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Multidimensional Capacities and Sustainable Blue Economy Outcomes: A Moderated-Mediation Model of Innovation and Capability Transformation

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Abstract
Sustainable Blue Economy development requires effectively integrating economic, environmental, institutional, technological, and human capacities to achieve long-term maritime sustainability. This study examines the factors influencing sustainable Blue Economy development in Pakistan's maritime industry, with particular emphasis on the mediating roles of sustainable innovation and capability transformation and the moderating role of institutional quality. Drawing on the dynamic capabilities perspective, the study develops an integrated framework explaining how enabling resources and organizational capacities translate into sustainable development outcomes. A quantitative research design was employed, and primary data were collected from 230 top-level managers, founders, and decision-makers across seven maritime sectors in Pakistan using a structured questionnaire and purposive sampling. The data were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM) through SmartPLS. The findings reveal that economic capacity, environmental sustainability, institutional governance, technological infrastructure, and human capital contribute to sustainable innovation and capability transformation. Both mediating mechanisms demonstrate significant relationships with sustainable Blue Economy development. Furthermore, institutional quality positively moderates the relationships between sustainable innovation and capability transformation and sustainable Blue Economy development. Notably, technological infrastructure demonstrates the strongest positive influence on sustainable innovation ($\beta = 0.414$, $p < 0.000$), while institutional quality significantly strengthens the innovation–sustainability relationship ($\beta = 0.442$, $p < 0.001$). The study contributes to the sustainable Blue Economy literature by distinguishing between innovation and capability transformation as complementary mechanisms of resource conversion. The findings offer practical implications for policymakers and maritime stakeholders in strengthening technological investment, institutional effectiveness, human capital, and environmentally responsible innovation to promote sustainable and inclusive maritime development in Pakistan.

Keywords: Economic Capacity; Human Capital; Institutional Governance, Capability Transformation; Blue Economy; SDG 14; Dynamic Capabilities; Sustainable Innovation; Institutional Quality; Pls-Sem; Pakistan

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Introduction

The sustainable blue economy presents a fundamental development challenge: how can ocean-based activities generate prosperity without degrading the ecosystems that sustain them? Expanding maritime production, Infrastructure, and investment does not, by itself, resolve this tension. Sustainable development requires economic activity to preserve marine ecosystem services and translate resource use into lasting environmental and social benefits. Accordingly, Spalding (2016) positions the blue economy around ocean-positive activities and assessment systems that recognize their ecological implications. This perspective shifts attention from the scale of ocean-based growth to the processes that make development sustainable. Pakistan provides a relevant setting for examining this challenge. The World Bank's Revitalizing Pakistan's Fisheries identifies governance, sustainable fisheries policies, and effective sector strategies as development priorities. These priorities motivate a broader explanatory question: under what conditions can economic, environmental, institutional, technological, and human capacities generate sustainable blue economy outcomes? Addressing this question requires distinguishing the availability of enabling capacities from their conversion into effective practices and measurable benefits.

Dynamic capabilities theory provides a basis for understanding how organizations achieve this. It focuses on how organizations reconfigure and integrate resources in changing environments, rather than on resources being owned to drive performance (Teece et al., 1997). In this spirit, investigate the connections among economic, social and environmental performance and dynamic capabilities in the Norwegian fishing industry, as well as the conditioning effect of the dynamism of the Environment (Harun et al., 2023). While this evidence does not establish equivalency in Pakistan, it provides impetus to consider the mechanisms linking capacities to sustainability, and the circumstances under which they work. The explanatory gap we address here is how heterogeneous capacities become sustainable outcomes through different transformation processes.

According to Prasetyo, Azwardi, and Kistanti (2023), economic capacity mobilizes resources, technological infrastructure provides access to operational and informational tools, and human capital provides the knowledge and skills to operate those tools. The institutional governance aspect offers capacity to coordinate, while the environmental sustainability dimension is comprised of commitments and practices to support ecological stewardship (Yang and Zhang, 2025). These inputs could facilitate development, but they do not indicate whether the maritime industry will create sustainable solutions or build the capabilities to do so. A resource conversion process must be understood within an integrated framework, alongside a resource availability process. Sustainable innovation and capability transformation are two mediators. Sustainable innovation is the development or adoption of products, processes and practices to improve sustainability. Capability transformation involves rearranging the knowledge, processes, materials and skills required to implement and maintain those solutions. The difference is significant: There is no operational Capacity to use an environmentally favorable technology unless that technology is

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adopted. This framework thus considers innovation and capability transformation as distinct pathways, connecting enabling capacities to sustainable development of the blue economy.

Sadiq et al. (2026) suggest institutional quality as the boundary condition. Institutional governance refers to industry's capacity to coordinate and run development activities, while institutional quality refers to the credibility of the broader rules under which they work, and their consistency and effectiveness. The indirect relationships between innovation, transformed capabilities, and sustainable outcomes are proposed to be contingent on institutional quality, as it influences the relationship between the two. This specification supports the moderated-mediation argument: institutional conditions can shape whether innovation and capability development deliver the expected benefits. What is the relationship between economic Capacity, environmental sustainability, institutional governance, technological infrastructure, and human capital on the one hand and sustainable development of the blue economy in Pakistan, with sustainable innovation and capability transformation, and what is the impact of institutional quality on these relationships? It builds three related contributions: a process-based account of capacity conversion, a differentiation between innovation and capability transformation, and an account of institutional quality as a boundary condition. The development of a sustainable blue economy is defined by three aspects: the economic, the social and the ecological, with SDG 14 serving as the guiding principle of marine sustainability. Outcome specification is therefore driven by SDG alignment, rather than by it being seen as a foregone conclusion.

Literature Review and Hypothesis Development

Conceptual foundations of sustainable Blue Economy development

The basic concept of the sustainable development of the Blue Economy. The Blue Economy is a way of doing economic activity that has come to mean an understanding of the connection between ocean-based development, the Environment, and health. Spalding (2016) separates the old ‘ocean economy’ from the new ‘Blue Economy’, highlighting the importance of valuing and recognizing ocean ecosystem services and identifying sustainable activities by distinguishing them from those that harm ecological systems. This approach goes beyond the monetary gains of ocean-related activities and considers the sustainability of the natural resources they rely on. Abid and Abid (2025) also insist on developing clear definitions, using adequate measurement tools and incorporating ecosystem services into economic accounts to identify and assess truly sustainable activities. This conceptualization aligns with the view that economic, environmental and social sustainability must be considered together, rather than treating economic growth as a sign of sustainable development.

In the context of the Norwegian fishing sector, Harun, Hogset, and Mwesiumo (2023) define sustainability performance in economic, social, and environmental terms and show how dynamic capabilities matter for performance in these terms. Their results also show that environmental dynamism affects the relationships between capabilities and economic and environmental performance differently from how it affects social

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performance. This evidence reinforces the need to view sustainability as multidimensional and shows that a single enabling factor will not necessarily yield the same level of improvement across dimensions. The SDGs are used to link all these dimensions to sustainable development. In particular, Wang et al. (2026) explore the relationship between perceptions of the Environment, society and governance (ESG) and pro-ocean environmental behavior and participation intentions in the context of Sustainable Development Goal 14 (SDG 14). Their results suggest that perceived behavioral control and subjective norms are relevant intervening variables, and that environmental attitudes and self-esteem moderate some of the relationships. These findings highlight the need to translate sustainability-oriented principles into ocean behavior, alongside formal governance arrangements and technological interventions.
The literature review on green innovation and sustainability also supports a process-oriented conception of sustainable development. The literature review of related research on green innovation and sustainability also leads to a process-oriented concept of sustainable development. The relevance of green innovation, digital technologies and collaborative approaches is found by Dote-Pardo et al. (2025) in a bibliometric analysis of research on innovative entrepreneurship and sustainability in emerging countries, and constraints on the development of innovative companies are highlighted. Aboagye-Dapaah, Appiah, and Dagadu (2024) also note that policy interventions in digitalization can help overcome financing problems and support innovation persistence by stimulating the concentration of human resources and technological upgrading in the industry. While these studies do not directly evaluate the Blue Economy in Pakistan, they offer complementary evidence that the sustainable development process is a complex interaction of economic, technological, institutional and capability factors. This study therefore views Sustainable Blue Economy Development as multidimensional, encompassing economic sustainability, environmental protection and relevant social outcomes aligned with the SDGs. It is unique in its emphasis on considering economic activity alongside its impacts on ocean ecosystem services and sustainability over time (Bhat et al., 2024). The framework further notes that achieving enabling outcomes through translation may be reliant on innovation and capability development (Ali et al., 2024). The central theoretical question, then, is not merely whether economic, environmental, institutional, technological and human capacities relate to sustainable development, but how these capacities contribute to outcomes and in what institutional context the linkages can be strengthened or weakened. This query raises the issue of integrating five independent variables, two mediators and an institutional-quality moderator in the context of Pakistan.

Economic Capacity and sustainable Blue Economy development

Economic Capacity is defined as the ability to mobilize and use economic resources to support sustainable development. In this framework, it is an enabling condition for investment in sustainability-oriented practices, innovation and capability development. However, the availability of economic Capacity does not guarantee sustainable performance, as resources may not be allocated to activities that deliver long-term

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environmental and ecosystem services (Li et al., 2025; Wasim et al., 2026). Studying innovation in emerging economies can help explain this difference. Dote-Pardo et al. (2025) list resource limitations and systemic obstacles as barriers to innovative entrepreneurship and sustainability. They also emphasize the importance of green innovation, digital technologies and collaborative efforts in sustainable development. Liang, Kim, and Lee (2026) find that dynamic capabilities are associated with economic, social, and environmental sustainability performance in the Norwegian fishing industry. Based on their findings, they argue that the resources and capabilities must be considered in relation to the performance outcomes they enable, not as the same as the outcomes. Likewise, Wu et al. (2025) found that organizational green learning mediates the relationship between green innovation strategy and green innovation performance, suggesting that intermediate processes bridge the gap between strategic orientation and innovation-related outcomes.

Thus, in Pakistan's Blue Economy framework, we anticipate direct relationships between economic Capacity and sustainable Blue Economy development, and indirect relationships between sustainable Blue Economy development and sustainable innovation and capability transformation. The direct pathways highlight how economic resources may support sustainable activities, and the indirect pathways explore how these resources affect innovation potential and the capacity to implement sustainability-oriented practices. However, these relationships are unknown in Pakistan's Blue Economy because of limited existing studies. As such, these relationships remain hypotheses, not conclusions based on empirical evidence.

H1a: Economic Capacity is positively associated with sustainable Blue Economy development in Pakistan.

H2a: Economic Capacity is positively associated with sustainable innovation.

H3a: Economic Capacity is positively associated with capability transformation.

Environmental sustainability and sustainable Blue Economy development

Development of the Sustainable Blue Economy and environmental sustainability. Environmental sustainability is integral to the framework, as it is essential to the long-term viability of ocean-related economic activities if marine ecosystems are not functioning. Ao et al. (2023) highlight the importance of considering ocean ecosystem services when assessing economic activities. This view suggests that sustainable development is not only about economic returns, but also about the implications for the natural systems that deliver those returns. The difference between ocean-related economic activity and sustainable ocean-based activity is therefore essential to conceptualizing the dependent variable. This position is supported by research in marine sustainability, which highlights the link between the sustainable protection of the Environment, governance and human actions. Building on these findings, Wu et al. (2025) explore the link between ESG perceptions and pro-ocean environmental behavior and SDG 14, highlighting the importance of behavioral mechanisms in bridging the gap between ESG perceptions, participation, and environmental action. Their findings support this argument, as environmental sustainability is not only the

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presence of environmental objectives but also the processes by which those objectives affect decisions and actions.

Environmental sustainability in the context of Pakistan refers to the environmental direction and environment-friendly conditions associated with development activities. It differs analytically from Sustainable Blue Economy Development, which reflects overall outcomes across economic, environmental and social dimensions. This distinction helps prevent construct overlap and increases the likelihood that the empirical analysis will examine meaningful relationships rather than correlations between essentially the same measures. Environmental sustainability is expected to directly drive sustainable Blue Economy development by focusing development activities on protecting the Environment (Harun et al. 2023; Spalding 2016; Wang et al. 2022). Thus, these relationships remain hypotheses.

H1b: Environmental sustainability is positively associated with sustainable Blue Economy development in Pakistan.

H2b: Environmental sustainability is positively associated with sustainable innovation.

H3b: Environmental sustainability is positively associated with capability transformation.

H4b: Environmental sustainability is positively associated with sustainable Blue Economy development in Pakistan.

H5b: Environmental sustainability is positively associated with sustainable innovation.

H6b: Environmental sustainability is positively associated with capability transformation.

Institutional governance and sustainable Blue Economy development

Institutional governance represents the governance-related Capacity through which sustainability objectives may be incorporated into development decisions and implementation processes. Its relevance to the Blue Economy stems from the need to coordinate economic activities with environmental objectives and ensure sustainability considerations are reflected in practice rather than remaining general policy intentions. Sadiq et al. (2026) emphasize the importance of agreed definitions, appropriate assessment practices, and measurable criteria for distinguishing sustainable from unsustainable ocean-related activities. These requirements underscore the relevance of institutional arrangements to operationalizing sustainable Blue Economy objectives.

Wang et al. (2026) draw a more direct link between governance and ocean sustainability by examining ESG perceptions and pro-ocean environmental behavior. Their findings indicate that ESG perceptions are associated with participation intentions and environmental behavior through perceived behavioral control and subjective norms. This evidence suggests that governance-related principles may influence sustainability outcomes through mechanisms that connect institutional signals with individual-level responses. Yang and Zhang (2025) likewise demonstrate the importance of institutional and organizational conditions in sustainability-oriented innovation. Their study of digital transformation and green innovation finds that financing constraints can impede green innovation and that ESG performance can

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mitigate some of these negative effects. However, the evidence comes from contexts different from Pakistan's marine economy. It therefore supports hypothesis formulation rather than the conclusion that stronger governance will necessarily produce the same effects in Pakistan.
H1c: Institutional governance is positively associated with sustainable Blue Economy development in Pakistan.
H2c: Institutional governance is positively associated with sustainable innovation.
H3c: Institutional governance is positively associated with capability transformation.

Technological Infrastructure and sustainable Blue Economy development
Technological Infrastructure represents the technological resources and systems that may enable sustainability-oriented activities. Within the framework, it differs from capability transformation because technology availability does not necessarily create the ability to integrate and apply it effectively. This distinction is supported by research that treats technology, innovation, and organizational capabilities as related but conceptually different elements of sustainability-oriented transformation. Technology's relevance to sustainable development also extends to marine sustainability. Wang et al. (2026) discuss technology-enabled approaches to marine monitoring and environmental governance and connect technological innovation with SDG 14-related objectives. Their study emphasizes the role of technological applications and governance-related processes in translating sustainability objectives into practical activities. For Pakistan's Blue Economy, technological Infrastructure is therefore expected to support sustainable development directly and indirectly through sustainable innovation and capability transformation. The direct pathway reflects the potential contribution of technological resources, whereas the mediated pathways recognize that Infrastructure alone may be insufficient without sustainability-oriented innovation and the capability to implement it.
H1d: Technological Infrastructure is positively associated with sustainable Blue Economy development in Pakistan.
H2d: Technological Infrastructure is positively associated with sustainable innovation.
H3d: Technological Infrastructure is positively associated with capability transformation.

Human capital and sustainable Blue Economy development
Human capital represents the knowledge, skills, and competencies that may support the effective use of resources and the implementation of sustainability-oriented practices. Its inclusion recognizes that technological Infrastructure and economic resources may not generate sustainable outcomes without the relevant human capabilities to interpret, integrate, and apply them. Mahmood and Mubarik (2020), studying Pakistan's SME industry, find that green skills development and employee training on circular economy practices significantly enhance circular economy performance. It also demonstrates the relevance of human capital to sustainability-oriented performance within a Pakistani industrial context. The relationship between human capital and innovation is further supported by Mubarik et al. (2022), who

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identify talent aggregation as one mechanism through which digital policy initiatives support the persistence of green innovation. Research on innovation and sustainability also highlights the importance of collaborative and inclusive approaches to sustainable development in emerging economies (Shahbaz, Mubarik, and Mahmood, 2021). Alongside these findings, Mubarik, Naghavi, and Mahmood (2019) support the proposition that human capital is not simply a background characteristic but a potentially important enabling condition for sustainability-oriented practices and capabilities. Nevertheless, these studies do not directly test the role of human capital in Pakistan's Blue Economy. The framework therefore extends the underlying logic to a new context by examining whether human capital contributes to sustainable innovation, capability transformation, and ultimately sustainable Blue Economy development.

H1e: Human capital is positively associated with sustainable Blue Economy development in Pakistan.

H2e: Human capital is positively associated with sustainable innovation.

H3e: Human capital is positively associated with capability transformation.

Sustainable innovation as a mediating mechanism

Sustainable innovation is the first mediating variable because the five capacity dimensions may contribute to sustainable Blue Economy development partly through developing or adopting sustainability-oriented solutions. This mechanism distinguishes the availability of enabling conditions from the processes through which those conditions are translated into innovation and subsequent outcomes. Hwang et al. (2025) provide evidence for an innovation-related mediating process, finding that organizational green learning partially mediates the relationship between green innovation strategy and green innovation performance. Their study also demonstrates that the strength of the relationship between organizational green learning and green innovation performance varies with green technological turbulence. These findings establish the relevance of considering intermediate learning mechanisms and contextual conditions when explaining innovation-related sustainability performance.

Sánchez-Rodríguez et al. (2025) provide complementary evidence by identifying financing constraints, talent aggregation, and industrial upgrading as mechanisms linking national big data pilot-zone reforms to persistent green innovation. Their findings indicate that policy and technological interventions can influence innovation through several interconnected pathways rather than a single direct effect. Adomako and Nguyen (2026), in a preprint examining artificial intelligence capability, eco-innovation, and sustainable performance among Vietnam's small and medium-sized hotels, report that eco-innovation mediates the relationship between artificial intelligence capability and sustainable performance. Because this study is a preprint and focuses on hospitality rather than the Blue Economy, its findings should be treated as preliminary contextual evidence rather than conclusive support for marine-economy relationships.

Prasetyo et al. (2023) also identify green innovation and digital technologies as relevant themes in the sustainability literature on emerging economies, while

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highlighting systemic barriers to the scaling of innovative ventures. This finding is particularly relevant to the framework because it suggests that innovation is a potential pathway to sustainability, but not one that should be assumed to operate independently of resource and institutional constraints. In the model, sustainable innovation is therefore expected to transmit part of the effect of economic Capacity, environmental sustainability, institutional governance, technological Infrastructure, and human capital to sustainable Blue Economy development. The mediating role of sustainable innovation remains a proposition to be empirically tested in the Pakistan maritime industry.

H4f: Sustainable innovation is positively associated with sustainable Blue Economy development in Pakistan.

H5f: Sustainable innovation mediates the relationship between economic Capacity and sustainable Blue Economy development.

H5f: Sustainable innovation mediates the relationship between environmental sustainability and sustainable Blue Economy development.

H5f: Sustainable innovation mediates the relationship between institutional governance and sustainable Blue Economy development.

H5f: Sustainable innovation mediates the relationship between technological Infrastructure and sustainable Blue Economy development.

H5f: Sustainable innovation mediates the relationship between human capital and sustainable Blue Economy development.

Capability transformation as a mediating mechanism

Capability transformation is a second mediator that complements sustainable innovation. Sustainable innovation concerns developing or adopting sustainability-oriented solutions, whereas capability transformation concerns the processes through which resources, knowledge, and competencies are integrated and adapted to support implementation. This distinction lets the framework examine whether enabling conditions contribute to sustainable outcomes by developing new solutions, transforming capabilities, or both. Harun et al. (2023) find that dynamic capabilities are associated with improved economic, social, and environmental sustainability performance in the Norwegian fishing industry. Their findings provide a relevant basis for investigating the relationship between capabilities and sustainability outcomes in an ocean-related industry.

Sulehri et al. (2024) emphasize collaboration and knowledge integration in explaining AI-driven circular transformation, innovation, and adaptive performance. Their findings support the relevance of considering how technological and organizational resources are combined and applied, rather than assuming that resource availability automatically improves performance. Watto (2025) also identifies talent aggregation and industrial upgrading as mechanisms through which policy-related digitalization can support persistent green innovation. These processes are relevant to capability transformation because they involve developing and integrating the resources and competencies associated with sustained innovation.

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The human-capital literature provides further complementary support. Mubarik, Naghavi, and Mahmood (2019) find that employee skills and green attitudes mediate selected relationships between green human resource practices and sustainability-related outcomes. Taken together, these studies suggest that capability development and the effective integration of human competencies matter for sustainability-oriented performance. The Blue Economy framework extends this reasoning by treating capability transformation as a distinct mediating mechanism through which economic, environmental, institutional, technological, and human capacities may contribute to sustainable development. Its empirical contribution will depend on whether capability transformation can be measured separately from sustainable innovation and whether its indirect effects can be distinguished statistically.

H1g: Capability transformation is positively associated with sustainable Blue Economy development in Pakistan.

H2g: Capability transformation mediates the relationship between economic Capacity and sustainable Blue Economy development.

H3g: Capability transformation mediates the relationship between environmental sustainability and sustainable Blue Economy development.

H4g: Capability transformation mediates the relationship between institutional governance and sustainable Blue Economy development.

H5g: Capability transformation mediates the relationship between technological Infrastructure and sustainable Blue Economy development.

H6g: Capability transformation mediates the relationship between human capital and sustainable Blue Economy development.

Institutional quality as a moderating variable

Institutional quality is a moderating variable that may explain why relationships between sustainability-oriented mechanisms and development outcomes vary across institutional conditions. Its role differs from institutional governance, an independent variable. Institutional governance captures a substantive enabling dimension, whereas institutional quality represents the institutional condition under which sustainable innovation and capability transformation may be translated into sustainable outcomes. The need to consider such contextual conditions is supported by research on digital transformation and green innovation. (Wu et al., 2025b) find that digital transformation can increase financing constraints and hinder green innovation, while ESG performance mitigates some of these negative effects. Their findings indicate that the sustainability implications of technological change depend partly on the conditions under which transformation occurs.

Wu et al. (2025) similarly find that the effects of national big data pilot-zone reforms on green innovation persistence vary across firm and regional conditions. Their findings emphasize that policy interventions do not operate the same way across contexts. Yang and Zhang (2025), examining standardization governance and urban green innovation, also report that intellectual property protection moderates the identified innovation-related pathways in different ways. These studies support the broader argument that contextual and institutional conditions can influence how

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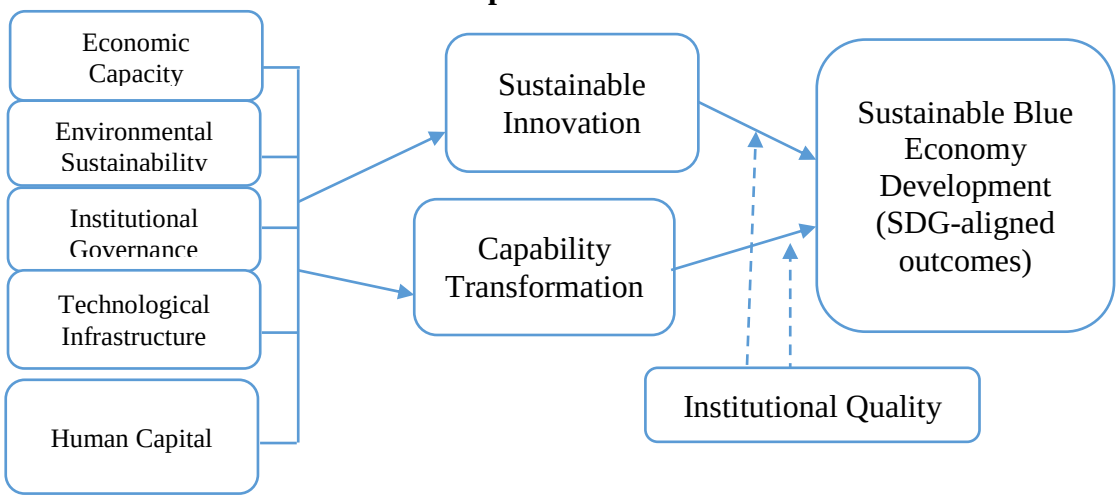
governance and resource-related arrangements translate into innovation. Wang et al. (2026) provide additional evidence for the importance of conditional relationships by finding that green technological turbulence moderates the relationship between organizational green learning and green innovation performance. Although technological turbulence is not the same construct as institutional quality, the study demonstrates the relevance of testing whether the relationship between an intermediate sustainability mechanism and its outcome depends on contextual conditions.

In marine sustainability, Adomako and Nguyen (2026) connect ESG perceptions, behavioral processes, and pro-ocean environmental outcomes. Their findings support examining the conditions under which governance-related signals translate into sustainability-oriented action, although their moderators are individual-level environmental attitudes and self-esteem rather than institutional quality. Collectively, these studies justify examining institutional quality as a boundary condition in the framework. However, they do not directly establish that institutional quality moderates the relationship between sustainable innovation or capability transformation and sustainable Blue Economy development in Pakistan. The direction and magnitude of these moderation effects therefore remain empirical questions. The framework specifies institutional quality as a moderator of the two mediator–outcome relationships. This provides a clear conditional-process structure in which sustainable innovation and capability transformation are expected to have stronger relationships with sustainable Blue Economy development when institutional quality is higher.

H1h: Institutional quality positively moderates the relationship between sustainable innovation and sustainable Blue Economy development, such that the relationship is stronger at higher levels of institutional quality.

H2h: Institutional quality positively moderates the relationship between capability transformation and sustainable Blue Economy development, such that the relationship is stronger at higher levels of institutional quality.

Theoretical Framework and Conceptual Model



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Source: Author Contribution

Research Methodology

The study adopted a quantitative research approach grounded in the positivist research philosophy, which assumes that research phenomena can be objectively examined through systematic observation, measurement, and statistical analysis. Positivism was considered appropriate because the study aimed to empirically investigate the relationships among economic capacity, environmental sustainability, institutional governance, technological infrastructure, human capital, sustainable innovation, capability transformation, institutional quality, and sustainable Blue Economy development in Pakistan's maritime industry. Furthermore, a deductive research approach was employed, whereby theoretically informed relationships and hypotheses were developed from the existing literature and subsequently tested using empirical data. The study employed a cross-sectional research design to collect primary data from relevant maritime industry stakeholders at a particular point in time.

The target population comprised top-level management personnel, including founders, senior managers, and key decision-makers representing seven major maritime sectors: shipping and transportation, ports and harbours, shipbuilding and repair, marine and fisheries, offshore energy, marine technology, and marine environmental management. A purposive sample of 230 respondents was selected to ensure participants had relevant managerial experience, professional knowledge, and decision-making responsibilities within their sectors. Primary data were collected using a structured, closed-ended questionnaire with items rated on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The collected data were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS. The analysis assessed the measurement model for reliability, convergent validity, and discriminant validity, then evaluated the structural model to examine the hypothesized direct relationships, the mediating effects of sustainable innovation and capability transformation, and the moderating effects of institutional quality.

Results and Discussion

The study used Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS to examine relationships among the study variables. The analysis covered measurement model assessment, discriminant validity, direct relationships, and mediation and moderation effects.

Reliability and Convergent Validity

The reliability results indicate that most constructs demonstrate satisfactory internal consistency, with Cronbach's alpha values ranging from 0.725 to 0.934. However, Human Capital (0.524) falls below the recommended 0.70 threshold, indicating relatively weak internal consistency. Regarding convergent validity, most constructs achieved AVE values above 0.50, supporting adequate convergent validity. However, Technological Infrastructure recorded an AVE of 0.474, which requires further attention. An AVE of 0.50 or above is generally recommended to establish convergent validity (F. Hair Jr. et al., 2014).

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Table 4.1 Reliability and Convergent Validity

	Cronbach's alpha	Average variance extracted (AVE)
Capability Transformation	0.901	0.772
Economic Capacity	0.934	0.882
Environmental Sustainability	0.788	0.540
Human Capital	0.724	0.506
Institutional Governance	0.767	0.523
Institutional Quality	0.774	0.774
Sustainable Blue Economy Development (SDG-aligned outcomes)	0.915	0.634
Sustainable Innovation	0.913	0.624
Technological Infrastructure	0.725	0.498

Discriminant Validity

Discriminant validity was assessed using the Heterotrait-Monotrait Ratio (HTMT) and Fornell-Larcker criteria. Most HTMT values remained below the recommended threshold of 0.85. However, Environmental Sustainability and Human Capital (0.887) and Economic Capacity and Sustainable Blue Economy Development (0.862) exceeded the stricter threshold. These values remain below the more liberal 0.90 threshold. The Fornell-Larcker results generally demonstrate satisfactory discriminant validity, as the square roots of AVE are higher than the corresponding inter-construct correlations (Henseler et al., 2015).

Table 4.2: HTMT

	CT	EC	ES	HC	IG	IQ	SBED	SI	TI	IQ x SI	IQ x CT
CT											
EC	0.304										
ES	0.611	0.284									
HC	0.766	0.364	0.887								
IG	0.592	0.343	0.732	0.706							
IQ	0.228	0.300	0.581	0.603	0.684						
SBE	0.28	0.86	0.27	0.35	0.42	0.30					

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D		1	2	9	2	1	4				
SI		0.729	0.299	0.455	0.587	0.594	0.741	0.325			
TI		0.698	0.320	0.621	0.268	0.720	0.699	0.287	0.634		
IQ	x SI	0.201	0.288	0.195	0.126	0.183	0.105	0.462	0.159	0.160	
IQ	x CT	0.019	0.161	0.089	0.315	0.136	0.057	0.265	0.214	0.159	0.621

Table 4.3: Fornell-Larcker criteria

	CT	EC	ES	HC	IG	IQ	SBED	SI	TI
CT	0.878								
EC	0.289	0.939							
ES	0.537	0.263	0.735						
HC	0.566	0.209	0.589	0.712					
IG	0.530	0.322	0.517	0.512	0.723				
IQ	0.795	0.328	0.518	0.466	0.549	0.880			
SBED	0.283	0.793	0.181	0.081	0.360	0.336	0.796		
SI	0.657	0.310	0.416	0.445	0.541	0.610	0.337	0.790	
TI	0.591	0.147	0.611	0.662	0.651	0.562	0.028	0.571	0.688

Direct Relationships

The structural model demonstrates that all reported direct relationships are positive and statistically significant ($p < 0.05$). Capability Transformation positively influences Sustainable Blue Economy Development ($\beta = 0.216$, $p = 0.011$). Economic Capacity, Environmental Sustainability, Human Capital, Institutional Governance, and Technological Infrastructure significantly influence Capability Transformation and/or Sustainable Innovation. Furthermore, Institutional Quality ($\beta = 0.331$, $p = 0.001$) and Sustainable Innovation ($\beta = 0.223$, $p = 0.004$) positively influence Sustainable Blue Economy Development. Technological Infrastructure demonstrates the strongest direct influence on Sustainable Innovation ($\beta = 0.414$, $p = 0.001$). These findings support the proposed relationships in the structural model.

Table 4.4: Path Coefficient

	Original sample	Sample mean	Standard deviation	T statistics (|O/STDE	Pvalues

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Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.216	0.224	0.085	2.539	0.011
Economic Capacity -> Capability Transformation	0.119	0.118	0.039	3.073	0.002
Economic Capacity -> Sustainable Innovation	0.180	0.181	0.039	4.598	0.000
Environmental Sustainability -> Capability Transformation	0.179	0.179	0.059	3.031	0.002
Environmental Sustainability -> Sustainable Innovation	0.220	0.210	0.058	3.793	0.000
Human Capital -> Capability Transformation	0.190	0.193	0.068	2.787	0.005
Human Capital -> Sustainable Innovation	0.320	0.290	0.074	4.324	0.000
Institutional Governance -> Capability Transformation	0.163	0.168	0.060	2.706	0.007
Institutional Governance -> Sustainable Innovation	0.218	0.221	0.058	3.796	0.000
Institutional Quality -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.331	0.347	0.080	4.133	0.000
Sustainable Innovation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.223	0.223	0.076	2.920	0.004
Technological Infrastructure -> Capability Transformation	0.213	0.208	0.082	2.582	0.010
Technological Infrastructure -> Sustainable Innovation	0.414	0.412	0.077	5.396	0.000

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Institutional Quality x Sustainable Innovation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.442	0.441	0.047	9.344	0.000
Institutional Quality x Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.820	0.830	0.310	2.645	0.006

Mediation Analysis

The specific indirect effects indicate that several relationships are mediated through Capability Transformation and Sustainable Innovation. Environmental Sustainability shows significant indirect effects through Capability Transformation (β = 0.390, p = .001) and Sustainable Innovation (β = 0.510, p = .001). Similarly, Technological Infrastructure, Human Capital, and Institutional Governance demonstrate significant indirect relationships with Sustainable Blue Economy Development through the proposed mediators. These findings highlight the importance of capability transformation and sustainable innovation as mechanisms for translating organizational and institutional resources into sustainable development outcomes. However, the negative indirect effect of Economic Capacity through Capability Transformation (β = −0.026, p = 0.039) requires further examination.

Table 4.5: Specific indirect effect Mediation effect

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Environmental Sustainability -> Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.390	0.410	0.099	3.939	0.000
Environmental Sustainability -> Sustainable Innovation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.510	0.610	0.145	3.517	0.000
Technological Infrastructure -> Sustainable Innovation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.092	0.090	0.031	2.977	0.003
Human Capital -> Sustainable Innovation -> Sustainable Blue Economy	0.070	0.061	0.017	4.176	0.000

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Development (SDG-aligned outcomes)					
Institutional Governance -> Sustainable Innovation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.049	0.050	0.023	2.151	0.032
Economic Capacity -> Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	-0.026	-0.026	0.012	2.061	0.039
Technological Infrastructure -> Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.076	0.048	0.030	2.533	0.005
Human Capital -> Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.041	0.042	0.012	3.416	0.000
Institutional Governance -> Capability Transformation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.035	0.036	0.017	2.015	0.044
Economic Capacity -> Sustainable Innovation -> Sustainable Blue Economy Development (SDG-aligned outcomes)	0.040	0.042	0.020	2.022	0.043

Conclusion

This study highlights the critical role of economic capacity, environmental sustainability, institutional governance, technological infrastructure, and human capital in advancing sustainable Blue Economy development in Pakistan's maritime industry. The findings demonstrate that these enabling factors contribute to sustainability outcomes through sustainable innovation and capability transformation, underscoring the importance of translating available resources into effective organizational practices and innovative solutions. Furthermore, institutional quality strengthens the relationships between sustainable innovation, capability

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transformation, and sustainable Blue Economy development. Overall, the study provides empirical insights into the mechanisms through which organizational and institutional capacities can support sustainable maritime development. It emphasizes that achieving a sustainable Blue Economy requires an integrated approach that combines technological advancement, skilled human resources, effective governance, environmental responsibility, and innovation to promote long-term economic prosperity, social well-being, and marine ecosystem preservation in Pakistan.

Recommendation & Policy Implications

Based on this study's findings, several recommendations are provided to promote sustainable blue economy development in Pakistan. First, maritime organizations and policymakers should increase investment in technological Infrastructure, including digital maritime systems, modern port facilities, sustainable shipping technologies, and marine monitoring systems. Second, greater attention should be given to human capital development through specialized training, professional education, and skill-development programs focused on sustainable maritime practices. Third, environmental sustainability should be strengthened through effective marine pollution control, responsible fishing practices, biodiversity conservation, and the adoption of environmentally friendly technologies. Fourth, the government should improve institutional governance and regulatory effectiveness by promoting transparency, accountability, inter-agency coordination, and consistent policy implementation. Fifth, the government should direct financial resources toward sustainable innovation, green technologies, and environmentally responsible maritime projects. Finally, maritime stakeholders should strengthen collaboration among government institutions, private organizations, research institutions, and local communities to build capacity and drive sustainable innovation. These measures can help Pakistan translate its maritime resources and economic potential into long-term, environmentally responsible, and socially inclusive blue economy development.

Future Research Implications

Future research should extend this study by examining sustainable blue economy development across a larger and more diverse sample of Pakistan's maritime industry. Researchers could adopt longitudinal and comparative research designs to explore changes in sustainability practices across different maritime sectors and countries. Further studies may also investigate the roles of artificial intelligence, digitalization, green financing, and regulatory effectiveness in promoting sustainable innovation and capability transformation. Additionally, exploring other institutional and organizational factors could provide deeper insights into the mechanisms that contribute to sustainable blue economy development.

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