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## Article

# Determinants of the Blue Economy Growth in the Era of Sustainability: A Case Study of Indonesia

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**Abstract:** The Sustainable Development Goals (SDGs) represent a fundamental global commitment to addressing a wide range of socio-economic and environmental challenges. A key component of these goals is the commitment to ocean sustainability, encapsulated in the concept of the blue economy. The blue economy, emerging in an era characterized by intricate dynamics and openness to transformation, is influenced by various determinants. This study utilizes panel data analysis and the pooled least squares method to investigate the factors influencing the share of the blue economy in the archipelagic provinces of Indonesia from 2012 to 2021. With its vast maritime territory and numerous islands, Indonesia provides a highly relevant context for examining these dynamics. The empirical results indicate that information and communication technology (ICT), fisheries capture, and aquaculture production positively impact the blue economy's share. Conversely, trade openness and electricity consumption exhibit a negative relationship with the blue economy's share. Moreover, the analysis reveals that investment does not have a significant effect on the blue economy's share. These findings underscore the critical importance of developing robust infrastructure and implementing stringent regulatory oversight on fishery product trade to enhance sustainable growth within the blue economy framework.

**Keywords:** blue economy; fisheries; gross domestic product; sustainable development



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## 1. Introduction

The Sustainable Development Goals (SDGs) represent a critical global commitment, with particular emphasis on marine ecosystems and fisheries, given that oceans cover the majority of the Earth's surface (Zhang et al. 2024). As a result, the increasing focus on SDG-related issues has brought greater attention to the concept of the blue economy, particularly among those responsible for the management of coastal and marine areas (Qi 2022). The blue economy framework seeks to promote economic growth, enhance social inclusiveness, and improve livelihoods, while simultaneously prioritizing the conservation of marine and coastal environments (Ayilu et al. 2022). Therefore, effective protection and management of this sector are crucial for ensuring its long-term sustainability.

On 25 September 2015, the SDGs were formally endorsed by all 193 Member States of the United Nations and came into effect on 1 January 2016. These goals build upon the foundation laid by the Millennium Development Goals (MDGs), serving as both a normative and technical framework for coordinated international efforts toward achieving global development objectives (Duxbury et al. 2017). Notably, the SDGs introduce a transformative perspective by recognizing that development is a “collective journey” (United Nations 2015, p. 3)—a shared endeavor by all nations, rather than a one-sided effort by the Global North aimed at the Global South (Wiktor-Mach 2020).

The development of the marine economy within the framework of sustainable development is crucial for achieving a balanced integration of economic progress and environmental conservation. By prioritizing sustainability in marine industries, nations can optimize the

use of ocean resources while simultaneously safeguarding ecological integrity for future generations. This multifaceted approach not only addresses urgent economic needs but also aligns with broader sustainable development goals, such as poverty alleviation, climate action, and biodiversity conservation. Implementing sustainable practices in sectors like fisheries, aquaculture, marine tourism, and renewable energy helps to enhance ecosystem health, strengthen local livelihoods, and create employment opportunities, particularly in coastal communities. Furthermore, the emphasis on renewable energy initiatives plays a critical role in mitigating climate change, while healthy marine ecosystems provide essential buffers against the adverse effects of extreme weather events on coastal regions. The integration of local communities in marine resource management is vital for achieving sustainable outcomes, as it fosters a sense of stewardship and ensures the equitable distribution of benefits. Ultimately, the development of the marine economy represents a comprehensive approach to addressing the interconnected challenges of economic and environmental sustainability, thereby increasing long-term resilience and promoting the well-being of future generations.

Indonesia, characterized by its vast maritime territory, has a sea area that far exceeds its landmass. Of the country's total area of 8.3 million km<sup>2</sup>, only 1.9 million km<sup>2</sup> is terrestrial, while 6.4 million km<sup>2</sup> is water, encompassing 17,504 islands stretching from Sabang in the west to Merauke in the east (KKP 2022). This extensive maritime domain is central to Indonesia's economy and culture, supporting key activities such as trade, cultural exchange, and information dissemination via maritime routes (Rochwulaningsih et al. 2019). Additionally, fishermen rely on electricity to preserve their catch (Sumaila et al. 2021; Taherzadeh-Shalmaei et al. 2021) and use digital technologies, including the internet and mobile devices, to market and sell their products. Maritime trade remains a critical driver of Indonesia's economic development. The growing involvement of private investors in natural resource sectors has expanded investment opportunities, as investors seek to diversify risk, enhance portfolio resilience, and improve reputational capital by prioritizing investments in natural resources (Kaiser 2019).

A fundamental determinant of economic output is investment, represented by gross fixed capital formation (GFCF), with empirical evidence showing that higher levels of GFCF are positively correlated with increased economic output. The blue economy encompasses five main activities: biological resource extraction, non-biological resource extraction, new resource generation, resource trading (including tourism and recreation), and ocean health maintenance (Smith-Godfrey 2022). In the context of Indonesia, the blue economy, supported by its vast maritime area and abundant marine resources, offers substantial opportunities for capital formation. This capacity for significant capital accumulation can attract long-term investment, thereby enhancing GFCF. Increased GFCF, in turn, facilitates improvements in infrastructure across various sectors, including fisheries (Eurostat 2013). Specifically, higher GFCF can lead to advancements in ship quality and production equipment, boosting productivity in the fisheries sector. This increase in productivity and income subsequently contributes to overall GDP growth. However, to optimize these outcomes, it is crucial to manage investments with a focus on sustainability to prevent the overexploitation of marine resources.

Robust infrastructure is essential for enhancing productivity within the fisheries sector, with electrical energy being a critical component for the storage and preservation of marine biota captured by fishermen (Bitoun et al. 2024). The availability and efficient distribution of electrical energy are key factors influencing productivity within the fisheries industry, which, in turn, contributes to broader economic growth. Therefore, policies aimed at expanding electrical energy distribution should prioritize the development of renewable energy sources to support and advance the blue economy framework (Cisneros-Montemayor et al. 2022). Moreover, various activities integral to the blue economy—such as post-harvest processing and shipbuilding—are heavily dependent on consistent access to electricity (Bhattacharya and Dash 2020).

In addition, the evolution of information and communication technology (ICT), particularly the proliferation of mobile phones and internet usage, has significantly transformed the economic landscape, driving growth (Haldar et al. 2023). The expansion of telecommunications networks enhances fishermen's social and business connections, facilitating product distribution and ultimately leading to higher income levels, which contributes to overall economic growth. As ICT is widely regarded as a productivity enhancer, its development is likely to have a positive correlation with blue economy indicators.

The blue economy framework is also significantly bolstered by a nation's participation in international trade, as indicated by the ratio of total exports and imports relative to GDP (Ortega et al. 2024). Increased trade openness stimulates business activities, boosts promotional and advertising efforts, and drives infrastructure improvements, which raise awareness of product origins and contribute to economic development (Bhattacharya and Dash 2021). These advancements can support the growth of the blue economy by increasing national income through both direct and indirect means.

However, while trade openness generally promotes economic growth, it may have negative consequences for fisheries production. According to export-led growth theory, although trade liberalization can enhance economic performance, it may also result in overfishing, leading to declines in fish stocks and production (Eisenbarth 2022).

The fisheries sector plays a vital role in both economic and social development by directly contributing to food security, providing livelihoods for coastal communities, generating significant export revenues, and supporting broader economic growth. Aquaculture and capture fisheries are indispensable national resources, not only ensuring food security but also enhancing livelihoods, creating employment opportunities, and contributing to economic stability (Rehman et al. 2019). In Indonesia, the fisheries sector is integral to national economic development, demonstrating positive outcomes (Kusdiantoro et al. 2019). The interplay between capture fisheries and aquaculture is pivotal in advancing the blue economy, as both sectors depend on aquatic ecosystems and offer opportunities for those employed within them to act as resource users and stewards (Phang et al. 2023).

There is an urgent need for in-depth research to clarify policymakers' expectations and the drivers shaping the scope and conceptual framework of a sustainable blue economy (Lee et al. 2020). While the existing literature frequently discusses the conceptual foundations and potential benefits of the blue economy—such as marine ecosystem utilization and governance—there is a notable lack of empirical investigations into the stakeholders driving the blue economy, particularly in archipelagic nations. Addressing this gap is a key focus of the present study.

This study aims to elucidate the principal determinants affecting the proportion of the blue economy in Indonesia, with a specific focus on the island provinces during the period from 2016 to 2021. It offers critical insights for researchers, policymakers, and governmental agencies involved in research, strategic planning, and policy formulation. The primary contribution of this study is to enhance the effective management and sustainable use of marine resources in Indonesia. Through a rigorous analysis of the key factors influencing the blue economy, this study provides policymakers with comprehensive evidence on the progression of blue economy initiatives and supports the development of informed and strategic policies to address maritime challenges effectively.

The following section presents a literature review that outlines the principles of the blue economy and sustainability, trade openness, gross fixed capital formation, electricity consumption, and information and communication technology, as well as fisheries and aquaculture production. Subsequently, the methods section describes the processes involved in collecting secondary data and the analytical techniques employed. The final sections present the results and discussion, followed by the conclusion.

## 2. Literature Review

The concept of the blue economy is gaining increasing global attention, particularly in relation to the Sustainable Development Goals (SDGs). It focuses on the sustainable

use of marine resources to enhance economic welfare while preserving the sustainability of marine ecosystems (Phelan et al. 2020). Research on the blue economy has expanded rapidly as global attention to the sustainability of marine environments and the role of the maritime economy in economic growth has grown. As an archipelagic nation with vast marine resources, Indonesia is well-positioned to leverage this approach (Hendarman et al. 2024). Alharthi and Hanif (2020) demonstrated that the blue economy plays a statistically significant role in economic growth and contributes to achieving the UN's Sustainable Development Goals.

The blue economy has emerged as a framework aimed at balancing economic growth with environmental sustainability in marine and coastal regions. It encompasses a wide range of activities, including fisheries, aquaculture, marine tourism, and renewable energy, emphasizing the sustainable use of ocean resources. This literature review compiles existing research on the blue economy and its connection to sustainability, focusing on key determinants such as trade openness, gross fixed capital formation (GFCF), electricity consumption, information and communication technology (ICT), and fisheries and aquaculture production.

In Indonesia, research on the blue economy has primarily focused on the fisheries and marine sectors, which are considered key economic drivers in many island provinces. Wiryawan et al. (2024) revealed that Indonesia has implemented the blue economy through six sectors, with marine capture fisheries, aquaculture, and fish processing being the most dominant. Kusdiantoro et al. (2019) noted that the development of capture fisheries has had a positive economic impact in Indonesia, contributing to GDP growth and stimulating economic activity. Additionally, (Nilsson et al. 2019) emphasized the importance of effective marine policies in addressing challenges such as overfishing and climate change to ensure sustainable fisheries. Achieving sustainable blue economy growth requires balancing economic activities with environmental protection, improving resource management, and promoting regional cooperation (Geng et al. 2024).

The blue economy is an economic system that recognizes the value of ocean resources while ensuring their sustainable management for future generations (Bennett et al. 2019). Its goal is to establish a framework that enables economic development without compromising the health of marine ecosystems. Scholars have stressed the importance of incorporating sustainability principles into economic activities to balance economic expansion with ecological conservation (Barbier 2016; Pomeroy and Andrew 2011). Achieving sustainability within the blue economy involves implementing practices that enhance marine ecosystem resilience while supporting local communities and economies (OECD 2024).

International trade is vital to the blue economy, as oceans and seas cover more than two-thirds of the Earth's surface and contribute to poverty alleviation by creating sustainable livelihoods and facilitating access to global markets (Matuga et al. 2019). Trade openness plays a significant role in the blue economy by enabling the exchange of goods and services, including marine products. Studies have shown that greater trade openness can improve the economic viability of the blue economy by providing access to broader markets for fisheries and aquaculture products (Geng et al. 2024). Furthermore, trade liberalization can promote the adoption of sustainable practices, as competition in global markets often incentivizes efficiency and sustainability improvements (Béné et al. 2016). However, increased international trade, while crucial to global economic growth, can negatively impact the blue economy. Hossain et al. (2024) found that increased maritime trade raises the risk of hazardous substances being released into the ocean, which can threaten marine ecological integrity. Therefore, aligning trade policies with sustainability goals is essential to avoid the overexploitation of marine resources.

Gross fixed capital formation (GFCF) is another critical factor influencing the development of the blue economy. Investment in infrastructure, technology, and capital assets is essential for improving productivity and sustainability in marine industries (World Bank 2018). Increases in GFCF in areas such as fisheries, aquaculture, and marine renewable energy can result in greater efficiency and reduced environmental impacts (Deb and Li



2023). Research has shown that countries with higher levels of GFCF tend to achieve better outcomes in terms of sustainable resource management and economic growth within the marine sector (Jansen and van den Bogaart 2020).

Electricity consumption is also a key element of the blue economy, especially in the operations of marine industries. Transitioning to renewable energy sources, such as offshore wind and solar power, is crucial for reducing the carbon footprint of marine activities (Andersen et al. 2023). Increased electricity consumption, when sourced from renewables, can enhance the sustainability of fisheries and aquaculture by powering technologies that improve resource efficiency (Menicou and Vassiliou 2010). Additionally, reliable electricity access is necessary for fostering the development of innovative technologies in marine industries, contributing to both economic growth and sustainability.

Information and communication technology (ICT) plays a transformative role in advancing the blue economy by improving data collection, management, and communication within marine sectors (Murray et al. 2018). The integration of ICT can enhance the monitoring and enforcement of sustainable practices, facilitate access to market information, and promote transparency across supply chains (Khaled and Hammas 2021). Research has shown that adopting ICT in fisheries and aquaculture can lead to better decision-making, increased productivity, and reduced environmental impacts (Berkes 2017). Therefore, promoting ICT development is essential for unlocking the full potential of the blue economy.

Fisheries and aquaculture production are central to the blue economy and are critical determinants of its sustainability. Effective management practices in these sectors are necessary for ensuring food security, supporting livelihoods, and maintaining ecological balance (FAO 2020). Studies have shown that adopting sustainable practices in fisheries and aquaculture can lead to healthier fish stocks and habitats, contributing to the overall sustainability of marine ecosystems (Grafton et al. 2016). Moreover, integrating sustainable aquaculture methods can ease the pressure on wild fish populations and enhance the economic viability of coastal communities (Bennett et al. 2019).

The blue economy represents a promising strategy for achieving sustainability in marine and coastal regions. The interactions between trade openness, gross fixed capital formation, electricity consumption, information and communication technology, and fisheries and aquaculture production significantly influence the development of the blue economy. Future research should explore the synergies among these determinants and their collective impact on sustainable development, as well as identify the best practices that can be implemented at local, national, and international levels to foster a resilient blue economy.

### 3. Methods

#### 3.1. Study Area

This study utilized secondary panel data from the *Badan Pusat Statistik* <https://www.bps.go.id> (accessed on 24 June 2023), aggregated as pooled data, to conduct a comprehensive analysis of the factors influencing the blue economy across Indonesia's archipelagic provinces, as identified by the Archipelagic Province Cooperation Agency (*Badan Kerja Sama Provinsi Kepulauan*). The eight provinces included in this agency are the Bangka Belitung Islands, North Sulawesi, Southeast Sulawesi, Riau Islands, West Nusa Tenggara, East Nusa Tenggara, Maluku, and North Maluku. The analysis focused on data from 2012 to 2021, a period selected due to the availability of relevant and usable information. These regions were chosen for their diverse economic and ecological characteristics, which reflect both the potential and challenges in developing the blue economy. Notably, these provinces are rich in marine resources and play a crucial role in Indonesia's trade and fisheries sectors.

#### 3.2. Data and Data Sources

This study utilizes secondary panel data from *Badan Pusat Statistik* <https://www.bps.go.id> (accessed on 24 June 2023), aggregated as pooled data, to conduct a comprehensive analysis of the determinants affecting the blue economy across Indonesia's island provinces.

The analytical framework is based on the determinants identified by [Bhattacharya and Dash \(2021\)](#), which include trade openness, cellular phone penetration, investment (represented by gross fixed capital formation), the distribution of electrical energy, and the output of capture and aquaculture fisheries. A detailed description of these variables is provided in Table 1.

**Table 1.** Variable descriptions.

Variables	Notation	Description
Blue Economy	BE	Blue economy share of GDRP Fishery sector per GDRP
Trade Openness	TO	Export + import per GDRP
Gross Fixed Capital Formation	GFCF	Gross fixed capital formation percentage of GDRP
Electricity Consumption	EC	Electricity distributed to the community (Gwh)
Information, Communication, and Technology	ICT	Percentage of population owning/operating cell phones
Fisheries and Aquaculture production	FNA	Fisheries capture plus aquaculture in metric tons

Source: Author compilation (2023).

### 3.3. Model

A quantitative analytical framework was employed, specifically using the pooled least squares estimation method as described by [Gujarati and Porter \(2009\)](#). The model's functional specification, incorporating these variables, is represented by the following equation:

$$\ln BE = f(\ln TO, \ln GFCF, \ln ICT, \ln EC, \ln FNA) \quad (1)$$

In alignment with the specified functional form, the regression equation pertinent to the research model is articulated as presented in Equation (2).

$$\ln BE_{i,t} = \beta_0 + \beta_1 \ln TO_{i,t} + \beta_2 \ln GFCF_{i,t} + \beta_3 \ln ICT_{i,t} + \beta_4 \ln EC_{i,t} + \beta_5 \ln FNA_{i,t} + e_{i,t} \quad (2)$$

In this analytical model,  $\ln BE$  was designated as the dependent variable, representing the natural logarithm of the blue economy share. The coefficient  $\beta$  represents the parameter estimate. The variable  $TO$  denotes trade openness, while  $GFCF$  stands for investment, proxied by gross fixed capital formation. The variable  $ICT$  represents information and communication technology, proxied by cellular phone ownership.  $\ln EC$  refers to the natural logarithm of electricity consumption, with electricity distribution serving as the proxy. Additionally,  $\ln FNA$  signifies the natural logarithm of production in capture fisheries and aquaculture. The indices  $i$  and  $t$  represent the time series and cross-sectional dimensions of the data, respectively, and  $e$  denotes the standard error.

This study employs a panel data regression model to address potential endogeneity and exogeneity issues. Panel data regression enables the combination of time series observations across multiple individuals or regions, providing deeper insights into the dynamics between the variables under investigation ([Biørn and Han 2016](#)). This method allows for the measurement of effects that may be missed when using only cross-sectional analysis (which compares differences between provinces at a single point in time) or time-series analysis (which tracks changes within a single province over time). By combining both time and cross-sectional dimensions, panel data offers richer insights and more reliable estimates, supporting the evaluation of complex relationships with fewer restrictive assumptions.

In this analysis, the random effects model was selected as the most appropriate approach for estimating outcomes. This model accounts for unobservable variations between individuals or provinces that could influence the dependent variable ([Bretó et al.](#)

2020). The random effects model assumes that these unobserved individual characteristics are random and uncorrelated with the independent variables. This assumption allows for more efficient and unbiased estimates, while accounting for the unique features of each province in the analysis.

### 3.4. Justification of Independent Variables

The selection of independent variables in this study is based on their theoretical and empirical relevance, highlighting key factors that influence blue economy growth in Indonesia. These variables not only capture economic and environmental aspects but also reflect the sustainability and inclusiveness of growth within the maritime sector. Each variable was carefully chosen for its critical role in promoting a sustainable blue economy, particularly in the context of Indonesia's archipelagic provinces, which heavily depend on marine resources.

Trade openness (TO) is widely recognized as a key driver of economic growth, particularly in the maritime and fisheries sectors. By opening access to global markets, trade openness enables Indonesian fisheries products to compete internationally, enhancing the sector's competitiveness and contributing to domestic production and community welfare (Destiningsih et al. 2020). However, according to Hossain et al. (2024), trade openness can also have negative effects on the blue economy, such as overfishing and environmental degradation due to the overexploitation of marine resources.

Investment, measured through gross fixed capital formation (GFCF), serves as a crucial indicator of the flow of funds into productive sectors like fisheries and maritime industries. Investments in maritime technology and innovation can enhance the sustainability, efficiency, and transparency of these sectors (Latief et al. 2023). However, it is important to assess whether such investments effectively benefit Indonesia's more remote and underdeveloped provinces.

Information and communication technology (ICT) has been acknowledged as a powerful driver of economic growth across various sectors, including the blue economy. Tijan et al. (2019) highlighted the application of digital technologies in marine transportation can help achieve blue economy goals. Consequently, ICT was selected as an independent variable in this study to measure its impact on blue economy growth, particularly in improving market access and accelerating technology adoption in the fisheries sector.

Energy consumption, particularly electricity, is vital for supporting operations in the fisheries and maritime sectors. Bhattacharya and Dash (2020) found that access to electricity positively impacts blue economy activities such as tourism and fisheries in Asian and Pacific island nations. However, it is important to note that fossil fuel-based electricity consumption negatively affects the blue economy by contributing to greenhouse gas emissions and climate change, which pose significant threats to coastal and marine ecosystems (Vrontisi et al. 2022).

Finally, fisheries and aquaculture production are at the core of Indonesia's blue economy. These sectors provide livelihoods and income to millions of people in coastal communities while significantly contributing to national food security. Pradeepkiran (2019) noted that aquaculture plays a vital role in economic development and global food supply in developing countries. Nevertheless, challenges such as overfishing, pollution, and climate change threaten the sustainability of marine ecosystems (Youssef et al. 2023).

This study aims to evaluate how factors such as trade openness, investment, ICT, energy consumption, and fisheries production influence blue economy growth in Indonesia, with a focus on ensuring sustainable and inclusive development. Each variable was selected based on its strong relevance to Indonesia's blue economy, which necessitates the responsible management of natural resources to foster sustainable and inclusive growth.



## 4. Results and Discussion

### 4.1. Results

Due to constraints in data accessibility, Maluku Province was excluded from the analytical framework, resulting in an analysis of seven archipelagic provinces over the period from 2012 to 2021. The results of the Jarque–Bera test indicate that the majority of the dataset conforms to a normal distribution, as evidenced by probability values exceeding the 0.05 threshold. However, the variable related to trade openness presents an anomaly, with a probability value below 0.05, indicating a statistically significant deviation from normality.

As shown in Table 2, the findings from the Chow test reveal a probability value of 0.000, which is well below the conventional threshold of 0.05. This outcome provides strong evidence favoring the fixed effects model over the common effects model (also known as the pooled ordinary least squares model). While the common effects model assumes homogeneity across entities, the fixed effects model accommodates entity-specific variations, emphasizing the importance of these distinctive characteristics in the analysis.

**Table 2.** Regression analysis output.

Variables	Coefficient	Error Term	t-Statistics	Probability
C	0.796314	0.098666	8.070834	0.0000 ***
Trade openness	−0.001577	0.000177	−8.911048	0.0000 ***
Gross fixed capital formation	0.039574	0.079971	0.494847	0.6224
Information, communication, and technology	0.010266	0.000637	16.11573	0.0000 ***
LNED	−0.612658	0.030319	−20.20696	0.0000 ***
LNENA	0.228164	0.022712	10.04579	0.0000 ***
R <sup>2</sup>	0.711367			
F-Statistics Prob	0.000 ***			
<b>Model Selection Test</b>	<b>Stat</b>	<b>Prob</b>		
Chow test	136.789	0.0000		
Hausman test	4.010	0.5483		
Lagrange multiplier test	12.568	0.0018		
<b>Diagnostic Test</b>		<b>Prob</b>		
Jarque–Bera	2.622	0.2777		
Cross LR	81.033	0.166		
Pesaran CD	6.210	0.080		

\*\*\* represent a significant level of 10%, 5%, and 1%. Source: EvIEWS 9<sup>l</sup> output, (2012–2021).

Following the determination of the fixed effects model’s superiority over the common effects model, the Hausman test was conducted to compare the fixed effects and random effects models. The Hausman test yielded a probability value of 0.5483, which exceeds the 0.05 threshold, suggesting that the random effects model is the more appropriate specification. The failure to reject the null hypothesis—which asserts the consistency of the random effects model—further supports this conclusion. The random effects model operates under the assumption that individual-specific effects are orthogonal to the explanatory variables, making it a suitable framework for this dataset.

The Lagrange multiplier test produced a probability value of 0.0018, providing clear evidence of significant variation in individual-specific effects. This result further reinforces the preference for the random effects model over the pooled ordinary least squares model, which does not account for such variation. Consequently, the random effects model offers a more accurate representation of the underlying data structure compared to the simpler pooled ordinary least squares approach.

Additionally, the results from the Jarque–Bera test, the cross-section likelihood ratio test, and the cross-section dependence test all exhibit probability values exceeding the 5% significance level. Specifically, the probability values obtained from the Jarque–Bera test surpass the 5% threshold, leading to the conclusion that the null hypothesis of normality

cannot be rejected. This suggests that the residuals of the regression model adhere to a normal distribution, a fundamental assumption underlying regression analysis.

Similarly, the probability values derived from the cross-section likelihood ratio test exceed the 5% significance level, indicating that the null hypothesis of homoscedasticity (constant variance) holds, thus suggesting that heteroscedasticity—where variance varies across observations—is absent. Furthermore, the Pesaran CD test produced probability values exceeding the 5% threshold, indicating the absence of cross-sectional dependence within the data. Cross-sectional dependence refers to the correlation between residuals across different units (provinces) at the same point in time. Its absence, as indicated by the results of the Pesaran CD test, reinforces the robustness of the panel regression model's assumptions and ensures the reliability of the conclusions drawn from the analysis.

Table 2 elucidates that the coefficient for trade openness (TO) is negative and statistically significant. This finding indicates that an increase in trade openness is inversely associated with the share of the blue economy in Indonesia's archipelagic provinces. Specifically, the data show that a unitary increment in trade openness corresponds to a 0.15% reduction in the blue economy share. This inverse relationship suggests that heightened trade openness may adversely influence the proportion of economic activities linked to the blue economy within these regions.

Conversely, the coefficient for investment, proxied by gross fixed capital formation (GFCF), presents an anomalous result. While the positive coefficient theoretically implies that increased investment could enhance the blue economy share, this relationship lacks statistical significance. The low t-statistic relative to the critical value from the t-distribution indicates that the presumed positive impact of investment on the blue economy share is not empirically robust.

The analysis also confirms anticipated results for the information and communication technology (ICT) variable, which exerts a statistically significant and positive effect on the blue economy share. The coefficient for ICT stands at 0.0102, suggesting that a 1% increase in ICT investment is associated with a 1.02% rise in the blue economy share. In contrast, the electricity distribution (ED) variable shows a negative and statistically significant coefficient, indicating that an increase in electricity distribution is associated with a decline in the blue economy share.

Furthermore, the coefficient for the fisheries and aquaculture production (FNA) variable is both positive and statistically significant, with a value of 0.228. This coefficient suggests that a 1% increase in capture and aquaculture production leads to a 0.228% increase in the blue economy share in Indonesia's archipelagic provinces, highlighting the crucial role of fisheries and aquaculture in sustaining the blue economy in these regions.

Utilizing the random effects model, it is evident that the combined effects of TO, GFCF, ICT, ED, and FNA collectively account for 71% of the variance in the blue economy share, as indicated by the R-squared value of 0.71. The remaining 29% of the variance is attributable to unobserved variables or other unexplained factors, suggesting the potential presence of additional determinants influencing the blue economy.

In summary, the negative and statistically significant coefficient for TO indicates that an increase in trade openness is correlated with a reduction in the blue economy share. Specifically, a one-unit increase in trade openness corresponds to a 0.15% decline in the blue economy share, suggesting that heightened trade openness may undermine blue economy activities in these provinces. This could be attributed to intensified competition from global markets or factors that shift economic focus away from local blue economy sectors.

Investment, measured by GFCF, exhibits a positive coefficient, theoretically suggesting that higher levels of investment could increase the blue economy share. However, this relationship fails to achieve statistical significance, as evidenced by a low t-statistic. This lack of significance indicates insufficient empirical support for a substantial impact of investment on the blue economy share, despite the positive coefficient.

The ICT variable demonstrates a statistically significant and positive effect on the blue economy share. A 1% increase in ICT investment is associated with a 1.02% rise in the blue

economy share, underscoring the pivotal role of technological advancements in enhancing the blue economy, likely through improvements in efficiency, innovation, and connectivity.

The coefficient for electricity distribution is negative and statistically significant, suggesting that an increase in electricity distribution correlates with a reduction in the blue economy share. This unexpected finding may reflect the complexities of energy distribution in archipelagic regions, where the expansion of electricity infrastructure might redirect economic activity away from traditional blue economy sectors, or where energy-intensive industries may indirectly inhibit the growth of these sectors.

Finally, the FNA variable presents a positive and statistically significant coefficient of 0.228, implying that a 1% increase in capture and aquaculture production corresponds to a 0.228% increase in the blue economy share. This emphasizes the essential role of fisheries and aquaculture in sustaining the blue economy in Indonesia's maritime regions.

In conclusion, the random effects model applied in this analysis reveals that TO, GFCF, ICT, ED, and FNA collectively explain 71% of the variance in the blue economy share, as denoted by an R-squared value of 0.71. The remaining 29% of the variance is attributable to factors not captured by the model, indicating the presence of other variables or dynamics influencing the blue economy.

The estimation results presented in Table 3 provide a comprehensive overview of the intercept values across Indonesia's archipelagic provinces. The data reveal that the intercepts for Bangka Belitung Islands, North Sulawesi, and Southeast Sulawesi are positive, indicating that, after controlling for the effects of the independent variables specified in the model, these provinces exhibit a higher baseline level of blue economy share compared to the others under examination. Specifically, the positive intercepts suggest that these regions possess more favorable foundational endowments in terms of blue economy share, likely due to intrinsic economic or structural advantages.

**Table 3.** The result of intercepts for each province as sample (random effect model).

No	Provinces	Intercepts
1	Bangka Belitung Islands	0.010321
2	Riau Islands	−0.019858
3	West Nusa Tenggara	−0.004332
4	East Nusa Tenggara	−0.013493
5	North Sulawesi	0.019291
6	East Sulawesi	0.029996
7	North Maluku	−0.021924

Source: Eviews 9<sup>o</sup> Output (2012–2021).

In contrast, the provinces of Riau Islands, West Nusa Tenggara, East Nusa Tenggara, and North Maluku demonstrate negative intercept values. This suggests that, holding other factors constant, these provinces start with a lower baseline level of blue economy share. The negative intercepts imply that, in the absence of the explanatory variables incorporated into the model, these regions are at a disadvantageous starting point regarding their blue economy share relative to those with positive intercepts.

The variance in intercept values among the provinces highlights the heterogeneity in baseline economic conditions and structural attributes across Indonesia's archipelagic regions. The positive intercepts observed in Bangka Belitung Islands, North Sulawesi, and Southeast Sulawesi indicate a relatively advantageous initial position in terms of blue economy share. Conversely, the negative intercepts for Riau Islands, West Nusa Tenggara, East Nusa Tenggara, and North Maluku underscore the more substantial challenges or structural impediments these regions face, adversely affecting their initial blue economy share.

These disparities in intercept values are crucial for a nuanced understanding of regional differences in baseline blue economy performance. They underscore the necessity

for context-specific policy interventions that address the unique economic and structural conditions of each province. Targeted policies are essential for mitigating the challenges faced by regions with lower baseline levels and for capitalizing on the strengths of those with higher initial blue economy shares. By tailoring interventions to the specific needs of each region, policymakers can more effectively enhance the overall contribution of Indonesia's archipelagic provinces to the blue economy.

The positive intercepts for Bangka Belitung Islands, North Sulawesi, and Southeast Sulawesi indicate that these provinces start with a higher baseline level of blue economy share, even after accounting for the effects of other variables in the model. This suggests that these provinces possess certain intrinsic economic or structural advantages, placing them in a more favorable position regarding the blue economy. Factors such as natural resources, infrastructure, or geographic advantages may inherently benefit their blue economy sectors.

In contrast, the negative intercepts for Riau Islands, West Nusa Tenggara, East Nusa Tenggara, and North Maluku suggest that these provinces start with a lower baseline blue economy share. Even when controlling for other factors, these provinces are at a relative disadvantage. The negative intercepts imply that these regions face structural challenges or economic impediments that hinder their initial blue economy performance, including limited access to resources, weaker infrastructure, or economic constraints that prevent them from fully capitalizing on blue economy opportunities.

The variation in intercept values across provinces highlights the diverse baseline economic conditions and structural differences in Indonesia's archipelagic regions. The positive intercepts in Bangka Belitung Islands, North Sulawesi, and Southeast Sulawesi reflect regions with a stronger starting position, while the negative intercepts in Riau Islands, West Nusa Tenggara, East Nusa Tenggara, and North Maluku suggest that these provinces face greater challenges. This heterogeneity emphasizes the need to consider each province's foundational conditions when assessing blue economy potential and designing policy interventions.

The differences in intercept values suggest that a one-size-fits-all policy approach would be ineffective in addressing the unique needs of each province. Instead, context-specific policy interventions are required. For regions with lower baseline levels (those with negative intercepts), policies may need to focus on overcoming structural obstacles, such as improving infrastructure or access to resources. For provinces with higher initial blue economy shares (those with positive intercepts), policies should aim to capitalize on and further strengthen their existing advantages. Tailored interventions would more effectively boost the blue economy across all provinces by addressing these regional disparities and leveraging each province's unique strengths and challenges.

#### 4.2. Discussion

The World Wildlife Fund (WWF) underscores the paramount importance of the Blue Economy framework as a transformative approach that can yield substantial social and economic benefits for contemporary societies. This framework is not merely a theoretical construct; it serves as a pragmatic tool for addressing a range of urgent global issues that threaten the well-being of both people and ecosystems. Among these pressing challenges are enhancing food security, alleviating poverty, and promoting better livelihoods, health, safety, equality, and political stability.

Food security, for instance, is intricately linked to the sustainable management of marine resources, as healthy oceans provide a significant source of protein for millions worldwide. By adopting the Blue Economy framework, societies can implement practices that ensure sustainable fish stocks, thereby securing food supplies for future generations. Similarly, the framework's focus on equitable access to marine resources can help lift communities out of poverty by creating new economic opportunities, thereby promoting social equity and stability.

Moreover, the Blue Economy framework plays a crucial role in restoring and preserving ecological integrity, which is fundamental for maintaining biodiversity. The decline

in marine biodiversity poses a threat not only to ecosystems themselves but also to the livelihoods of communities that depend on these resources. By fostering practices that enhance productivity and resilience in marine environments, the framework supports the long-term health of these ecosystems, which in turn sustains the communities reliant on them.

The emphasis on clean technologies and renewable energy sources within the Blue Economy framework is particularly salient in the context of climate change and environmental degradation. Transitioning to renewable energy and adopting circular material economy practices can significantly reduce the environmental footprint of coastal and marine activities. This transition not only mitigates climate impacts but also fosters innovation and economic growth in emerging sectors, thereby enhancing overall societal resilience.

However, it is crucial that the implementation of the Blue Economy framework operates within the ecological limits of our planet. Unsustainable practices, even when framed within the context of economic growth, can lead to detrimental consequences for both the environment and society. Thus, a balanced approach that prioritizes ecological sustainability alongside economic development is essential. By doing so, the Blue Economy framework can serve as a foundation for sustainable development, ensuring that economic and social stability is maintained for both current and future generations.

The ocean presents significant potential for alleviating global hunger and malnutrition while also addressing the environmental impacts associated with traditional food systems. This potential can be realized through the development of a Blue Economy that seeks to maximize economic returns while ensuring the equitable and sustainable utilization of marine resources. However, the current focus of the Blue Economy on production and profit has overshadowed considerations of distributional equity, leading to an imbalance in its overarching narrative (Farmery et al. 2021). This issue is particularly relevant to the present findings, underscoring the need for a balanced approach that harmonizes economic gains with equitable distribution. Such an approach is essential for enhancing the effectiveness of the Blue Economy framework in addressing both economic and social objectives.

Fisheries and aquaculture are fundamental components of the Blue Economy, highlighting the substantial economic potential of marine sectors such as shipping, oil and gas, and large-scale fisheries. The Blue Economy framework advocates for the integration of these high-value sectors, emphasizing regional development through water clusters while considering national and regional populations (Voyer et al. 2018). This integration is especially pertinent to the current findings, which emphasize the necessity of aligning sectoral interests within the Blue Economy framework to achieve comprehensive economic and environmental benefits. By including diverse marine sectors under the Blue Economy umbrella, regional economic development can be fostered, contributing to sustainable management practices that benefit both the economy and the environment.

The estimation results from this study reveal a concerning negative impact of trade openness on the blue economy share. Specifically, increased trade within the fisheries sector tends to promote the intensified exploitation of marine resources, leading to overfishing and jeopardizing the sustainability of marine ecosystems (Abe et al. 2017). This finding illustrates the complex interplay between trade policies and the sustainability of the Blue Economy, indicating that while trade openness can stimulate economic activity, it simultaneously presents substantial risks to marine resource management. The challenge lies in balancing the drive for economic growth through trade with the imperative to protect marine ecosystems. Therefore, policies such as stricter fisheries export regulations, catch quota restrictions, and stronger trade controls are needed to protect marine ecosystems while supporting international trade.

Implementing the Blue Economy framework necessitates substantial financial investment, especially when sustained over long periods. Such investments should involve both vertical and horizontal collaboration among governmental and non-governmental entities (Mahardianingtyas et al. 2019). The role of maritime infrastructure is crucial in supporting resource allocation, global value chains, trade, and economic growth (Fratila et al. 2021).



Investments in ocean and coastal infrastructure—including advancements in technology and transportation—are essential for facilitating positive economic growth (Gherghina et al. 2018; Meersman and Nazemzadeh 2017). Although the investment indicator in this study, proxied by gross fixed capital formation, does not show a significant impact on the blue economy share, this may be due to the aggregation of investments across various sectors that do not directly affect the fisheries and maritime sectors. Investments that are too dispersed, without a clear focus on maritime sectors, may obscure the actual impact on the development of the blue economy. To enhance its effectiveness, investment policies need to be more targeted, promoting specific investments in sectors such as sustainable fisheries, marine technology, and coastal infrastructure. As noted by Sumaila et al. (2021), unequal access to financial and marine resources also limits the distribution of benefits from these investments. Therefore, efforts to expand access to financing for coastal communities and maritime sector players through inclusive financing schemes are necessary to ensure that investments contribute more equitably and effectively to the growth of the blue economy.

In summary, while the Blue Economy framework offers a promising avenue for addressing pressing social and economic challenges, its current focus on profit generation risks undermining critical issues of equity and sustainability. Achieving a successful Blue Economy requires a concerted effort to balance economic growth with equitable resource distribution and sustainable practices. Policymakers must recognize the interconnectedness of trade, investment, and environmental stewardship to create a more resilient and inclusive Blue Economy that benefits all stakeholders. By fostering collaboration across sectors and investing in targeted initiatives, it is possible to harness the full potential of the ocean for the benefit of both people and the planet.

Conversely, ICT exerts a positive and significant influence on the blue economy share. The advancement of infrastructure and technology, particularly in marine resource exploration and management, contributes to an increased blue economy share. This finding aligns with Al-shammari et al. (2022), who assert that innovations in ICT are increasingly integrating environmentally friendly energy sources, thereby bolstering sustainable practices within the marine sector. Therefore, policies that encourage the development of ICT infrastructure in coastal areas, including incentives for technology companies to invest in the marine sector, are essential to support the sustainable growth of the blue economy.

In stark contrast, the distribution of electricity demonstrates a negative impact on the blue economy share. The dependence on fossil fuels for electricity generation exacerbates environmental degradation and elevates carbon emissions (Asongu et al. 2020), adversely affecting economic growth and hindering the development of a sustainable blue economy (Zhang 2018). This situation highlights the pressing need for policies that prioritize the expansion of renewable energy sources as a means to support the Blue Economy framework (Aye and Edoja 2017). Transitioning to renewable energy not only mitigates environmental harm but also enhances the resilience of marine ecosystems, thereby promoting sustainable economic growth.

The positive relationship between capture fisheries and aquaculture production and the blue economy share suggests that increases in production within these sectors are correlated with a rise in the blue economy share in Indonesia's archipelagic provinces. This finding corroborates the assertions of Kusdiantoro et al. (2019), who emphasize the vital role of the fisheries sector in Indonesia's economic development. The development of the Blue Economy model holds promise for fisheries and maritime affairs, leading to enhanced efficiency in production activities, improved marketing channels, increased product diversification, and the promotion of environmentally sustainable practices (Rini et al. 2021).

The ocean's economic contributions are substantial, encompassing a wide array of marine industries, including coastal tourism, offshore oil and gas, shipbuilding, and maritime transport. However, these activities often present challenges related to resource overexploitation (Sarker et al. 2018). In Indonesia, the fishing sector faces significant issues, such as the inadequate implementation of responsible fisheries standards, intense pressure from

small fishing fleets, illegal fishing practices, and a reliance on imported fish feed (Elia and Indrajaya 2022). Additionally, the proliferation of microplastics poses a considerable marine pollution challenge, contributing to global ocean litter (Raubenheimer and McIlgorm 2018).

To effectively address these challenges and promote a sustainable Blue Economy, comprehensive development strategies are imperative. Such strategies should encompass strengthening oversight mechanisms for marine and coastal activities, enhancing institutional capacity for resource management and law enforcement, expanding allocations for sustainable energy initiatives, and developing efficient marketing systems for fishery products. Leveraging advanced technologies, such as the internet, optimizing capture fisheries management based on ecosystem carrying capacity, and improving data collection methodologies are crucial elements of a sustainable Blue Economy.

Furthermore, these strategies should focus on strengthening social security for fishery cultivators, empowering coastal communities, and establishing efficient, transparent management systems to ensure the sustainable use of marine and coastal resources. By fostering an integrated approach that combines technological innovation, community engagement, and environmental stewardship, stakeholders can collaboratively mitigate the challenges facing the Blue Economy, ensuring that it contributes to economic growth while promoting ecological resilience and social equity.

Based on the analysis of the challenges and opportunities within the fisheries and aquaculture sectors, the following specific, actionable, and tailored policy recommendations are proposed to advance the sustainable Blue Economy in Indonesia.

Firstly, strengthening regulatory frameworks for sustainable fisheries management is crucial. This involves developing and enforcing comprehensive regulations grounded in scientifically derived quotas and sustainable fishing practices. Establishing clear guidelines for determining maximum sustainable yield (MSY), alongside regular assessments of fish stocks, is critical for mitigating overfishing risks. Such regulatory measures are essential for ensuring that fisheries operate within ecologically sustainable limits, preserving marine biodiversity, and supporting the long-term viability of fisheries-based economies.

Secondly, adopting renewable energy solutions within the fisheries and aquaculture sectors is a vital strategy for enhancing environmental sustainability. Investing strategically in renewable technologies, such as solar photovoltaic systems and wind turbines, can significantly reduce the ecological footprint of these industries. Financial incentives, including subsidies and grants, should support the installation of renewable energy infrastructure in coastal regions. Additionally, promoting micro-grid systems powered by renewable sources would be particularly beneficial in remote coastal areas, ensuring a reliable and sustainable energy supply for fisheries operations and aquaculture facilities.

Thirdly, enhancing institutional capacities at local, regional, and national levels is essential for improving fisheries resource management and enforcement. Strengthening the technical and operational capabilities of enforcement agencies is critical to combat illegal, unreported, and unregulated (IUU) fishing activities. Moreover, developing community-based monitoring systems can engage local stakeholders in compliance efforts, fostering shared responsibility.

Fourthly, integrating information and communication technology (ICT) into fisheries and aquaculture management is an important innovation for optimizing data collection and analysis. Utilizing technology-driven platforms like mobile applications and online databases enables real-time data collection on catch sizes, species distribution, and fishing effort. This enhanced data management framework provides a robust empirical foundation for decision-making, thus improving fisheries management and policy formulation.

Fifthly, advancing research and development in sustainable aquaculture technologies is crucial for driving innovation and promoting environmentally sustainable practices. Collaboration between academic institutions and private sector stakeholders should be prioritized to develop and disseminate advanced aquaculture technologies, such as integrated multi-trophic aquaculture (IMTA) systems. These innovations are key to minimizing

environmental degradation while maximizing resource efficiency, thereby supporting the sustainable growth of the aquaculture industry.

Sixthly, providing access to financial resources for small-scale fishers and aquaculture operators is essential for encouraging the adoption of sustainable practices. Developing specialized financial instruments, such as low-interest loans and micro-financing mechanisms, enables stakeholders to invest in environmentally sustainable projects. Such investments may include adopting sustainable fishing gear or participating in eco-certification schemes, enhancing the environmental credibility and market competitiveness of fisheries and aquaculture products.

Seventhly, developing effective marketing strategies for sustainably sourced fishery products is crucial for improving market access and boosting consumer demand for environmentally responsible goods. Marketing initiatives that emphasize sustainability credentials through branding will help differentiate these products. Promoting local products through farmers' markets and digital platforms can increase consumer awareness and support for sustainably sourced seafood, fostering a more informed and responsible consumer base.

Eighthly, formulating integrated coastal zone management (ICZM) plans is vital for balancing environmental, economic, and social objectives in coastal regions. These plans should be developed through inclusive processes that engage local communities, ensuring their perspectives are considered. ICZM plans must address key issues such as habitat protection, pollution control, and sustainable tourism development, thereby promoting long-term coastal ecosystem sustainability while supporting economic growth.

Ninthly, empowering coastal communities is critical for building socio-economic resilience in regions dependent on fisheries and aquaculture. This can be achieved through targeted programs aimed at enhancing skills for alternative livelihoods and ensuring equitable access to marine resources. Encouraging community participation in decision-making processes leads to more inclusive and effective fisheries governance, ensuring that the voices of those most impacted by policy decisions are heard.

Finally, raising public awareness and education is fundamental to fostering sustainable seafood consumption and responsible fishing practices. Collaborative public education campaigns with NGOs, educational institutions, and media platforms are essential for informing consumers about the environmental and economic importance of sustainability in the fisheries sector. These efforts play a pivotal role in shaping consumer preferences and promoting responsible consumption, thereby contributing to broader sustainability goals and environmental stewardship within the fisheries and aquaculture industries.

## 5. Conclusions

The Sustainable Development Goals (SDGs) represent a foundational global commitment, encompassing a wide array of socio-economic and environmental priorities. Among these, SDG 14 emphasizes the principle of ocean sustainability through the conceptual framework of the blue economy. This framework, which originated in a context marked by considerable complexity and a propensity for transformative change, is influenced by a multitude of determinants. It is particularly salient in the case of Indonesia, a nation distinguished by its vast maritime domain and numerous islands, which presents both substantial opportunities and significant challenges for future development.

The empirical analysis conducted in this study, utilizing a random effects model, reveals that information and communication technology (ICT) and fisheries capture, along with aquaculture production, are critical positive determinants of the blue economy's share. Specifically, advancements in ICT and increases in fisheries production have been shown to significantly enhance the contribution of the blue economy. These findings underscore the necessity for the implementation of more stringent and nuanced policy measures aimed at managing and optimizing the blue economy's share. Such policies are pivotal for advancing sustainable development within Indonesia, leveraging the identified determinants to effectively support and expand the blue economy framework.

Collaboration between researchers and policymakers in Indonesia is crucial for the advancement of the blue economy. Future research endeavors should aim to incorporate a broader range of variables that could potentially influence the blue economy. This expanded scope would enhance the precision and depth of the findings, thereby providing a more comprehensive understanding of the dynamics of the blue economy and its potential for fostering sustainable growth.

Nonetheless, this study is subject to several methodological limitations. Firstly, the analysis is constrained by its focus on data from only seven of Indonesia's 33 provinces. This limitation may affect the generalizability of the results to the national level, potentially overlooking regional variances. Secondly, the study's scope is confined to five specific factors empirically demonstrated to influence the blue economy. While these factors are significant, they do not encompass the full spectrum of potential determinants. Thirdly, the current research does not fully address all possible indicators that could impact the blue economy in Indonesia.

Therefore, further research is imperative to address these limitations. Future studies should include data from additional provinces across Indonesia and explore a wider array of factors that may influence the blue economy. Such comprehensive investigations will provide a more robust and nuanced understanding of the determinants of the blue economy, thereby facilitating more effective and targeted policy interventions to enhance its sustainability and impact.

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