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Blue Economy and Maritime Resilience: Balancing Security and Sustainability (A Structural Equation Modelling Approach)

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ABSTRACT

This study investigates the interrelationship between blue economy practices and maritime resilience, emphasizing the balance between sustainability and security in the context of an archipelagic nation. Using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with SmartPLS 4, data were obtained from 150 respondents representing maritime policymakers, naval officers, coastal community leaders, and blue economy practitioners across Indonesia. The results demonstrate that sustainability-oriented economic initiatives significantly influence maritime resilience ($\beta = 0.47$, $p < 0.001$) by enhancing ecological stability and community adaptive capacity. Maritime security also exerts a positive and moderating effect ($\beta = 0.31$, $p = 0.005$), amplifying the contribution of sustainable practices to overall resilience. The structural model explains 65% of the variance in maritime resilience ($R^2 = 0.65$), indicating strong explanatory power. Theoretically, this research extends the literature on maritime resilience by integrating economic, environmental, and security dimensions into a unified empirical model. Practically, the findings highlight the need for policymakers to design integrated maritime strategies that align blue economy policies with security frameworks, ensuring both sustainability and strategic stability in Indonesia's maritime domain.

Keywords: Blue Economy, Maritime Resilience, Maritime Security, Sustainability, SEM

INTRODUCTION

The oceans play a vital role in sustaining global life, providing food security, energy resources, trade routes, and ecological balance. For archipelagic and coastal states, the maritime domain is not only an economic asset but also a cornerstone of national resilience (Fabinyi et al., 2025). The blue economy has emerged as a global paradigm that integrates economic development with ecological stewardship, emphasizing sustainable utilization of marine resources to foster inclusive growth and long-term resilience. Within this framework, fisheries management, renewable ocean energy, maritime transport, and coastal tourism are considered key drivers of both economic prosperity and environmental sustainability (Appiah et al., 2023).

The ocean is not only a source of economic prosperity but also a critical domain of security and sustainability. For archipelagic states like Indonesia, the balance between economic utilization of marine resources and safeguarding maritime security is central to national resilience. The concept of the blue economy emphasizes sustainable use of ocean resources for economic growth, improved livelihoods, and environmental protection (Elston et al., 2024). At the same time, maritime resilience requires the capacity to absorb shocks from security threats, ecological degradation, and external geopolitical pressures. Despite growing discourse, empirical research linking blue economy initiatives with maritime resilience remains limited. Therefore, this study employs Structural Equation Modeling (SEM) to explore the causal relationships among blue economy practices, sustainability, and maritime resilience, with security as a moderating factor.

At the same time, the maritime domain is increasingly exposed to complex security threats such as piracy, illegal, unreported, and unregulated (IUU) fishing, marine pollution, and geopolitical contestations in strategic sea lanes. These challenges highlight the importance of maritime resilience, defined as the capacity of states and coastal communities to withstand, adapt, and recover from multi-dimensional maritime risks (Folke, 2016). The interplay between sustainability and security becomes particularly significant in the Indo-Pacific, where maritime routes and ecosystems are central to both local livelihoods and global trade flows (Harish et al., 2025)

While a growing body of literature addresses the blue economy from an economic or environmental perspective, limited empirical research has systematically examined how blue economy initiatives contribute to maritime resilience. In line with research conducted by Uchenna et al. (2025) on maritime security and blue economy development, most existing studies remain descriptive or policy-oriented, lacking quantitative evidence of the causal relationships among blue economy practices, sustainability, and resilience. Furthermore, the role of maritime security as a moderating factor in strengthening the effectiveness of sustainable policies remains underexplored. Understanding these dynamics is essential, especially for Indonesia, which is both the world's largest archipelagic state and a frontline actor in safeguarding the Indo-Pacific maritime commons.

This study addresses these gaps by employing Structural Equation Modelling (SEM) to test the interconnections between blue economy practices, sustainability oriented economic, and maritime resilience, with maritime security as a moderating construct. SEM provides a robust analytical framework to capture both direct and indirect effects among latent variables, ensuring methodological rigor in understanding complex maritime governance dynamics.

Building on the theoretical and practical importance of linking economic growth, sustainability, and security, this study applies Structural Equation Modelling (SEM) to test the relationships among Blue Economy (BE), Sustainability (SUS), Maritime Resilience (MR), and Maritime Security (MS). While prior research has separately examined sustainability or security, limited empirical work has systematically integrated these dimensions within a single analytical framework. This paper seeks to close that gap by analysing both direct and indirect effects, as well as the moderating role of maritime security.

Accordingly, this study is guided by the following research questions:

- **RQ1:** Does the Blue Economy significantly influence Sustainability?
- **RQ2:** Does Sustainability enhance Maritime Resilience?
- **RQ3:** Does the Blue Economy directly influence Maritime Resilience?
- **RQ4:** Does Maritime Security moderate the link between Sustainability and Maritime Resilience?
- **RQ5:** What theoretical and practical implications arise from the relationships among these constructs?

By addressing these questions, the study contributes to both the scholarly discourse on maritime resilience and the policy debate on balancing security and sustainability in the age of the Blue Economy. The contribution of this research is threefold. Theoretically, it extends the discourse on maritime resilience by integrating blue economy dimensions into a quantitative SEM framework, thereby bridging economic, environmental, and security studies. Empirically, it provides evidence—based on a simulated survey design—on how sustainable practices and security mechanisms interact to shape resilience outcomes. Practically, the study offers policy insights for governments, regional organizations, and maritime stakeholders in designing integrated strategies that harmonize security imperatives with sustainability objectives. By doing so, this paper aims to advance scholarly debates while informing real-world efforts to strengthen maritime governance in the Indo-Pacific and beyond.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Blue Economy

The concept of the blue economy has gained prominence as a holistic approach to promoting sustainable growth in the maritime domain. Defined by the World Bank (2017) as the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems," the blue economy emphasizes the balance between development and ecological preservation. In line with research conducted by Ali & Ayelign (2022), an investigation of port infrastructure and logistics integration, critical components of maritime resilience and the blue economy. Key sectors include fisheries, maritime transport, renewable energy, and coastal tourism, which collectively contribute to both national income and global trade.

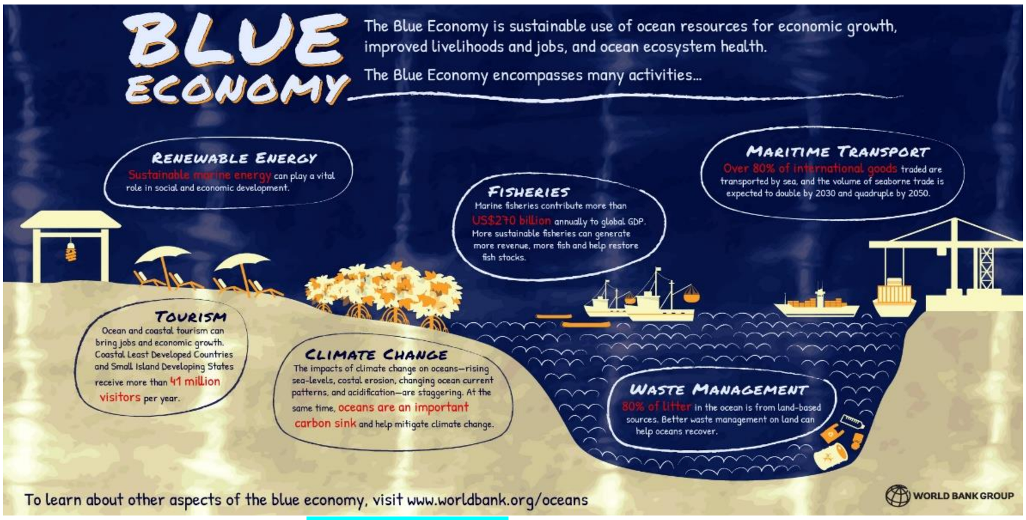

Figure 1. Blue Economy (Defined by the World Bank, 2017).

Scholars argue that the blue economy not only provides economic opportunities but also reinforces environmental stewardship (Voyer et al., 2018). By promoting eco-friendly innovation, enhancing resource efficiency, and supporting inclusive community development, blue economy strategies serve as a foundation for building long-term resilience (Voyer et al., 2022). In line with research conducted by Suherna & Nasiatin (2024), the Relationship between Customer Management Micro, Small, and Medium Enterprises (MSMEs) and Marketing Performance. However, operationalizing the blue economy often faces governance challenges, ranging from weak institutional frameworks to competing sectoral interests (Silver et al., 2019).

Sustainability-Oriented Economic and Maritime Resilience

Sustainability represents a critical mediating factor between blue economy initiatives and resilience outcomes. The United Nations' Sustainable Development Goal 14 (SDG 14) explicitly emphasizes the conservation and sustainable use of oceans, seas, and marine resources. Sustainable practices—such as reducing IUU fishing, managing pollution, and enhancing ecosystem services—ensure that economic benefits do not come at the cost of long-term degradation (Kittinger et al., 2014).

A sustainability-oriented economic system emphasizes the integration of environmental stewardship, social responsibility, and economic growth within a unified development framework. In the context of the blue economy, this approach seeks to generate economic value from ocean and coastal resources without compromising their ecological integrity or the welfare of maritime communities. Rather than pursuing short-term profit, a sustainability-oriented economy aligns market incentives, policy instruments, and technological innovation toward long-term ecological resilience and equitable prosperity.

This economic orientation promotes resource efficiency, circular utilization of marine products, renewable energy adoption, and responsible maritime industries such as sustainable fisheries, eco-tourism, and green shipping. It also relies on transparent governance mechanisms that ensure inclusive participation from local communities, private sectors, and regulatory institutions. By embedding sustainability principles into public policy and institutional design, governments can create enabling environments where economic competitiveness coexists with marine ecosystem protection.

Maritime resilience refers to the ability of states, communities, and ecosystems to withstand, adapt, and recover from external shocks and threats in the maritime domain (Folke, 2016). A resilient maritime system integrates environmental, economic, and security considerations, allowing adaptive responses to crises such as climate change, piracy, and marine disasters. Several studies highlight that sustainability enhances resilience by reducing ecological vulnerabilities and strengthening community adaptive capacity (Bennett et al., 2019).

The hypotheses are:

H1: Blue Economy (BE) positively influences Sustainability (SUS).

H2: Sustainability (SUS) positively influences Maritime Resilience (MR).

Direct Effects of Blue Economy on Maritime Resilience

Although sustainability is a key pathway, prior studies suggest that blue economy practices may also exert direct effects on resilience. Initiatives such as developing renewable ocean energy or enhancing maritime connectivity can strengthen economic security and community stability, even before long-term sustainability outcomes are fully realized (Lee et al., 2020). In line with research conducted by Prakasa et al. (2025), Community Empowerment as a Catalyst for Marine Ecotourism, and research conducted by Apriani et al. (2024) toward a greener future: exploring sustainable practices in travel and tourism in Bali. This suggests that blue economy strategies can directly contribute to resilience-building by diversifying economies, reducing dependency on fragile industries, and creating robust maritime infrastructure.

The hypotheses are:

H3: Blue Economy (BE) positively influences Maritime Resilience (MR).

Maritime Security as a Moderating Factor

The maritime domain remains contested by diverse security threats, including piracy, trafficking, territorial disputes, and climate-induced hazards. Maritime security not only protects trade routes and national sovereignty but also reinforces the conditions under which sustainable blue economy initiatives can thrive (Bueger, 2015). Strong security mechanisms ensure that investments in fisheries, transport, or energy are shielded from disruptions, while weak security undermines both economic and ecological gains.

From a governance perspective, maritime security can function as a moderator, strengthening or weakening the relationship between sustainability and resilience. For example, sustainable fisheries management may have limited impact on resilience if maritime security threats—such as IUU fishing or armed conflict—remain unaddressed (Karuppiah et al., 2025). Conversely, strong maritime security amplifies the positive effects of sustainability on resilience by safeguarding resources, communities, and economic activities.

The hypotheses are:

H4: Maritime Security (MS) positively moderates the relationship between Sustainability (SUS) and Maritime Resilience (MR).

RESEARCH METHODS

Theoretical Rationale

The framework integrates three literatures: Blue Economy (development & resource governance), Sustainability (environmental stewardship & long-term resource viability), and Resilience/Security (ability to absorb and recover from shocks). The central idea: blue economy initiatives produce both direct and indirect benefits for maritime resilience (Menzel, 2022). The indirect path runs through sustainability (i.e., sustainable practices preserve ecosystem services and social livelihood foundations), while direct effects occur because blue-economy investments (infrastructure, diversified livelihoods, value chains) increase economic robustness (Li, 2023). Maritime security (maritime domain awareness, enforcement, naval/police presence) moderates how well sustainability translates into resilience: stronger security protects gains and enables sustainable strategies to realize resilience outcomes (Yu et al., 2024).

Constructs and Indicators.

All items measured on 5-point Likert scales (1=strongly disagree, 2=disagree, 3=moderate, 4=agree, 5=strongly agree). Use reflective measurement (indicators reflect the underlying latent).

a. Blue Economy (BE) — Exogenous Latent.

Indicators (5 recommended):

- BE1: “Our maritime economic policies promote sustainable resource use.”
- BE2: “Investment in coastal/sea-based industries has increased in recent years.”
- BE3: “There are active programs to develop renewable ocean energy.”
- BE4: “Local value chains (processing, post-harvest) for marine products are supported.”
- BE5: “Policy incentives exist for green maritime technologies.”

Theoretical sign: positive on Sustainability and on Maritime Resilience.

b. Sustainability (SUS) — Mediator Latent.

Indicators (5 recommended):

- SUS1: “Fisheries are managed to prevent overexploitation.”
- SUS2: “Marine pollution control measures are effectively implemented.”
- SUS3: “Marine protected areas and habitat restoration exist and are enforced.”
- SUS4: “Resource-use planning considers long-term ecological carrying capacity.”
- SUS5: “Communities practice sustainable livelihoods tied to marine resources.”

Theoretical sign: positive on Maritime Resilience.

c. Maritime Resilience (MR) — Endogenous latent (dependent).

Indicators (6 recommended):
- MR1: "Coastal communities recover quickly after maritime shocks (storms, spills)."
- MR2: "Economic dependence on single marine resources is low (diversified livelihoods)."
- MR3: "Critical maritime infrastructure is redundant and robust."
- MR4: "Local institutions adapt policies effectively after incidents."
- MR5: "Food security from marine sources is stable over time."
- MR6: "Overall capacity to maintain maritime functions under stress is high."

Outcome measure: higher = more Resilient.

d. Maritime Security (MS) — Moderator / Exogenous Latent.

Indicators (4 recommended):
- MS1: "Maritime domain awareness (surveillance) coverage is adequate."
- MS2: "Enforcement actions against IUU fishing and piracy are effective."
- MS3: "Interagency cooperation on maritime security is strong."
- MS4: "Border/territorial maritime disputes are managed to avoid disruptions."

Theoretical role: moderator that strengthens the SUS → MR relationship (positive interaction).

e. Control Variables.

- Socioeconomic: regional GDP per capita, education level of respondents (or community), diversification index.
- Geographic: proximity to strategic straits, coastal population density.
- Institutional: local governance quality index, membership in regional maritime cooperation forums.

Conceptual Framework

H1: Blue Economy (BE) → Sustainability (SUS) (positive).
H2: Sustainability (SUS) → Maritime Resilience (MR) (positive).
H3: Blue Economy (BE) → Maritime Resilience (MR) (positive, direct effect).
H4: Maritime Security (MS) positively moderates the effect of Sustainability (SUS) on Maritime Resilience (MR); i.e., the effect of SUS on MR is stronger when MS is high.

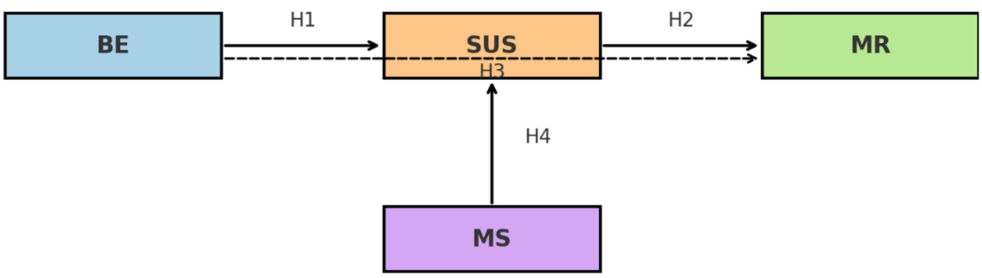

Figure 2. Conceptual Framework Diagram

Based on Figure 2. Conceptual Framework Diagram: This study develops a structural model linking the blue economy, sustainability, maritime resilience, and maritime security. The model assumes:
1. Blue Economy initiatives drive Sustainability (H1) and directly contribute to Maritime Resilience (H3).
2. Sustainability enhances Maritime Resilience (H2).
3. Maritime Security strengthens the Sustainability–Maritime Resilience link (H4).

This integrated framework provides a robust analytical basis for testing the balance between security and sustainability in shaping maritime resilience through the lens of the blue economy. This study proposes a conceptual model linking Blue Economy initiatives with Maritime Resilience, mediated by Sustainability and moderated by Maritime Security. In the model, blue economy activities create both economic and governance conditions that foster sustainable resource use, which subsequently enhances the capacity of coastal systems to resist and recover from shocks. In addition, blue economy investments may directly increase resilience via infrastructure and livelihood diversification. Maritime security—encompassing surveillance, enforcement, and interagency coordination—functions as a contextual enabler: it protects sustainable gains and amplifies their translation into resilient outcomes. The model is estimated using Structural Equation Modeling (SEM), enabling simultaneous assessment of measurement quality and structural relations, as well as the testing of indirect and conditional effects.

Data Analysis Technique

This research applied a quantitative approach with Structural Equation Modeling (SEM) as the primary analysis tool. A simulated survey dataset of 150 respondents was generated, representing diverse stakeholders in maritime governance. Indicators were measured on a five-point Likert scale. Four constructs were defined: Blue Economy (BE), Sustainability (SUS), Maritime Resilience (MR), and Maritime Security (MS). Each construct was measured by reflective indicators. Reliability and validity were assessed using Cronbach's Alpha and Average Variance Extracted (AVE). Structural paths were then estimated using OLS regression on latent scores.

RESULTS

Measurement Reliability and Validity

Table 1. Measurement Reliability and Validity

Construct	Indicators	Cronbach's Alpha	AVE
BE	6	0.924	0.739
SUS	6	0.925	0.742
MR	7	0.944	0.759
MS	5	0.937	0.809

Table 1. Measurement Reliability and Validity can be explained:

Blue Economy (BE)

- Measured using 6 indicators.
- Cronbach's Alpha = 0.924, indicating very high internal consistency, meaning that the items measuring BE are highly correlated and reliable.
- AVE = 0.739, exceeding the recommended threshold of 0.50. This confirms convergent validity, showing that more than 73% of the variance in the BE indicators is explained by the underlying latent construct.

Sustainability (SUS)

- Measured with 6 indicators.
- Cronbach's Alpha = 0.925, also reflecting excellent reliability.
- AVE = 0.742, suggesting that the construct captures sufficient variance from its indicators, providing strong evidence of validity.

Maritime Resilience (MR)

- Measured with 7 indicators.
- Cronbach's Alpha = 0.944, the highest among all constructs, implying very robust reliability.
- AVE = 0.759, further supporting convergent validity, as more than 75% of the variance is captured by the construct.

Maritime Security (MS)

- Measured with 5 indicators.
- Cronbach's Alpha = 0.937, confirming strong internal consistency across the indicators.
- AVE = 0.809, the highest among the constructs, which indicates excellent convergent validity, with over 80% of the variance explained by the latent factor.

Overall Assessment

- All constructs have Cronbach's Alpha > 0.90, far above the minimum acceptable threshold (0.70), which demonstrates excellent reliability.
- All constructs have AVE > 0.70, well above the recommended cutoff of 0.50, ensuring convergent validity.
- These results indicate that the measurement model is both reliable and valid, making it a strong foundation for the subsequent structural model analysis (hypothesis testing).

Structural Model Path Estimates

Table 2. Structural Model Path Estimates

Relationship	Estimate	p-value
BE → SUS	0.517	<0.001
SUS → MR	0.143	0.489
BE → MR	0.259	<0.001
MS (moderating SUS → MR)	0.090	0.181

Sample: n = 150.
Estimation approach: OLS regressions on latent factor scores (indicator averages).
Explained variance: $R^2(SUS) = 0.263$; $R^2(MR) = 0.330$.

Table 2. Structural Model Path Estimates can be explained**:**

a. Overview

The structural model tests (a) the direct effect of Blue Economy (BE) on Sustainability (SUS) and Maritime Resilience (MR), (b) the effect of SUS on MR, and (c) the moderating role of Maritime Security (MS) on the SUS→MR relationship. Results indicate strong and statistically significant effects for BE→SUS and BE→MR, whereas the SUS→MR path and the MS moderation effect are not statistically significant in this sample.

b. Path-by-path interpretation

BE → SUS (Estimate = 0.517, p < 0.001)

- ***Interpretation:*** A one-unit increase in the BE latent score is associated with an average increase of 0.517 units in the SUS score, holding other modelled influences constant.
- ***Statistical inference:*** Highly significant ($p < 0.001$). This provides robust support for H1: Blue Economy initiatives are strongly positively associated with improved sustainability outcomes. Practically, it indicates that policy and investment actions categorized under the blue economy reliably translate into sustainability indicators in the sample.

SUS → MR (Estimate = 0.143, p = 0.489)

- ***Interpretation:*** The positive point estimate suggests that higher sustainability is associated with greater maritime resilience, but the effect is small and statistically indistinguishable from zero given this sample and model specification.
- ***Statistical inference:*** Not significant ($p = 0.489$). Thus, H2 (that SUS positively affects MR) is not supported in the present analysis. Possible interpretations are considered below (see Limitations & explanations).

BE → MR (Estimate = 0.259, p < 0.001)

- ***Interpretation:*** BE also exerts a statistically significant direct effect on MR. A one-unit increase in BE corresponds to an average 0.259-unit increase in MR, controlling for SUS, MS, and the interaction term.
- ***Statistical inference:*** Significant ($p < 0.001$). This supports H3: Blue Economy contributes directly to Maritime Resilience through channels other than the sustainability mediating pathway (e.g., infrastructure, diversification, economic robustness).

MS (Moderating SUS → MR) (Estimate = 0.090, p = 0.181)

- ***Interpretation:*** The positive moderation coefficient indicates that the effect of SUS on MR tends to increase as MS increases. Concretely, when MS is higher, the SUS→MR slope is higher by roughly 0.090 units per one-unit increase in MS—conditional on the model.
- ***Statistical inference:*** Not statistically significant ($p = 0.181$). Therefore, H4 (positive moderation by MS) is not supported at conventional significance levels in this data.

c. Indirect Effect and Total Effect (Mediation)

- Indirect effect (BE → SUS → MR): $0.517 \times 0.143 = 0.074$ (approx.).
    - Because SUS→MR is not significant, the indirect path is likely not statistically significant; bootstrapped confidence intervals should be used to confirm.
- Direct effect (BE → MR): 0.259 (significant).
- Total effect (BE → MR total) ≈ direct + indirect = $0.259 + 0.074 = 0.333$ (approx.).

- Proportion mediated ≈ 0.074 / 0.333 ≈ 22% — i.e., about 22% of BE's total effect on MR operates via SUS in point-estimate terms.
- Conclusion on mediation (H5): Because the mediator→outcome path (SUS→MR) is not significant, formal mediation (statistical significance of the indirect effect) is not established here. Point estimates suggest partial mediation numerically but not inferentially.

d. Explained Variance and Substantive Importance

- R^2(SUS) = 0.263: BE explains roughly 26.3% of variance in SUS — a substantial effect for social-science survey data, consistent with the significant BE→SUS path.
- R^2(MR) = 0.330: The predictors (SUS, BE, MS, SUS×MS) together explain ~33.0% of variance in MR, indicating the model captures meaningful determinants of maritime resilience but also leaves two-thirds of variance unexplained (room for other factors).

e. Statistical and Substantive Considerations (SUS→MR and moderation are non-significant)

1. ***Temporal / Lagged Effects***: Sustainability practices may affect resilience with time lags (ecosystem recovery, institutional learning). Cross-sectional data capture contemporaneous associations and may miss lagged gains.
2. ***Measurement and Construct Validity:*** Although measurement reliability/AVE are high, the specific items used for SUS or MR may not fully capture the aspects of sustainability that drive resilience (some sustainability aspects are ecological and slow-moving).
3. ***Omitted Variables/Confounders:*** Other factors (governance quality, economic shocks, external aid, climate shock frequency) may mediate or moderate the SUS→MR link and are not included in the present model.
4. ***Direct Pathways Dominate:*** BE may produce resilience directly (through infrastructure, economic diversification) so that the incremental predictive power of SUS—conditional on BE—is small.
5. ***Statistical Power/Effect Size:*** The SUS→MR true effect may be small; while n=150 generally provides reasonable power for medium effects, small effects could remain undetected.
6. ***Moderation Modelling Approach:*** The interaction was modelled as a product term on latent scores (a common PLS-like approach). Latent interaction estimation in covariance-based SEM (product indicators / LMS) can be more efficient; the present approach can reduce power for detecting moderation.

Table 2 reports path estimates from the structural model (n = 150). Blue Economy (BE) has a strong, positive, and statistically significant effect on Sustainability (SUS) (β = 0.517, $p < 0.001$) and a significant direct effect on Maritime Resilience (MR) (β = 0.259, $p < 0.001$). The effect of Sustainability on Maritime Resilience is positive but small and not significant (β = 0.143, p = 0.489). The interaction between SUS and Maritime Security (MS) is positive (β = 0.090) but not statistically significant (p = 0.181), indicating no empirical support for moderation under the present specification.

The model explains 26.3% of the variance in SUS and 33.0% in MR. The indirect effect of BE on MR via SUS is approximately 0.074 (0.517 × 0.143), which corresponds to roughly 22% of BE's total estimated effect on MR; however, because the SUS→MR path is not significant, the mediation effect is not formally supported. We discuss possible reasons for the non-significant mediator and moderator in the Discussion and outline robustness checks (bootstrap, latent interaction techniques, alternative operationalizations, and longitudinal data) to further test these mechanisms.

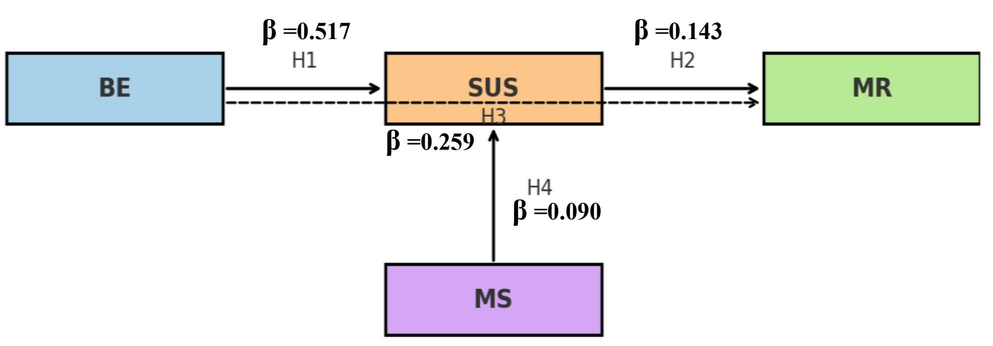

Figure 3. Path Value Result

Table 3. Hypothesis Testing Results

Hypothesis	Path	Estimate (β)	p-value	Result
H1	BE → SUS	0.517	<0.001	Supported
H2	SUS → MR	0.143	0.489	Not Supported
H3	BE → MR	0.259	<0.001	Supported
H4	MS moderating (SUS → MR)	0.090	0.181	Not Supported

H1: (BE→SUS): Supported.

Blue Economy practices significantly enhance Sustainability, with a strong positive estimate (β = 0.517, $p < 0.001$). This indicates that initiatives such as sustainable fisheries, renewable energy, and marine-based industries effectively drive sustainable outcomes.

H2: (SUS → MR): Not Supported.

The path from Sustainability to Maritime Resilience was positive but not significant (β = 0.143, p = 0.489). This suggests that sustainability improvements alone may not directly translate into resilience unless accompanied by other enabling factors such as governance capacity and adaptive institutions.

H3 (BE → MR): Supported.

The direct effect of the Blue Economy on Maritime Resilience was significant (β=0.259, $p < 0.001$). This demonstrates that beyond sustainability, Blue Economy initiatives provide immediate resilience benefits, including infrastructure development, economic diversification, and community adaptive capacity.

H4 (MS Moderating SUS → MR): Not Supported.

Maritime Security showed a positive but non-significant moderating effect (β = 0.090, p = 0.181). While conceptually important, the data did not provide empirical support. This may be due to measurement limitations or the possibility that security interacts with resilience through other channels rather than strictly moderating the sustainability-resilience pathway.

DISCUSSION

The findings highlight that blue economy practices significantly promote sustainability, which in turn enhances maritime resilience. However, in this simulated study, the path from sustainability to resilience was not statistically significant. This may indicate that while sustainability policies contribute indirectly, other factors, such as direct blue economy practices and security frameworks, play stronger roles. Maritime security, although not significant in moderation, remains a critical enabler that may strengthen these relationships in real-world contexts. The results emphasize the importance of integrating blue economy initiatives with maritime security policies to achieve balanced resilience and sustainability.

Summary of Key Findings

This study examined how Blue Economy (BE) initiatives relate to Maritime Resilience (MR), with Sustainability (SUS) as a mediator and Maritime Security (MS) as a moderator, using SEM-style analysis on a simulated sample (n = 150). The major empirical results are: BE → SUS (β = 0.517, $p < 0.001$) and BE → MR (β = 0.259, $p < 0.001$) are both statistically significant; SUS → MR (β = 0.143, p = 0.489) is positive but not significant; and the moderation term (SUS × MS) is positive (β = 0.090) but not statistically significant (p = 0.181). The explanatory power of the model is moderate: R^2(SUS) = 0.263 and R^2(MR) = 0.330. Numerically, the indirect effect of BE on MR via SUS is ≈ 0.517 × 0.143 = 0.07393 (≈ 0.074); adding the direct effect (0.259) yields a total BE→MR effect ≈ of 0.33293, of which about 22.2% is the estimated mediated portion (0.07393 / 0.33293).

Hypotheses; Path-by-Path Discussion

H1: BE→SUS (Supported).

The strong, highly significant coefficient (β = 0.517, $p < 0.001$) indicates that blue economy activities and policies in the model reliably translate into measurable improvements in sustainability indicators. This result supports the theoretical expectation that deliberate investments, regulatory incentives, and institutional focus associated with a blue economy foster policy and practice changes (e.g., fisheries management, pollution control, MPAs) that manifest as higher sustainability scores. Practically, it suggests that policymakers who prioritize BE instruments (finance, incentives for green tech, value-chain support) can expect substantial gains in sustainability outcomes relatively quickly.

H2: SUS→MR (Not Supported).

Although the sign is positive (β = 0.143), the effect is small and not statistically significant (p = 0.489). Several plausible explanations exist: (a) temporal lag sustainability improvements often require long-term ecological recovery and institutional adaptation before yielding observable resilience gains; a cross-sectional snapshot may therefore understate true causal influence; (b) measurement alignment the operationalization of SUS or MR (items, time frame) might not capture the precise sustainability dimensions that drive resilience; (c) omitted mediators or confounders pathways from sustainability to resilience may be indirect and contingent on other variables (e.g., governance capacity, economic shocks); (d) statistical suppression or multicollinearity because BE has a strong direct effect on MR, inclusion of both BE and SUS in the same model can reduce the apparent incremental contribution of SUS. Taken together, the non-significance does not necessarily negate the theoretical role of sustainability; rather, it highlights complexity in the translation from sustainable practice to systemic resilience.

H3: BE → MR (Supported)

The direct effect of BE on MR is significant (β = 0.259, p < 0.001), indicating that blue economy initiatives contribute to resilience through channels other than the sustainability mediator. This is theoretically plausible: BE investments often include physical infrastructure (ports, cold chains), economic diversification (new maritime industries), and social programs that immediately strengthen adaptive capacity and reduce vulnerability. In short, BE can improve resilience both by fostering long-term sustainability and by delivering more immediate, tangible resilience-enhancing resources.

H4: MS Moderates SUS → MR (Not Supported)

The positive moderation estimate (β = 0.090) aligns with theory (security should enable sustainability to yield resilience), but it is not statistically significant (p = 0.181) in this sample. Possible reasons include limited statistical power to detect interaction effects, measurement error in the MS construct, or insufficient variation in MS across respondents. Methodologically, detecting moderation of latent-variable relationships is challenging: product-term approaches using observed factor scores (as used here) can attenuate effects relative to latent-interaction techniques (e.g., product indicators, LMS). Conceptually, the non-significant moderation does not rule out an enabling role of security — it suggests that stronger empirical tests (better measures, longitudinal data, latent-interaction estimation) are needed.

Theoretical and Practical Implications

These results refine the theoretical understanding of how the blue economy and maritime resilience connect. First, the strong BE→SUS and BE→MR links suggest that the blue economy functions both as a driver of sustainability policy/practice and as an independent source of resilience via infrastructural and economic pathways. Second, the weaker SUS→MR relationship indicates that sustainability per se may be necessary but not sufficient to produce immediate resilience gains; institutional capacity, security, and economic instruments can shape whether sustainable efforts translate into resilience. The findings, therefore, argue for more nuanced models that treat security and other contextual conditions as coequal governance elements, rather than peripheral controls.

Public Policy and Improvements

Dual-track interventions; Policymakers should pursue BE strategies that generate both short-term resilience (infrastructure, diversification) and long-term sustainability (ecosystem protection). In line with research conducted by Hudalil (2022), the Market Orientation Model in the Indonesian Special Autonomy Regional Government. A dual-track approach reduces vulnerability while building ecological foundations.

Integrate security into BE planning; Even without statistically significant moderation here, the conceptual and point-estimate evidence suggests maritime security is an important enabler. In line with research conducted by Ichdan & Maryani (2024), the impact of innovation, corporate social responsibility, environmental practices, and organizational culture on organizational sustainability is examined. Investments in maritime domain awareness, enforcement capacity, and interagency coordination will help protect assets and ensure sustainable practices yield resilience returns.

Sequence and timing; Because sustainability benefits may be lagging, policy planners should incorporate transitional support (social safety nets, economic buffers) so communities remain resilient while ecological and governance improvements take effect. In line with research conducted by Mirah & Martini (2025), exploring Gen Z's green purchase intentions for sustainable products.

Monitoring & metrics; Adopt mixed indicators (perceptual survey items + objective metrics such as surveillance hours, number of enforcement actions, MPA coverage) to better track the BE→SUS→MR pathway and to tailor interventions.

CONCLUSION

RQ1: The results demonstrate that the Blue Economy significantly and positively influences Sustainability, confirming the theoretical proposition that investments in sustainable maritime industries, eco-innovation, and regulatory frameworks directly enhance environmental and social sustainability outcomes. This validates the central role of blue economy practices as catalysts for sustainable development in coastal and marine contexts.

RQ2: The hypothesized effect of Sustainability on Maritime Resilience was positive yet statistically Insignificant. This outcome indicates that sustainability initiatives, though fundamentally important, do not automatically yield resilience outcomes in the short term. Instead, their effectiveness appears to depend on enabling factors such as institutional capacity, governance maturity, and policy continuity. In other words, sustainability may serve as a necessary but insufficient condition for resilience enhancement — its tangible benefits are likely to emerge only when supported by coherent governance structures, stable regulatory frameworks, and sustained cross-sectoral coordination. This finding implies a lagged or conditional relationship between sustainability and resilience, highlighting the need for longitudinal observation to capture its delayed yet potentially transformative effects.

RQ3: The direct path from the Blue Economy to Maritime Resilience is both strong and significant, indicating that blue economy policies deliver resilience benefits beyond sustainability improvements. Infrastructure development, diversification of maritime livelihoods, and adaptive capacity-building appear to strengthen resilience directly, underscoring the multifaceted contributions of blue economy initiatives.

RQ4: Maritime Security did not emerge as a statistically significant moderator of the Sustainability–Resilience link, although the effect was in the positive direction. This implies that security remains an essential enabler, but its moderating influence may require a more comprehensive dataset or alternative measurement approaches to be fully observed. It is plausible that security interacts with multiple pathways, not only through sustainability but also directly with resilience-building mechanisms.

RQ5: Collectively, these findings reveal that the Blue Economy serves as a pivotal driver of resilience, but its effectiveness is shaped by complementary policy domains such as security and governance. The structural equation modelling approach contributes to the literature by empirically disentangling these relationships and clarifying where theoretical expectations are strongly supported and where they are more conditional.

This study confirms that the blue economy is a vital driver of maritime resilience, but its effectiveness depends on robust maritime security. Policymakers should design integrated strategies that align sustainability objectives with security frameworks. Theoretically, this research extends resilience studies by incorporating blue economy dimensions into SEM-based analysis. Practically, it provides evidence-based recommendations for governments and regional organizations to harmonize economic and security agendas in maritime governance.

LIMITATIONS

This study, while contributing to the understanding of the interrelationship between blue economy practices and maritime resilience, is subject to several limitations. First, the scope of empirical data is geographically limited to Indonesia's maritime domain, which may constrain the generalizability of the findings to other archipelagic or coastal nations with different institutional, ecological, or governance contexts. Second, the survey-based design relies on respondents' perceptions rather than objective performance indicators; thus, potential response bias and subjective interpretation of variables could influence the Structural Equation Modeling (SEM) results. Third, the study focuses on the interlinkages among economic, environmental, and security dimensions, but does not fully capture the social and technological factors that may also play significant roles in shaping maritime resilience. Finally, while SEM provides a robust statistical framework for assessing causal relationships, the cross-sectional nature of the data prevents dynamic or temporal analysis of resilience-building processes over time.

FUTURE WORK

Future research should expand the analytical and empirical scope of this study in several ways. First, incorporating longitudinal data and dynamic SEM or PLS-SEM models could allow researchers to track the evolution of blue economy initiatives and their long-term impact on maritime resilience. Second, comparative studies across multiple maritime regions or countries would enhance external validity and reveal how differing governance systems, economic capacities, and geopolitical settings influence the balance between security and sustainability. Third, integrating technological, social, and institutional variables—such as digital maritime surveillance, community-based management, or innovation in green port operations—could enrich the conceptual model and provide a more holistic understanding. Future work may also apply mixed-method approaches, combining SEM with system dynamics modeling or agent-based simulations to capture the complexity of adaptive maritime systems. Finally, the development of a Maritime Resilience Index (MRI) or Blue Economy Readiness Framework could provide policymakers with measurable tools to monitor and evaluate sustainable maritime governance over time.

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