** (0.034)	0.1839* (0.089)	0.1509* (0.097)
TRD	0.0092 (0.735)	-0.0113 (0.713)	-0.0113 (0.837)	-0.0598*** (0.015)
FDI	-0.2824** (0.043)	-0.1275 (0.488)	-0.1275 (0.550)	-0.0510 (0.742)
ME	-1.0047*** (0.000)	-2.0076 (0.484)	-2.0076 (0.740)	1.0066** (0.048)
RQ. EST	-1.0480 (0.142)	-0.4938 (0.612)	-0.4938 (0.831)	-2.1488** (0.038)
TR	-0.2462 (0.132)	-0.0891 (0.654)	-0.0891 (0.811)	-0.5294** (0.049)
Constant	77.9937*** (0.000)	79.1287*** (0.000)	79.1287*** (0.000)	86.3903*** (0.000)
Observations	90	90	90	90
Hausman Test	0.0000			
Overall R ²	0.9223	0.9384		
R-squared			0.9384	
F Test	6.44			
Wald Chi ²			1169.91	
Prob > Chi ²			0.0000	

Prob > F	0.0000			
No. of Years	15	15	15	15
No. of Countries	6	6	6	6

Note: Values in parentheses are p-values. * and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

To summarize the direction and relative magnitude of the dynamic estimation results, Figure 2 presents

the GMM-based estimated effects of key explanatory variables on SDG performance.

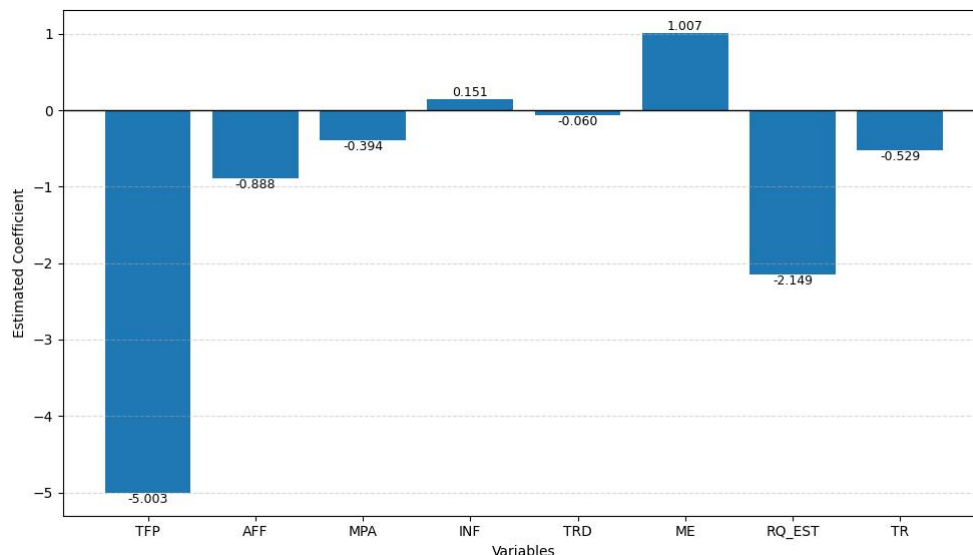


Figure 2. GMM-Based Estimated Effects on SDG Performance

5.4 Model Selection and Overall Model Fitness

The Hausman test result is statistically significant at 0.0000 which shows the Fixed Effects model is more suitable than the Random Effects model. This indicates that there are other country specific properties that are correlated with the explanatory variables and are not observed. Thus, the Fixed Effects model offers a more robust baseline estimate of the association between the drivers of the Blue Economy and SDG performance.

The overall R² values of the FE and RE models are high suggesting that the explanatory variables used explain a significant amount of the variation in the SDG Index. Similarly, the PCSE model also has a high R-squared value of 0.9384 and the Wald Chi-square statistic is significant at the 1% level. The results obtained validate the explanatory power of the model and the relevance of the institutional, macroeconomic, trade and Blue Economy variables selected to explain the sustainable development performance of the IORA countries in the sample.

The use of PCSE and GMM also contributes to the robustness of the findings. The PCSE addresses heteroskedasticity, serial correlation and contemporaneous correlation, whereas the GMM attempts to correct for potential endogeneity and reverse causality. Thus, FE, RE, PCSE, and GMM will enable a more holistic understanding of the Blue Economy/SDG relationship.

5.5.1 Aquaculture Production and SDG Performance

For Aquaculture Production (AP), a positive relationship is found with all estimation techniques and is highly significant. Even when the coefficient is shown as 0.0000 because the measurement scale of aquaculture production is very large (in metric tons), it is statistically significant, meaning that there is a meaningful relationship between aquaculture and sustainable development outcomes. In future estimation, the log form of AP will be used to enhance the interpretation of its coefficient.

The positive relationship implies that aquaculture has the potential to play a role in sustainable development in terms of food security, job creation, nutrition, income generation and livelihood diversification. Additionally, aquaculture offers a viable alternative to capture fishing and helps alleviate the strain on these fisheries, thus contributing to sustainable use of marine resources and coastal economic resilience. This is of significant relevance from the sustainable entrepreneurship point of view, as aquaculture can provide opportunities for coastal SMEs, fish-processing companies, fish-hatcheries and fish-feed providers, cold-chains and innovation-based marine start companies. Hence, responsible aquaculture can be a strategy for environmental sustainability, and an entrepreneurship-driven development path in IORA economies.

5.5 Discussion of Blue Economy Variables

5.5.2 Total Fisheries Production and SDG Performance

The results of the Total Fisheries Production (TFP) model are mixed. It is positive and significant in the FE and RE models but turns negative and significant in the PCSE and GMM models. The negative and significant coefficients in the more robust PCSE and GMM specifications indicate that too much fisheries production could be detrimental to SDG performance if fisheries production is linked to overfishing, habitat degradation, loss of marine biodiversity and ecosystem imbalance.

The discovery suggests that fisheries production can be good for short-term economic output, but can be detrimental to long-term sustainability, if regulation is not set correctly. Intensive fisheries activities can sometimes be more focused on maximizing short-term economic gains rather than protecting the ecosystem, thereby reducing the contribution to the SDGs related to the life below water, responsible consumption, environmental protection and livelihoods. The outcome suggests that fisheries-based businesses need to move towards responsible fisheries management, certified production, value addition, traceability, and sustainable business practices for sustainable entrepreneurship.

5.5.3 Agriculture-Forestry-Fishing and SDG Performance

The Agriculture-Fisheries-Forests (AFF) is negatively related to the SDG Index and the relationship is significantly negative in all models. It indicates that sustainable development benefits may be limited where there is increased reliance on the basic resource utilization activities. The negative relationship can be explained by the environmental impacts of deforestation, coastal degradation, resource intensive use, carbon emissions, and resource extraction of low value.

While AFF activities can be sources of income and employment, they can also be related to poor environmental standards, low technological upgrading, low productivity and unsustainable use of resources in developing economies. The discovery shows the necessity of changing the traditional activity of the primary sector to sustainable and innovative enterprise models. For instance, the fisheries cooperatives, agro-marine SMEs, eco-certified producers and resource-based enterprises can implement cleaner technologies, circular production systems and sustainable value-chain practices.

5.5.4 Marine Protected Areas and SDG Performance

The SDG Index negatively and significantly correlates with Marine Protected Areas (MPA) across all the models. On the surface it may seem paradoxical as MPAs are supposed to preserve marine biodiversity, recover fish populations and

enhance ecosystem health. The negative coefficient could, however, be the result of short-term economic adjustment costs of conservation policies. In coastal areas where fishing is a primary source of livelihood and where marine resources are extracted, the imposition of restrictions on the access to these resources can lead to lower income generation and employment and decrease local economic activity.

The result implies that conservation policies should be put in place alongside livelihood support mechanisms. Positive long-term sustainability outcomes are more likely to result from MPAs if they are supported by compensation schemes, alternative livelihood programs, eco-tourism, skills training, community participation, and coastal SME support. Marine conservation from an entrepreneurship point of view should be associated with sustainable business opportunities like eco-tourism, monitoring services, sustainable aquaculture and biodiversity-friendly coastal businesses.

5.6 Discussion of Control Variables

5.6.1 GDP Growth

All the models have a growth rate of GDP that is not statistically significant. This discovery also indicates that economic growth is not always a positive development in terms of sustainable development. In IORA economies, GDP growth may be unevenly spread between sectors and/or between different levels of social welfare, environmental quality and inclusive development may be overlooked. Therefore, policies geared toward sustainability, green innovation and inclusive enterprise development are crucial for the attainment of sustainable growth and sustainable development that is relevant to SDG.

5.6.2 Inflation

In the models, the inflation rate (INF) is positively correlated with the SDG Index and statistically significant, with the degree of significance changing. Moderate inflation is a sign of an active economic demand, production growth, rising employment and greater investment. The moderate inflation rate in emerging economies can at times go hand in hand with economic dynamism that can encourage public spending, infrastructure investment and social sector investment. This finding, however, should be taken with a pinch of salt because high or volatile inflation could have adverse implications for the welfare of the households and sustainability of the enterprises.

5.6.3 Trade Openness

The results of Trade Openness (TRD) are mixed. It is not statistically significant in the FE, RE and PCSE models but is negative and statistically significant in the GMM model. This implies that a higher level of

trade openness can have a negative impact on SDG performance, as trade liberalisation can lead to pollution, extraction of natural resources or unsustainable production.

The discovery suggests that as a single factor, trade openness is not enough for sustainable development. IORA economies require environmentally responsible trade policies, green export standards, sustainable certification systems and support for SMEs to be able to access sustainable value chains to make trade beneficial for SDG outcomes. In the case of Blue Economy sectors, the links with responsible fisheries and sustainable aquaculture, clean logistics and technology upgrading should be highlighted.

5.6.4 Foreign Direct Investment

Foreign Direct Investment (FDI) is negatively related in the models but is only statistically significant in the FE model. This indicates that the impact of FDI on sustainable development is less and is also contingent on the nature and quality of the FDI. FDI can also not have a positive impact on SDG performance if it goes into sectors with high pollution levels, or sectors that lack regulations.

The focus of FDI for Blue Economy development should be on sustainable aquaculture, marine renewable energy, green port infrastructure, green biotechnology or biotechnology related products, climate-resilient coastal infrastructure, and innovation-based SMEs. Regulatory systems must be robust to guarantee foreign investment is used to aid environmental protection, employment generation, technology development and transfer, and inclusive development.

5.6.5 Merchandise Exports

There is mixed performance for Merchandise Exports (ME). In FE model, the coefficient is negative and significant in GMM model, the coefficient is positive and significant. The positive GMM result implies that dynamic relationship and endogeneity relationship between export growth and SDG performance can be in terms of increased national income, employment, foreign exchange earnings, technology transfer and fiscal capacity.

This discovery suggests that sustainable development can be achieved through exports if they are produced in a diverse, value-adding and environmentally friendly manner. IORA economies have the potential for sustainable entrepreneurship through export-oriented Blue Economy industries like seafood processing, aquaculture products, marine logistics services and eco-certified fisheries that meet the environmental standards and market requirements of the international market.

5.6.6 Regulatory Quality

It is negative, and statistically insignificant, in the FE, RE and PCSE models, but negative and statistically significant in the GMM model. Regulatory quality

tends to be expected to promote sustainable development, but the negative GMM coefficient could hint at implementation shortcomings, regulatory inflexibility, compliance costs or institutional inefficiency in the economies under consideration.

This outcome indicates that regulation needs to be well thought out. Strict or poorly designed regulations can make it more expensive for companies, particularly small and medium-sized enterprises, to comply with the regulations without providing immediate benefits for sustainability. Hence, the quality of the regulations needs to be enhanced by making them transparent, by streamlining the procedures involved, by involving stakeholders, by digital governance and by assisting specific sustainable Blue Economy companies.

5.6.7 Tariff Rate

There is a negative relationship between Tariff Rate (TR) and the SDG Index, and it becomes statistically significant in the GMM model. This suggests that higher levels of trade barriers could have a negative impact on sustainable development performance through the availability of green technologies, modern production equipment, sustainable aquaculture inputs, environmental monitoring systems, and international cooperation.

High tariffs can impact competitiveness and stifle innovation, particularly in the case of Blue Economy businesses that rely on imported technology, renewable energy equipment, cold-chain systems, processing machinery and digital monitoring tools. Hence, lowering the barriers to the import of greener technologies and more sustainable production factors can facilitate blue entrepreneurship, competitiveness of SMEs and SDG-driven development.

6. Key Findings

6.1 Aquaculture Production and SDG Performance

In all the estimation methods, the empirical result indicates a positive, strong and statistically significant influence of Aquaculture Production (AP) on Sustainable Development Goals (SDG) Index. This means that sustainable aquaculture development plays an important role in the economic development, food security, livelihood diversification, job creation and environmental sustainability of the selected IORA economies. This result indicates that aquaculture can be an important avenue for enterprise development for the Blue Economy in a sustainable way. With responsible production, innovation and good governance, aquaculture farms, fish-processing units, hatcheries, cold-chain services, feed suppliers and marine-based SMEs can help to achieve the SDGs.

The Fisheries Sector is resource-intensive and contributes 6.2 % of GDP. The Fisheries Sector is resource-intensive and accounts for 6.2 % of GDP.

6.2 The industry group Agriculture–Forestry–Fishing (AFF) and the Total Fisheries Production (TFP) have significant negative impacts on SDG performance, especially in the more complex model specification. This indicates that when production is not supplemented by conservation measures, responsible harvesting and effective regulatory regimes, then the more resources are used the more this can hinder sustainable development outcomes. The results are in line with the theoretical tenets of ecological overexploitation and the Environmental Kuznets Curve argument, which posits that environmental degradation may worsen during the early stages of economic development but improve as institutional capacity, technology and environmental awareness grow. The negative impact of TFP and AFF suggests the move away from extractive growth towards value-added, innovation-based and sustainable enterprises in the context of the IORA economies.

6.3 Marine Protected Areas and Conservation Trade-Offs

The negative association between Marine Protected Areas (MPA) and SDG performance indicates that there could be short-term trade-offs between conservation policies and local economic productivity. MPAs can have a negative impact on fishing communities and marine industries at first by limiting access to marine resources but are intended to protect marine biodiversity and restore the health of the marine ecosystems. This discovery does not mean that MPAs are bad in the long-term. However, it suggests that investing in conservation policies should not be done in isolation, without livelihood support mechanisms, alternative economic opportunities, community engagement and adaptation through entrepreneurship. The economic costs of conservation can be lowered in the short term by ways of eco-tourism, sustainable aquaculture, marine monitoring services, and diversification of the coastal economy to include those that are not destructive to biodiversity.

6.4 Macroeconomic and Institutional Factors.

The other control variables have only moderate positive effects on SDG performance, with Inflation (INF) being the most notable. This could be a sign of a link between the inflation rate and the level of economic activity, investment decisions and production growth. The result, however, should be understood with caution since the high or volatile inflation may have adverse impacts on household welfare and sustainability of businesses. The GMM estimation reveals that Regulatory Quality (RQ) . . . There is a high and negative correlation

between EST (and TR) and SDG performance. This points to the fact that Inefficiencies within institutions, inadequate policy enforcement, tight and rigid regulations, and trade barriers can impede sustainable development efforts in the selected economies of the IORA. Poor regulatory implementation and high tariff barriers can restrict access to green technologies, sustainable production inputs and international markets and innovation systems, from an enterprise-development point of view. This has a negative impact on Blue Economy businesses particularly for small and medium scale enterprises and startups in the business of the sea.

6.5 Sustainable Development and Merchandise Exports

The Merchandise Exports (ME) component significantly and positively influences the SDG performance in the GMM estimate. The result underlines the significance of market integration, export diversification and the competitiveness of trade for sustainable development, which is crucial for countries in the world. Export-oriented Blue Economy sectors (aquaculture products, seafood processing, eco-certified fisheries, marine logistics, and sustainable ocean-based products) can help achieve SDGs in IORA economies with the help of environmental standards, value addition and responsible policies. The overall results from the findings are presented. Results from the findings are presented overall.

When looked at together, the results indicate that the sustainable development of aquaculture, good fisheries management, sustainable trade practices, institutional development and enterprise innovation are necessary for future development towards the SDGs in IORA economies. The findings also indicate that a Blue Economy should not be considered as an approach to resource management. It must be seen as a long-term entrepreneurship route that can be used as a tool for coastal SMEs, marine-based businesses, fisheries co-operatives, aquaculture projects and blue innovation ecosystems.

7. Conclusion

The study examined the correlation among the drivers of the Blue Economy and sustainable development for six economies of the IORA (India, Indonesia, Australia, South Africa, Mauritius, and Kenya) between 2010 and 2024. The study uses panel data analysis such as Fixed Effects, Random Effects, Panel-Corrected Standard Errors, and Generalized Method of Moments to offer empirical findings regarding the relationship between marine economic activities, conservation efforts, trade integration, and institutional factors and SDG performance. The findings indicate that aquaculture

production has a significant effect on SDG outcomes which include food security, employment creation, livelihood diversification and sustainable enterprise development. This indicates that aquaculture can be an effective means of entrepreneurship and inclusive coastal development if done responsibly. However, total fisheries production and agriculture–forestry–fishing activities have negative impacts on SDG performance, suggesting that resource-intensive production activities can generate ecological pressures if they are not underpinned by good governance and sustainable production. The negative correlation between Marine Protected Areas and SDG performance may be due to potential trade-offs in the near-term between conservation and economic activity. Good trade helps growth and development to be sustainable, and bad trade helps growth to be unsustainable. The overall study findings are that a sustainable development approach in IORA economies should focus on a balanced Blue Economy strategy which includes responsible aquaculture, sustainable fisheries management, institutional strengthening, green innovation, trade facilitation, and support for coastal SMEs. This can be a way to help make the Blue Economy a force for sustainable entrepreneurship, inclusive growth and long-term realization of SDGs.

Acknowledgements

We thank our parent organisation, KIIT (Deemed to be University), Odisha, India. which facilitates us with all the required resources for this study. The authors take all the responsibility for all the errors and omissions (if there are any).

Data Availability Statement

Data can be made available on reasonable request.

Funding Sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

- Asif, M. (2023). Blue economy and power politics in the Indian Ocean: Challenges and opportunities. *Journal of Nautical Eye and Strategic Studies*, 2(2), 2–37. <https://doi.org/10.58932/mulg0003>
- Asif, M. (2023b). Blue economy and power politics in the Indian Ocean: Challenges and opportunities. *Journal of Nautical Eye and Strategic Studies*, 2(2), 2–37. <https://doi.org/10.58932/mulg0003>
- Axon, S., & Collier, S. (2022). Breaking Blue: Establishing comprehensive policy for a just and inclusive transition for the Blue Economy. *Marine Policy*, 147, 105343. <https://doi.org/10.1016/j.marpol.2022.105343>
- Benevolo, F. (1999). The Italian maritime economy in the Mediterranean area. In *World Transport Research: Selected Proceedings of the 8th World Conference on Transport Research World Conference on Transport Research Society* (No. Volume 1).
- Boonstra, W. J., Valman, M., & Björkvik, E. (2018). A sea of many colours–How relevant is Blue Growth for capture fisheries in the Global North, and vice versa?. *Marine Policy*, 87, 340–349.
- Borgianni, Y., Cascini, G., & Rotini, F. (2012). Investigating the patterns of Value-Oriented Innovations in Blue Ocean Strategy. *International Journal of Innovation Science*, 4(3), 123–142. <https://doi.org/10.1260/1757-2223.4.3.123>
- Chansoria, M. (2018). Blue Economies of the Indian Ocean Region: Japan's Role in Transition to Sustainable Development and Growth. *Policy*.
- Childs, J. R., & Hicks, C. C. (2019). Securing the blue: political ecologies of the blue economy in Africa. *Journal of Political Ecology*, 26(1), 323–340.
- Doyle, T. (2018). Blue economy and the Indian Ocean rim. *Journal of the Indian Ocean Region*, 14(1), 1–6.
- FAO. (2020). The State of World Fishery and Aquaculture 2020 (SOFIA).
- Gul, S., Shafiq, U., Mir, S. A., Iqbal, G., & Lone, H. Q. (2024). Enhancing global food security through sustainable fisheries and aquaculture: A comprehensive review. *Asian Journal of Agricultural Extension, Economics & Sociology*, 42(10), 60–70.
- Jackson, J. B., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., ... & Warner, R. R. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *science*, 293(5530), 629–637.
- Jouffray, J. B., Blasiak, R., Norström, A. V., Österblom, H., & Nyström, M. (2020). The blue acceleration: the trajectory of human expansion into the ocean. *One earth*, 2(1), 43–54.
- Keen, M. R., Schwarz, A. M., & Wini-Simeon, L. (2018). Towards defining the Blue Economy: Practical lessons from pacific ocean governance. *Marine Policy*, 88, 333–341.
- Khan, R. (2019). RESOURCE AMASSEMENT AS A TOOL OF MAXIMIZING SEA POWER IN THE INDIAN OCEAN. *Andalas Journal of International Studies (AJIS)*, 8(1), 62. <https://doi.org/10.25077/ajis.8.1.62-74.2019>
- Llewellyn, L. E., English, S., & Barnwell, S. (2016). A roadmap to a sustainable Indian Ocean blue economy. *Journal of the Indian Ocean Region*, 12(1), 52–66. <https://doi.org/10.1080/19480881.2016.1138713>
- Martínez-Vázquez, R. M., Milán-García, J., Manso, J. R. P., & De Pablo Valenciano, J. (2023). Impact of blue economy sectors using causality,

- correlation and panel data models. *Frontiers in Marine Science*, 10. <https://doi.org/10.3389/fmars.2023.1034054>
18. McKinley, E., Aller-Rojas, O., Hattam, C., Germond-Duret, C., San Martín, I. V., Hopkins, C. R., ... & Potts, T. (2019). Charting the course for a blue economy in Peru: a research agenda. *Environment, Development and Sustainability*, 21(5), 2253-2275.
 19. Ogutu, M. O. (2021). The Indian Ocean Rim Association: Lessons from this regional cooperation model. *South African Journal of International Affairs*, 28(1), 71-92. <https://doi.org/10.1080/10220461.2021.1915863>
 20. Plink, N., Semeoshenkova, V., Eremina, T., Ershova, A., & Mushket, I. (2021). Improvement of maritime management as a key aspect of sustainable development and blue growth in the Russian Federation. *Journal of Marine Science and Engineering*, 9(11), 1212. <https://doi.org/10.3390/jmse9111212>
 21. Potgieter, T. (2018). Oceans economy, blue economy, and security: notes on the South African potential and developments. *Journal of the Indian Ocean Region*, 14(1), 49-70.
 22. Rahman, M. M. (2021). Analyzing the institutional and regulatory framework for operationalizing the blue economy in Bangladesh: Lessons from Australia. *Preprint*. In Review. <https://doi.org/10.21203/rs.3>.
 23. Sarangi, U. (2022). Blue economy, blue finance and ocean governance for achieving sustainable development goals. *Natural Resources Forum*, 47(1), 3-21. <https://doi.org/10.1111/1477-8947.12267>
 24. Sarker, S., Bhuyan, M. A. H., Rahman, M. M., Islam, M. A., Hossain, M. S., Basak, S. C., & Islam, M. M. (2018). From science to action: Exploring the potentials of Blue Economy for enhancing economic sustainability in Bangladesh. *Ocean & Coastal Management*, 157, 180-192.
 25. Sdoukopoulos, E., Tsafonias, G., Perra, V. M., Boile, M., & Lago, L. F. (2019). Identifying skill shortages and education and training gaps for the shipbuilding industry in Europe. In *Sustainable Development and Innovations in Marine Technologies* (pp. 458-465). CRC Press.
 26. Smith-Godfrey, S. (2016). Defining the blue economy. *Maritime affairs: Journal of the national maritime foundation of India*, 12(1), 58-64.
 27. Spalding, M. J. (2016). The new blue economy: the future of sustainability. *Journal of Ocean and Coastal Economics*, 2(2), 8.
 28. Wenhai, L., Cusack, C., Baker, M., Tao, W., Mingbao, C., Paige, K., ... & Yufeng, Y. (2019). Successful blue economy examples with an emphasis on international perspectives. *Frontiers in Marine Science*, 6, 261.
 29. Santos, T. (2025). Sailing on Waves beyond National Sovereign Land Borders: On the Crossroads between International Ocean Relations and the Blue Economy. *Contexto Internacional*, 47(2), e20220067.
 30. Mukhopadhyay, R., Loveson, V. J., Iyer, S. D., & Sudarsan, P. K. (2020). *Blue economy of the Indian Ocean: resource economics, strategic vision, and ethical governance*. CRC Press.