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Climate Neutrality of the Economy

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INDONESIA'S MARINE RESOURCES INNOVATION: DIGITAL TRANSFORMATION IN BLUE ECONOMY POLICY FOR ECONOMIC SUSTAINABILITY

Abstract

Indonesia has the potential to become the «World Maritime Axis», which still requires further action, in particular through strengthening its maritime potential. This study analyzes the influence of sectors in the blue economy, as proxied by the Fishermen's Exchange Rate (NTN), foreign tourists, defense budget, maritime sector investment, and Information and Communication Technology (ICT) Index, on Gross Domestic Product (GDP). In addition, this study looks at the effect of the ICT Index on the blue economy, specifically through the Fisheries Gross Domestic Product variable, as a projection of digitization in the blue economy. Using secondary data on the maritime sector in Indonesia, this research

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employs a two-model regression on time series data for the period from 2013 to 2023. The results of Model 1 indicate that the fishermen's exchange rate, foreign tourists, and investment variables positively impact GDP, but these effects are statistically insignificant. In contrast, the defense budget and ICT Development Index variables have a positive and significant effect on GDP. Model 2 reveals that the impact of digital transformation, as indicated by the ICT Development Index, on Fisheries Gross Domestic Product is positive and significant. These results suggest that inclusive policies are necessary to enhance the impact of blue economy sectors on GDP. Therefore, we propose strategies such as the digital transformation of blue economy sector infrastructure, based on the Internet of Things (IoT) ecosystem, and blue financing through blue bonds.

Key Words:

blue economy, blue financing, digital transformation, marine resources.

JEL: O22, Q22, G38.

2 formulas, 3 figures, 4 tables, 66 references.

Problem Statement

Indonesia is a maritime nation with 17,500 islands and approximately 108,000 kilometers of coastline. As the world's largest archipelago, Indonesia's oceans comprise more than two-thirds of its territory and are a key component of its well-being, cultural wealth, and prosperity. With one of the highest levels of marine biodiversity in the world, Indonesia's oceans provide an important source of food security, livelihoods, climate regulation and sequestration, and economic well-being through sectors including fisheries and aquaculture, coastal tourism, marine construction, and marine transportation (World Bank, 2021).

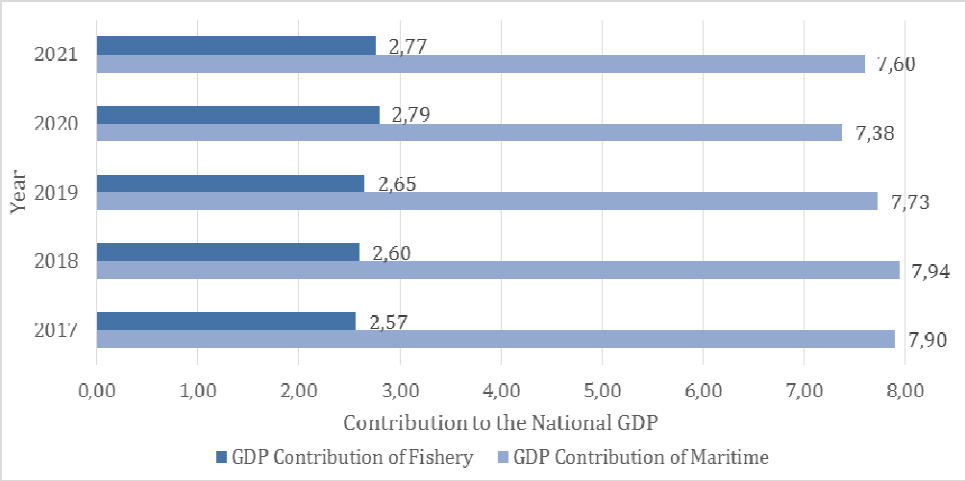
Indonesia has the potential to become the «World Maritime Axis», which still requires further action, particularly through strengthening the maritime potential (Pulungan, 2024). In an economic context, this view paves the way for a coun-

try to increase growth through investment, trade, and quality improvement in the maritime sector (Afpriyanto et al., 2023). In the «World Maritime Axis» view, Indonesia should still strive to improve its maritime potential and connectivity in the Indo-Pacific region. Then, by strengthening this maritime potential Indonesia will be able to improve its economy on a regional and even global scale in the coming years.

The blue economy currently contributes only a small fraction of the national GDP, yet the sector has shown growth. Over the past five years, the blue economy has contributed an average of 7.6% of Indonesia's GDP (see Figure 1). Between 2017 and 2020, the blue economy has grown by an average of 10.5% per year. This suggests that there is considerable opportunity to capitalize on in the long term. According to the Indonesian Vision 2021 of the Indonesian Ministry of National Development Planning (*Bappenas*), the blue economy is expected reach 12.45% of the national GDP by 2045. However, additional investment is needed to increase the growth potential of the blue economy.

Figure 1

Maritime sector contribution to Indonesia's GDP, %

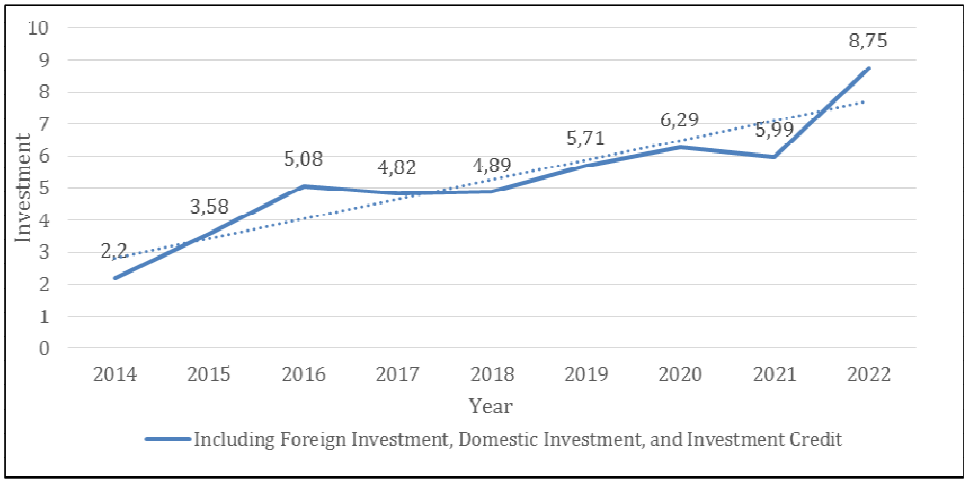


Source: Ministry of Marine Affairs and Fisheries (2024a).

The 2024 Indonesia's State Budget information book (*UU APBN dan Nota Keuangan*) (Kementerian Keuangan Republik Indonesia, n. d) describes several development focuses that are the main highlights in the 2024 State Budget expenditure, and the three development focuses are very close to the application of the blue economy, namely food security (114.3 trillion IDR), infrastructure supporting The New National Capital City (*Ibu Kota Nusantara*) project (423.4 trillion IDR), and security resilience (331.9 trillion IDR). With these budgets and strategic outputs, the government apparently still cannot fully rely on financing from routine revenue sources in the APBN. Therefore, an alternative for obtaining additional financing to cover the shortfall is through «blue financing». Blue financing is a framework that gathers low-cost funds from various investors, both private and government, for high-impact projects or projects in the blue economy through market-based instruments (Tirumala & Tiwari, 2022). The overall volume of maritime sector investment over the period from 2014 to 2022 is shown in Figure 2.

Figure 2

Maritime sector investment (IDR trillions)



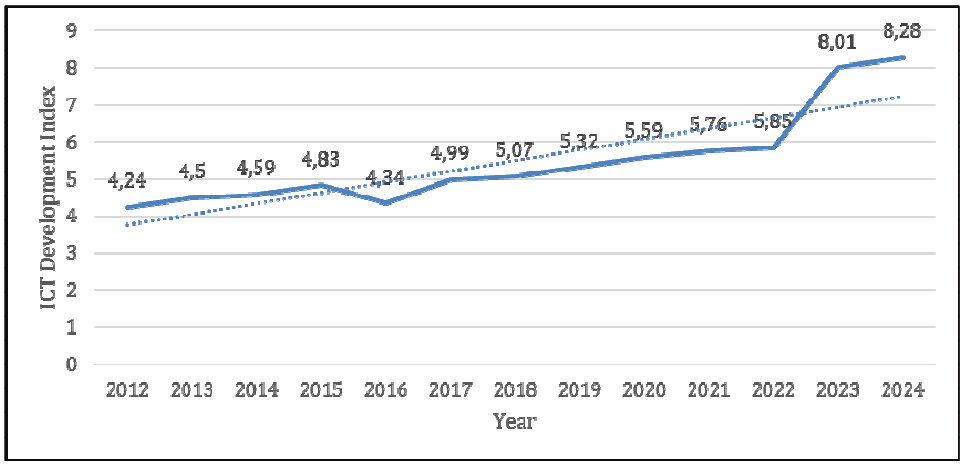
Source: Ministry of Marine Affairs and Fisheries (2024b).

On the other hand, Indonesia is currently moving towards the «Golden Indonesia 2045 Vision». One of the focuses of the vision relates to Indonesia's goal of becoming a high-income country by 2045. The Coordinating Ministry for Economic Affairs (Kementerian Koordinator Bidang Perekonomian Republik Indonesia, 2024) has set the following targets: a nominal GDP of 9.8 trillion dollars, a middle-income population share of 80%, and a manufacturing industry contribution to GDP reaching 28%, and employment of 25.2%. These conditions will then make Indonesia enter the top five countries with the largest GDP in the world in 2045. And this vision will only be realized if Indonesia carries out economic transformation including transformation in the blue economy sectors.

Optimizing the blue economy can also be achieved through digital transformation, considering the potential for technological progress in Indonesia as reflected in the ICT Development Index. As illustrated in Figure 3, Indonesia's ICT Development Index saw a significant rise in 2023, reaching a score of 8.01 compared to 5.85 in 2022. In 2024, this index rose again to 8.28 points. These increases demonstrate progress in the development of information and communication technology in Indonesia.

Figure 3

ICT Development Index in Indonesia



Source**:** Central Bureau of Statistics – BPS (n. d. -a).

Indonesia's maritime potential has not been optimally utilized. The development of ferry ports, the construction of pioneer ships, the production of fishery products, and the development of fishing ports are some of the success parameters outlined in the National Medium-Term Development Plan (RPJMN) for the next five years. Thus, the digitization of the maritime sector in Indonesia can help improve efficiency, security, and services, as well as support the development of a digital economy based on maritime culture.

In view of the above, **the purpose of this study is twofold**: first, to analyze the influence of blue economy sectors on Indonesia's gross domestic product (GDP); second, to examine the effect of the ICT Development Index on the blue economy as a projection of digitization within this sector. The main research problem is to determine how digitalization and blue finance can enhance the potential of the blue economy and contribute to Indonesia's overall economic growth.

Literature Review

Digital transformation in the blue economy

The blue economy significantly influences economic growth by leveraging ocean resources sustainably to enhance various sectors such as fisheries, tourism, and maritime transport. This approach not only supports economic activities but also ensures the preservation of marine ecosystems. The blue economy's potential to drive economic growth is evident in regions such as East Java, where fish catching and farming has had a significant impact on economic growth. Similarly, in Nigeria, the blue economy is seen as a catalyst for expanding government revenue and supporting sustainable economic development (Esin & Okon, 2024). Production from the fisheries sector has been shown to have a significant impact on economic growth. The implementation of blue economy principles can further enhance these effects by promoting sustainable practices (Humairoh et al., 2024). The blue economy's focus on sustainable fisheries helps in maintaining fish stocks, which is crucial for long-term economic benefits.

Maritime transport and coastal tourism are key components of the blue economy that contribute to economic growth. These sectors are linked to increased per capita income and are vital for regions with significant coastal activities (Martínez-Vázquez et al., 2023). Coastal tourism, driven by the blue economy, not only boosts local economies but also creates jobs and supports livelihoods. Effective policy coordination and stakeholder engagement are essential for maximizing the blue economy's potential. In Nigeria, strong political will and robust institutions are recommended to address challenges and bolster revenue growth through the blue economy. Indonesia's adoption of blue-green economic

policies highlights the importance of integrating sustainable development goals with economic growth strategies. While the blue economy offers substantial opportunities for economic growth, challenges such as overfishing, pollution, and climate change pose significant threats to its sustainability. Addressing these challenges requires international cooperation, investment in research, and the adoption of innovative technologies to ensure the long-term viability of the blue economy (Youssef, 2023).

The blue economy refers to an economic system that utilizes marine resources for sustainable economic growth (Maeyangsari, 2023). In addition, there are other components involved in the blue economy system, namely human resources (HR) and natural resources (Ervianto, 2018). Human resources include labor and employment, while natural resources are related to marine ecosystems and their sustainability (Purbani et al., 2016). In practice, the blue economy also involves a circular economic system. A digital economy based on maritime culture has great potential in the blue economy system. The rise of digital-based business industries that can reach people across continents is a great economic potential. Indonesia's marine development is expected to realize Indonesia as an independent, advanced, strong, and national interest-based archipelago (Ilma, 2016).

The potential for digitization in the maritime sector in Indonesia is very important to improve efficiency, security, and services in the maritime sector (Putri & Burhanuddin, 2024). Digital transformation is expected to make it easier for stakeholders to run their businesses, create security in transactions, and shorten the time needed to carry out the activity process in the maritime sector (Sari et al., 2021). Digital transformation can improve services, address global maritime business challenges, support environmental sustainability through clean and efficient operational activities, and create synergies among all stakeholders in the shipping sector (Johnson et al., 2023).

Additional investment through blue financing

Blue financing refers to financial and investment mechanisms specifically geared towards sustainable marine and ocean-related projects that aim to support the conservation and responsible use of marine resources (Fahrurrozi, 2020). Blue finance plays an important role in promoting the concept of the blue economy, which focuses on sustainable development, conservation of marine ecosystems, and increasing economic opportunities related to oceans and coastal areas (Ng & Tao, 2016). Blue financing is a financial or investment instrument that ensures the conservation of the marine environment and related resources, and enhances the blue economy. The parameters of blue financing include the use of debt formats such as private placement, securities, and covered bonds, as well as different types of capital, sources, and investment models (March et al., 2023).

Blue financing focuses on mobilizing capital for projects that support the sustainable use of marine resources (Mathew & Robertson, 2021). It is a response to the growing recognition of the critical role of oceans in global ecosystems and economies, as well as the urgent need to address the challenges they face, such as climate change, overexploitation of marine resources, and pollution. The conceptual framework for blue financing emphasizes the importance of legal and institutional mechanisms to increase investment in ocean development programs, highlighting the need for collaboration among stakeholders to provide incentives for private investment and public donations (Shiiba et al., 2022).

Investing in blue finance involves channeling funds to sustainable blue economy projects, which focus on the conservation and sustainable use of marine resources. This investment strategy is gaining traction as a means to address financing gaps in sustainable development, particularly for Small Island Developing States (SIDS) and regions with significant marine resources. The Seychelles' experience with blue bonds and debt-for-nature swaps exemplifies successful blue finance initiatives, highlighting the importance of a favorable policy environment, international partnerships, and sound financial management (Benzaken et al., 2024). Despite the potential of blue finance, some challenges remain. The lack of standardized governance and reporting in the blue bond market raises concerns about «blue laundering», where projects may not deliver genuine environmental benefits. Furthermore, the influence of Western NGOs and investors in shaping blue finance practices can marginalize local communities, highlighting the need for inclusive and equitable investment strategies (Torrance et al., 2023). Addressing these issues is critical to ensuring that blue finance effectively supports sustainable development goals.

Blue finance is important because it supports the sustainable development of marine resources, which is critical to achieving global environmental and economic goals. This type of financing is particularly important for countries with extensive coastlines, such as Indonesia, which can utilize their marine resources to avoid the middle-income trap and contribute to the Sustainable Development Goals (SDGs) by protecting marine ecosystems. Blue financing instruments, such as blue bonds, offer innovative ways to fund projects that enhance marine ecosystems, thereby promoting a sustainable blue economy (Hariyanto, 2020). While blue finance brings many benefits, it also faces challenges such as ensuring the effective uptake of funds in domestic and global markets and aligning diverse stakeholder interests. Overcoming these challenges requires strategic planning and collaboration between governments, financial institutions, and local communities to maximize the impact of blue finance initiatives (Knodt et al., 2023).

Methodology

Data

This research uses secondary data on the maritime sector in Indonesia. The data comes from the Central Bureau of Statistics (BPS), World Bank Indicator Open Data, and the Ministry of Marine Affairs and Fisheries with a period from 2012 to 2023. The use of time series data was chosen to be able to determine the estimation and prediction of the blue economy sector of the Indonesian economy over time. The selection of the period from 2012 to 2023 is due to data availability factors.

Table 1

Variables and Data Sources

Variables	Description	Source
Dependent Variables		
lnGDP	Natural Logarithmic Gross Domestic Product (constant price)	World Bank Indicator Open Data (World Bank, 2023)
lnGDPFish	Natural Logarithmic Fisheries Gross Domestic Product (constant price)	Ministry of Marine Affairs and Fisheries Annual Report (2024)
Independent Variables		
NTN	Fishermen's Exchange Rate	Central Bureau of Statistics – BPS (n.d.-b)
lnTourist	Natural Logarithmic Foreign Tourist	Central Bureau of Statistics – BPS
lnDef	Natural Logarithmic Defense Budget	Central Bureau of Statistics – BPS
lnInv	Natural Logarithmic Maritime Investment	Ministry of Marine Affairs and Fisheries Annual Report (2024)
ICT	ICT Development Index	Central Bureau of Statistics – BPS (n.d.-a)

Source: compiled by the authors.

The dependent variable in this study is Indonesia's Gross Domestic Product (GDP). GDP plays a very important role as a key economic indicator, especially within the macroeconomic scope. GDP also affects the implementation of policies and economic sustainability (Kusdiantoro et al., 2019). In addition, the Fisheries Gross Domestic Product variable was chosen as it represents the marine sector (Afpriyanto et al., 2023). The independent variables in the study are proxied by several variables based on previous research. The blue economy sector is proxied by the Fishermen's Exchange Rate (NTN), foreign tourists, defense budget, and the ICT Development Index (Budiono et al., 2015; Fadhila, 2019; Wahyuningsih, 2013; Wardhana, 2016).

Model Specifications

This study applies regression to time series data. Time series econometrics is a branch of econometrics that examines economic or financial data that changes over time. Time series analysis can be used for forecasting, studying trends and patterns in data, and understanding the relationship between economic variables that change statically or dynamically (Pauwels et al., 2004).

Model 1 shows the effect of each variable related to the blue economy on the overall economy. The model takes the form of Equation 1:

$$lnGDP_t = \beta_0 + \beta_1 NTN_t + \beta_2 lnTourist_t + \beta_3 lnDef_t + \beta_4 lnInv_t + \beta_5 ICT_t + u \quad (1)$$

Where: $lnGDP_t$ denotes the natural logarithmic form of Indonesia's Gross Domestic Product, influenced by sectors in the blue economy; NTN_t denotes the Fishermen's Exchange Rate, a proxy for the fisheries sector in the blue economy, calculated from the ratio of the price index received by fishermen to the price index paid by fishermen (Central Bureau of Statistics, n. d. -b); $lnTourist_t$ denotes foreign tourists as an indicator of infrastructure in marine tourism; $lnDef_t$ is a logarithmic form of the defense budget and maritime resilience indicator; $lnInv_t$ denotes maritime investment, calculated from the infrastructure sectors that support the development and realization of the maritime axis; ICT_t is the technological progress and digital transformation index in Indonesia; β_0 is the intercept; $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are coefficients that represent the relationship between respective variables (NTN_t, $lnTourist_t$, $lnDef_t$, $lnInv_t$ and ICT_t) and the dependent variable (lnGDP); and u is the unobserved variables/error term.

Model 2 shows the technology variables that affect the marine economy as indicated by the fisheries' gross domestic product. The model takes the form of Equation 2:

$$lnGDPFish_t = \beta_0 + \beta_1 ICT_t + u \quad (2)$$

Where: $lnGDPFish_t$ denotes the Maritime Gross Domestic Product of Indonesia, which is calculated based on economic activities sourced from the ocean and coastal areas; ICT_t is technological progress and digital transformation index in Indonesia; β_0 is the intercept; and β_1 is the coefficient, which indicates the expected change in the Fisheries Gross Domestic Product ($lnGDPFish_t$) for a one-unit change in the ICT_t variable, holding all other factors constant.

Research Results

The descriptive statistics (Table 2) show the characteristics of the five variables analyzed, where variables with the prefix «ln» have been transformed into natural logarithms. The ICT variable has a mean of 5.258 with a standard deviation of 1.022, indicating moderate variation in the information and communication technology index. The NTN variable, which reflects the Fishermen's Exchange Rate, has a mean of 107.5 with a standard deviation of 4.046, indicating relative stability in its value. Meanwhile, the lnTour variable, which represents the number of tourists in natural logarithm form, has an average of 15.94 with a standard deviation of 0.664, indicating modest variations. The lnDef variable, which represents government spending on defense in natural logarithms, has a mean of 32.29 with a standard deviation of 0.210, reflecting very low variability and stability in defense spending. In contrast, lnInv, which represents investment in natural logarithm form, has a mean of 28.77 with a standard deviation of 1.275, indicating greater variability in investment compared to other variables.

Table 2

Descriptive statistics

Variables	N	mean	sd	min	max
ICT	12	5.258	1.022	4.240	8.010
NTN	12	107.5	4.046	102	114.3
lnTourist	12	15.94	0.664	14.26	16.59
lnDef	12	32.29	0.210	31.91	32.55
lnInv	12	28.77	1.275	26.05	29.89

Next, we explore the impact of variables on GDP and Fisheries GDP using time series regression models. The results are presented in Table 3.

Table 3

Estimation results

Variables	(1)	(2)
	lnGDP	lnGDPFish
NTN	0.00609	
	(0.00319)	
lnTour	0.0163	
	(0.0279)	
lnDef	0.514**	
	(0.179)	
lnInv	0.00308	
	(0.0196)	
ICT	0.0420**	0.144***
	(0.0172)	(0.0338)
Constant	9.025***	11.57***
	(2.200)	(0.181)
Observations	12	12
R-squared	0.980	0.645

Notes: Standard errors are in parentheses. Significance levels are indicated as follows: *** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1. Variables without stars are not statistically significant. Source: calculated by the authors.

The coefficient results in Table 3 cannot be interpreted directly because there are two variables that are not in the form of natural logarithms, namely the NTN and ICT variables. Both variable coefficients must be multiplied by 100 to make the interpretation of linear variables into natural logarithms in percentage form. As for the other variables, because they are already in the form of natural logarithms, they can be directly interpreted in percent form by adjusting positively or negatively to the dependent variable. The R-squared value for Model 1 is 0.980, indicating that this model can explain 98% of the lnGDP variable, while the remaining 2% is explained by other variables outside the model. Model 2 has an R-squared of 0.645, indicating that this model explains 64.5% of the variation in lnGDPFish, while 35.5% is explained by other variables outside the model.

Column 1 in Table 3 shows that a one-unit increase in the Fishermen's Exchange Rate (NTN) will generally increase GDP by 0.6%. Meanwhile, a one percent increase in foreign tourists will increase GDP by 0.016%. Both of these variables have elasticity with a positive but insignificant effect. The defense budget variable has a positive and significant effect on GDP, increasing it by 0.514% (p-value = 0.000). Investment has a positive but insignificant effect on

GDP. Digital transformation through the ICT Development Index has a positive and significant effect on GDP, with an increase of 4.2%.

Column 2 in Table 3 shows that the effect of digital transformation, indicated by the ICT Development Index, on Fisheries Gross Domestic Product is positive and significant. A one-unit increase in the ICT Index will increase Fisheries GDP by 14.4% (p-value = 0.000).

Breusch-Godfrey Autocorrelation Test

In regression analysis, it is important to identify and address autocorrelation to ensure that the results of the analysis are reliable and valid. Autocorrelation occurs when the residuals of a regression model are not independent of each other or there is a relationship between the independent variables and the error term/unobserved variables, which can lead to inefficient estimation and biased statistical inference (Wooldridge, 2016).

For this reason, it is important to use appropriate statistical methods to detect autocorrelation and, if necessary, make adjustments to the model to overcome autocorrelation problems. We applied the Breusch-Godfrey test as a method used to detect the presence of autocorrelation in the residuals of a regression model. The results are presented in Table 4.

Table 4

Results of the Breusch-Godfrey autocorrelation test

Model 1

lags (p)	lhi^2	df	prob>chi^2
1	1.878	1	0.1705

H0: no serial correlation

Model 2

lags (p)	lhi^2	df	prob>chi^2
1	0.291	1	0.5896

H0: no serial correlation

Notes: lags (p) – number of lags, lhi^2 – Breusch-Godfrey statistic, df – degrees of freedom; prob>chi^2 – p-value from the chi-squared test. Source: calculated by the authors.

As shown in Table 4, the first model has no serial correlation problem because Prob > chi^2 = 0.1705 > alpha, h0 cannot be rejected, so there is no serial correlation in the model at the 1%, 5%, and 10% significance levels. Likewise with model 2: Prob > chi^2 = 0.5896 > alpha, h0 cannot be rejected, so there is no serial correlation in the model at 1%, 5%, and 10% significance levels.

Discussion

The results show that both the ICT variable and the defense budget variable have significant positive effects on the overall economy. ICT advancements and efficient defense budget management play an important role in driving economic growth, particularly within the blue economy sector. To optimize the potential of the blue economy and ensure sustainable and inclusive growth, an integrated strategy is necessary. We propose two strategies to achieve this goal: (1) digital transformation of the blue economy sector infrastructure based on the Internet of Things ecosystem, and (2) blue financing through blue bonds.

Digital transformation of blue economy sector infrastructure based on the Internet of Things ecosystem

Digital transformation in the blue economy can be a solution to the challenges of strengthening the potential of the blue economy in Indonesia. ICT advancements are critical for boosting the blue economy, which includes sustainable economic activities related to oceans, seas, and coasts. The digitization of the marine sector is a multifaceted transformation that impacts various aspects of the industry, from human resource development to logistics and sustainability. This digital shift is critical to improving competitiveness, operational efficiency, and environmental sustainability in the maritime industry.

Technological advancements play an important role in facilitating information exchange for users, including fishermen. By utilizing digital tools and platforms, fishermen can stay connected, informed, and empowered to make data-driven decisions for their fishing activities and transactions. Increased digitization, especially in the tourism industry, has revolutionized the way businesses engage with consumers, market their products, and improve the overall customer experience through digital tools and platforms (Cempaka et al., 2022). The integration of modern technologies in maritime defense is essential to strengthen monitoring and detection capabilities in maritime operations. Collaboration with the maritime industry is essential for the development and application of cutting-edge tech-

nologies in maritime defense, such as drone technology and smart sensors, to enhance monitoring and detection capabilities (Sumarlin et al., 2023).

The integration of technologies such as Geographic Information Systems (GIS), remote sensing, and satellite imaging has significantly improved the management and utilization of marine resources, especially in fisheries and aquaculture (Luna, 2024). These technologies facilitate better data collection, analysis, and decision-making, leading to efficient management of marine resources. The blue economy is seen as an essential component for smart, sustainable, and inclusive growth. However, challenges such as a lack of investment in knowledge and poor access to finance hinder innovation in the sector. The commercialization of marine data and the development of predictive models are also driving the new blue economy, offering economic benefits through improved observational capabilities and forecasting (Alifa & Zahidi, 2024).

Digital transformation significantly impacts the sustainability of marine living resources. It improves the performance of capture fisheries, shellfish aquaculture, and marine aquaculture through improved digital public services and e-commerce practices (Ha, 2024). The effects of digitalization on marine resources are nonlinear, becoming more pronounced as digital maturity is reached. The digital economy plays an important role in improving the economic quality of marine fisheries through green technology innovation. Although the initial level is low, the economic quality of marine fisheries has shown fluctuating improvement due to digital progress (Jiang et al., 2024).

Marine logistics software optimizes operations and reduces carbon emissions, contributing to environmental sustainability in the maritime logistics industry (Watson, 2023). Embracing digital solutions in logistics is recommended to achieve a greener maritime future. The integration of IT and OT systems in maritime transportation and port infrastructure improves operational efficiency but also introduces cybersecurity challenges. Overcoming these challenges involves re-evaluating cyber-physical security, implementing business continuity plans, and increasing stakeholder awareness (Progoulakis et al., 2023). While digitalization offers many benefits, it also presents challenges, especially in cybersecurity and the need for a robust digital infrastructure. The maritime sector must balance these aspects to fully utilize the potential of digital transformation while ensuring security and sustainability.

Despite technological advancements, blue growth initiatives tend to focus on market-based mechanisms, often neglecting the social dimensions of sustainable development. Frameworks that emphasize local and dialogical approaches can address these shortcomings and better serve coastal communities (Kokkinou et al., 2018). In Indonesia, a blue economy strategy is essential for economic progress, with sectors such as marine fisheries, aquaculture, and coastal tourism playing an important role. The country needs to implement more policies to support these sectors and ensure the use of marine resources. Overall, while ICT advancement is essential for sustainable blue economy development, a balanced approach that includes social considerations is needed for holistic growth (Doce et al., 2024).

Blue financing through blue bonds for additional financing and digitization

The relationship between defense spending and economic growth is complex. Historically, defense spending has been substantial, with significant increases reflecting the strategic emphasis on military capabilities. While there is evidence of a positive correlation between defense spending and economic growth, the impact is relatively small, suggesting that reductions in defense budgets would not unduly hamper economic performance (Atesoglu & Mueller, 1990). High defense spending may reduce economic growth by diverting resources from critical areas such as innovation and infrastructure, as seen in the success of economies, which allocate fewer resources to defense. In addition, defense spending can stimulate technology-intensive sectors, potentially increasing industrial competitiveness (Gold & Adams, 1990).

Previous research also shows that the effects of defense spending on broader economic indicators like Gross Domestic Private Investment and Gross National Product are not statistically significant, implying that other factors mainly drive economic growth (Çetin et al., 2018). This suggests that reallocating resources from defense to the blue economy has the potential to drive economic growth through investment in sustainable industries and innovation, provided that the transition is managed effectively to harness the «peace dividend» for economic development (Bakulina et al., 2021).

Therefore, a policy focused on additional financing, which should be allocated efficiently and effectively, is necessary (Eshbayev et al., 2024). This policy should consider development priorities and ensure that investments in ICT and defense provide optimal returns to the economy (Dhingra et al., 2024). For example, ICT funding could focus on developing equitable digital infrastructure and improving the quality of human resources in the ICT sector, while defense financing could be optimized by modernizing the defense equipment and increasing the capabilities of the domestic defense industry (Devidze, 2022).

Blue finance and digitalization are increasingly recognized as critical components in advancing sustainable development, especially in the context of blue economies. Blue finance, which involves lending to sustainable and environmentally friendly ventures, has been shown to improve banking performance by increasing net interest margins and reducing solvency risk, especially when coupled with investments in digitalization. Digitalization, in this context, refers to the adoption of digital technologies that can streamline operations and reduce risks in the marine finance sector. The integration of blue finance and digitalization presents both challenges and opportunities for sustainable development. Blue finance, which supports the blue economy by promoting the sustainable use of

ocean resources, faces challenges such as the need for international collaboration and policy coherence to maximize its benefits.

Blue bonds are financial instruments issued by governments or financial institutions to support environmental conservation projects, especially those related to marine ecosystems and aquatic resources (Thompson, 2022). These financial instruments are important in supporting environmental sustainability, strengthening the blue economy sector, and providing sustainable financing alternatives for environmental projects. Blue bonds have an important role in financing marine ecosystem projects as they support environmental sustainability and conservation (Noor, 2022). Blue bonds are a new financial instrument designed to support a sustainable blue economy, which includes projects related to ocean and freshwater conservation.

Blue bonds not only support marine ecosystem initiatives but also enhance the diversification of Islamic finance products, promoting economic growth and environmental protection. Blue bonds represent an innovative approach to Islamic finance, aligning with the principles of the blue economy and contributing to the development of sustainable financial instruments (Althalet et al., 2021). The issuance of Blue Sukuk by governments provides a strong signal to financial markets, demonstrating a commitment to sustainable finance practices and blue economy concepts (Proczek & Garbarczyk, 2023). A key challenge is the lack of standardized definitions and metrics, which hinders market development and the ability to effectively measure impact. Blue bonds offer issuers the opportunity to enhance their reputation and attract more investors by demonstrating a commitment to sustainable development (Heidkamp et al., 2022). While blue bonds present a promising avenue for financing sustainable marine projects, they also face challenges such as the need for standardized metrics and the risk of prioritizing commercial over community interests. Addressing these issues is critical to the continued growth and effectiveness of the blue bond market (Bosmans & de Mariz, 2023). They are particularly important as they provide a dedicated funding mechanism to address the under-funded Sustainable Development Goals (SDGs) related to water and marine resources. The blue bond market, although still in its infancy, has shown significant growth potential and is seen as a catalyst for ocean and water financing.

The impact of blue bonds on digitalization is diversified, intertwining financial innovation with technological advancements to enhance sustainable development (Urekeshova et al., 2023). Blue bonds, similar to green bonds, are financial instruments aimed at supporting marine and ocean-based projects that contribute to environmental sustainability (Chugh, 2023). The integration of digitization in the issuance and management of these bonds can significantly improve their effectiveness and transparency. For example, digitization, especially through blockchain technology, can streamline the issuance process, improve traceability, and ensure compliance with environmental standards, thereby reducing the risk of greenwashing and increasing investor confidence. In addition, the digital transformation of bond markets, including blue bonds, can facilitate the standardization

of environmental, social, and governance (ESG) metrics, which is critical to attracting responsible investors and scaling the market to meet growing demand (Pavlidis, 2023). In addition, the positive relationship between digitalization and marine financial performance, demonstrated by increased digital investment, can enhance the capacity of the financial sector to support sustainable ventures, including those financed by blue bonds (Khan et al., 2024). This synergy between blue bonds and digitalization not only strengthens the role of the financial sector in sustainable development but also aligns with broader economic recovery plans that prioritize sustainable growth in the post-pandemic era. As such, the digitization of blue bonds is an important step towards a more efficient, transparent, and sustainable financial ecosystem (Lin et al., 2024).

Conclusions

The development of Indonesia's economic sectors and the trends of the blue economy show a positive, albeit fluctuating, contribution from 2012 to 2023. The regression results from Model 1 show that the fishermen's exchange rate, foreign tourists, and investment variables have a generally positive impact on Gross Domestic Product (GDP), although these effects are statistically insignificant. The defense budget and ICT Development Index variables, however, have a positive and significant effect on GDP. The results of Model 2 reveal that digital transformation, as indicated by the ICT Development Index, has a positive and significant impact on Fisheries Gross Domestic Product, meaning that an increase in the ICT Index will lead to an increase in Fisheries GDP. In both regression models, no issues with serial correlation were found. To support the significance of the influence of the blue economy on GDP, inclusive policies are needed. The two strategies that could be applied include: (1) digital transformation of blue economy sector infrastructure based on the Internet of Things (IoT) Ecosystem and (2) blue financing through blue bonds.

While this study provides valuable insights, there are some limitations that can serve as recommendations for future research. Limited data and regional coverage may limit the generalizability of the findings, so future research is recommended to use a broader and more recent dataset. In addition, the methods used, which are based on quantitative approaches only, can be strengthened with qualitative or mixed methods analysis to gain a deeper understanding. Some additional variables, such as social and environmental factors, can also be further explored to get a more complete picture. In addition, the evolving policy dynamics suggest the need for longitudinal studies to assess the long-term impact of the phenomenon under study. Future research can also expand the context of analysis by conducting comparative studies between countries or sectors to increase the relevance and applicability of the research results.

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