Harnessing the Blue Economy: Pioneering Sustainable Maritime Growth in Southeast Asia

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Abstract. This study evaluates the impact of *blue economy* implementation on the growth of the maritime sector in five developing Southeast Asian countries, namely Indonesia, Malaysia, Vietnam, Thailand, and the Philippines, during the period 2018-2022. Employing a panel data regression model, the study examines the role of the *blue economy*, green technology adoption, and government regulations in fostering maritime sector growth. The findings reveal that the implementation of the *blue economy* has a significantly positive effect on maritime sector growth, with a coefficient of 0.45 ($p < 0.05$). Additionally, green technology adoption is shown to improve operational efficiency, indicated by a coefficient of 0.38 ($p < 0.05$), while supportive government regulations contribute significantly with a coefficient of 0.30 ($p < 0.05$). These findings underscore the importance of an integrated policy framework that connects the *blue economy*, technological innovation, and regulation to promote sustainable maritime sector growth in developing countries. This study provides practical recommendations for policymakers to accelerate maritime industry transformation through a more targeted and measurable approach.

Keywords: *Blue Economy*, Government Regulation, Maritime Sector Growth, Southeast Asia, Panel Data

1 Introduction

The maritime industry is a cornerstone of the global economy, facilitating the movement of over 80% of the world's trade by volume via sea routes annually [1]. Its significance extends beyond transportation, as it is crucial for the economic stability and growth of numerous nations, particularly those with extensive coastlines and reliance on international trade. However, despite its indispensable role, the industry faces mounting challenges, especially in terms of sustainability and the efficient use of marine resources. These challenges are exacerbated by the global shift towards sustainable development and increasing environmental pressures. The transformation of the maritime industry in the 21st century is, therefore, no longer solely a matter of enhancing economic productivity, but also of incorporating responsible environmental management practices to ensure long-term sustainability. This shift has given rise to the concept of the blue economy—a holistic approach to marine resource management that balances economic growth with environmental conservation.

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The blue economy aligns with the Sustainable Development Goals (SDGs), particularly SDG 14, which advocates for the conservation and sustainable use of the oceans, seas, and marine resources [2]. It emphasises an integrated framework that supports economic activity while preserving marine ecosystems. Although the concept has gained considerable attention from academics and policymakers globally, empirical studies examining its direct impact on maritime sector growth remain sparse. Most existing literature focuses on theoretical frameworks or qualitative case studies that discuss the potential benefits of the blue economy without providing robust quantitative analyses [3, 4]. This lack of empirical evidence impedes a clear understanding of how blue economy policies translate into tangible economic outcomes, particularly in developing regions where maritime industries play a pivotal role in national economies. The challenge lies in quantifying the economic benefits while maintaining environmental stewardship, a balance that has yet to be sufficiently explored through rigorous empirical research.

Additionally, a significant research gap exists regarding the role of green technology innovation in enhancing operational efficiency and sustainability in the maritime sector. While the adoption of green technologies—such as renewable energy sources for ships, improved waste management, and more efficient maritime logistics—is often highlighted as a critical factor for the blue economy's success, few studies have quantitatively assessed its actual impact, particularly in developing Southeast Asian nations [5]. Many of these countries, including Indonesia, Malaysia, Vietnam, Thailand, and the Philippines, rely heavily on traditional energy sources and face infrastructural and financial barriers to adopting new technologies. Consequently, the contribution of green technologies to improving the economic and environmental performance of the maritime sector in these regions remains underexplored. Existing studies often focus on developed economies where the integration of green technologies is more advanced, leaving a critical gap in understanding how these innovations affect developing maritime economies.

Given these outlined gaps, this study aims to bridge them by evaluating the impact of blue economy policy implementation on maritime sector growth in five key Southeast Asian developing nations—Indonesia, Malaysia, Vietnam, Thailand, and the Philippines. In addition, this research seeks to empirically assess the role of green technology in promoting sustainability and operational efficiency within the maritime sector over a five-year period. By employing a panel data regression model, this study offers new empirical insights into the relationship between blue economy implementation, green technology adoption, and maritime sector growth. These findings will provide crucial evidence to guide policymakers in formulating more effective, measurable policies that support both economic growth and environmental sustainability in developing regions.

Moreover, Southeast Asia presents a unique case for studying the blue economy due to its complex mix of rapidly developing economies and rich marine biodiversity. The region is home to some of the world’s busiest shipping lanes and largest fishing grounds, which are critical to the livelihoods of millions. However, the increasing exploitation of marine resources has led to significant environmental degradation, including overfishing, coral reef destruction, and marine pollution. These challenges are exacerbated by the effects of climate change, such as rising sea levels and ocean acidification, which disproportionately impact coastal communities and industries.

While the blue economy offers a promising framework for addressing these issues by promoting sustainable economic activities that benefit both people and the planet, Southeast Asia's integration of these principles remains uneven and often hindered by political, economic, and infrastructural constraints. Therefore, understanding how blue economy initiatives and green technologies can foster sustainable growth in such a diverse and dynamic region is crucial. Yet, the empirical evidence needed to guide effective policy interventions remains limited, particularly in the context of the region's developing economies. This study, therefore, seeks to fill this critical gap by providing data-driven insights into how the blue economy and green innovations can transform the maritime sector in Southeast Asia, contributing both to economic development and environmental sustainability.

2 Literature Review

To understand the relevance of the blue economy to the transformation of the maritime industry, it is essential to refer to foundational theories. The Sustainable Development Theory, first introduced in the Brundtland Report in 1987, highlights the necessity of balancing economic growth, environmental protection, and social equity [6]. This theory closely aligns with the blue economy concept, where marine resource management must meet the needs of the present generation without compromising the ability of future generations to meet their own [7]. In this context, sustainable development in the maritime sector depends not only on economic exploitation but also on marine ecosystem conservation and the adoption of environmentally friendly technologies.

Complementing the Sustainable Development Theory, Schumpeter's Theory of Technological Innovation is central to understanding the transformation of the maritime industry. Schumpeter posits that technological innovation is the key driver of creative destruction, where new technologies replace old ones to create greater efficiency and productivity [8]. In the blue economy context, green technology innovations, such as renewable energy and clean technologies in the maritime sector, are viewed as essential for improving operational efficiency and environmental sustainability. Green technologies in the maritime industry help reduce carbon emissions and enhance fuel and resource use efficiency [9]. A study by Schatz et al. found that the application of green technologies, such as eco-friendly fuels and ship innovations, can significantly reduce environmental impacts and increase productivity [5]. However, green technology adoption in developing countries, particularly in Southeast Asia, remains limited and requires further research to evaluate its long-term impact on the maritime industry [10].

Government regulation also plays a crucial role in promoting sustainability in the maritime sector. Environmental Governance Theory emphasises the importance of strong regulations and policies to ensure that technological innovations and sustainable practices are effectively adopted [12]. In the blue economy context, supportive regulations can strengthen the relationship between green technology adoption and maritime economic growth. A study by Keen et al. highlighted that blue economy policies in Pacific nations often face implementation challenges due to the imbalance between economic and environmental goals, exacerbated by insufficient

regulatory support and unstable socio-economic conditions [3]. Similarly, Silver et al. demonstrated that competing discourses in international ocean governance frequently result in conflicts between short-term economic interests and long-term conservation goals [4]. Thus, the success of blue economy implementation is heavily dependent on supportive government regulations that ensure sustainable industrial transformation.

Previous literature on the impact of the blue economy and technological innovations in the maritime sector typically focuses on the economic potential of sustainable marine resource utilisation. For instance, Lam et al. emphasised the importance of adopting information and communication technologies (ICT) in ports to improve logistics efficiency, reduce operational costs, and increase transparency in international trade [5]. Digital technologies, such as advanced ship tracking systems and port automation, have proven to enhance maritime productivity in several developed countries. However, the implementation of such technologies in developing countries remains hindered by infrastructure and capital limitations, preventing optimal green technology and blue economy adoption in Southeast Asia [10].

There remains a significant gap in the empirical evaluation of the blue economy and technological innovation impacts in Southeast Asia. Countries such as Indonesia, Malaysia, Vietnam, Thailand, and the Philippines occupy strategic positions in global maritime trade, yet the adoption of blue economy policies and green technologies in these countries remains limited [12]. Furthermore, few empirical studies specifically highlight the contribution of green technology innovation to maritime sector growth in these nations. Therefore, this study seeks to fill this gap by evaluating the impact of the blue economy and technological innovation on maritime sector growth in five developing Southeast Asian countries, using a quantitative approach with a panel data regression model.

Based on the literature reviewed, the hypotheses proposed in this study are as follows:

H_1: The implementation of the blue economy has a positive influence on the growth of the maritime industry sector in developing countries in Southeast Asia.

H_2: Green technology innovation has a significant impact on improving operational efficiency and sustainability in the maritime sector.

H_3: Government regulations that support the blue economy strengthen the relationship between technological innovation and maritime industry sector growth.

3 Methodology

This study uses a quantitative approach with a linear regression model on panel data. This approach was chosen because it can capture relevant temporal and spatial dynamics in measuring the relationship between independent and dependent variables in several countries over a period of time. The countries sampled in this study are developing countries in Southeast Asia, namely Indonesia, Malaysia, Vietnam, Thailand and the Philippines. These countries were chosen because their maritime sector has a significant contribution to the national economy, as well as initiatives to implement the blue economy concept in their maritime industry policies. The research

period covers the last five years, from 2018 to 2023, utilising secondary data obtained from reliable sources such as the World Bank, OECD, IMF, and UNCTAD.

The data used in this study include variables related to the implementation of the blue economy, green technology innovation, government regulation, and maritime industry growth. The data is obtained from various government publications and international institutions that have high credibility in providing statistical data related to the maritime economy and the environment. The secondary data used in this study facilitates cross-country analysis and provides a comprehensive picture of the influence of blue economy policies and technological innovation on the development of the maritime sector.

Data analysis was conducted using a panel data regression model. This approach combines cross-country data and time series data, thus providing an advantage in testing the effect of research variables simultaneously and dynamically. Three main models are used in panel regression, namely Pooled Least Squares (PLS), Fixed Effect Model (FEM), and Random Effect Model (REM). The Hausman test is conducted to determine which model is most suitable for use in this study, whether a model with fixed effects or random effects. In addition, to test the research hypothesis, several important statistical tests were conducted, including the F test to measure the simultaneous effect of independent variables on the dependent variable, as well as the T test to measure the significance of the effect of each independent variable partially on the dependent variable.

In order to ensure that the regression model used fulfils the classical assumptions of linear regression, several classical assumption tests were conducted. The normality test is conducted to ensure that the residuals are normally distributed, while the multicollinearity test aims to ensure that there is no high linear relationship between the independent variables that may affect the accuracy of the results. The heteroscedasticity test is conducted to check whether the residual variance remains constant, which is an important requirement in regression. An autocorrelation test is also conducted to ensure that there is no correlation between residuals from different time periods, so that the resulting model is valid and unbiased.

The linear regression model used in this study can be expressed by the following equation:

$$Y_{¿} = a + B_1 X_1 + B_2 X_2 + B_3 X_3 + \varepsilon_{¿} \quad (1)$$

Where:

$Y_{¿}$= Growth of the maritime industry sector in country *i* at time *t*.

X_1= Blue economy implementation

X_2= Green technology innovation

X_3= Government regulations related to the maritime industry

$\varepsilon_{¿} = ¿$ Error.

This study will examine how the implementation of blue economy, green technology innovation, and government regulation simultaneously and partially affect the growth of the maritime sector in Southeast Asian developing countries during the period 2018-2022.

4 Result and Discussion

This study uses panel data regression to analyse the relationship between blue economy implementation, green technology adoption, government regulation, and maritime sector growth in five Southeast Asian developing countries in the period 2018-2022. The models tested included analyses using Pooled Least Squares (PLS), Fixed Effect Model (FEM), and Random Effect Model (REM). After conducting the Hausman test, the Fixed Effect model was selected as the most suitable model for this study because this model can take into account the specific effects of each country in the study sample.

Table 1. Result Test

Test	Result
Maritime Sector Growth (dependent)	Dependent Variable
Blue Economy Implementation	0.45 ($p < 0.05$)
Green Technology Adoption	0.38 ($p < 0.05$)
Government Regulation	0.30 ($p < 0.05$)
F-Test	Significant ($p < 0.05$)
T-Test (Blue Economy)	Significant ($p < 0.05$)
T-Test (Green Tech)	Significant ($p < 0.05$)
T-Test (Regulation)	Significant ($p < 0.05$)
Normality Test	Normal Residuals
Multicollinearity Test (VIF)	No Multicollinearity (VIF < 10)
Heteroskedasticity Test	No Heteroskedasticity
Autocorrelation Test	No Autocorrelation

Source: Author own estimation (2024)

Maritime Sector Growth. The growth of the maritime sector is the dependent variable in this study. The percentage value of the maritime sector's contribution to each country's GDP is measured to see how the independent variables (blue economy implementation, green technology adoption, and government regulation) affect it. This variable is at the centre of the regression analysis.

Blue Economy Implementation (Coefficient = 0.45, $p < 0.05$). The implementation of the blue economy concept has a significant positive influence on the growth of the maritime sector. With a coefficient of 0.45, this result indicates that each increase in the blue economy implementation score by one unit will increase maritime sector growth by 0.45%. This is a highly significant result and suggests that the blue economy can be a key driver of maritime sector transformation in developing countries.

Green Technology Adoption (Coefficient = 0.38, p < 0.05). Green technology adoption also showed a significant positive effect with a coefficient of 0.38. This means that every one unit increase in green technology adoption is associated with a 0.38% increase in maritime sector growth. This effect of green technology is consistent with previous literature which shows that green technology innovation is able to increase efficiency and productivity, while reducing negative impacts on the environment.

Government Regulation (Koefisien = 0.30, p < 0.05). Government policies that support the maritime sector and sustainability have a significant effect with a coefficient of 0.30. This suggests that government regulation plays an important role in strengthening the relationship between innovation, blue economy and maritime sector growth. Governments with stricter policies that favour sustainability will see more stable and significant growth in the maritime sector.

F-Test (Significant, p < 0.05). The F test is used to determine whether all independent variables simultaneously affect the dependent variable. The significant results ($p < 0.05$) indicate that the variables of blue economy implementation, green technology adoption, and government regulation together have a significant effect on the growth of the maritime sector. This confirms that the regression model used can explain the relationship between these variables.

T-Test (Partial Significance of Each Variable). The T-test was conducted to test the partial effect of each independent variable. The significant results for blue economy implementation ($p < 0.05$), green technology ($p < 0.05$), and government regulation ($p < 0.05$) indicate that each independent variable has an individually significant influence on the dependent variable. This supports the hypothesis that these three factors are the main drivers of maritime sector growth.

Normal Residuals. The normality test shows that the residuals of the regression model are normally distributed. This is important because it ensures that the regression model fulfils one of the basic assumptions of linear regression, namely error normality. This means that the predictions from the regression model are unbiased.

No Multicollinearity, VIF < 10. Multicollinearity test is conducted to see if there is a strong linear relationship between the independent variables. The test results show that there is no multicollinearity problem with the Variance Inflation Factor (VIF) value below the threshold of 10, which means that the independent variables in the model are independent of each other and do not have too strong a correlation.

No Heteroskedasticity. The heteroscedasticity test shows that the residual variance remains constant, which means that the model does not suffer from heteroscedasticity

problems. This is very important for the validity of the model, as heteroscedasticity can lead to biased and inefficient coefficient estimates.

No Autocorrelation. The autocorrelation test ensures that there is no correlation between residuals in different periods. The results show that the model does not have autocorrelation, which means that errors in one time period are not correlated with errors in another time period. This increases the reliability of the regression results.

One of the most interesting findings of this study is the significant effect of blue economy implementation on maritime sector growth, with the highest coefficient of 0.45. This shows that the implementation of blue economy policies in developing countries in Southeast Asia plays a very important role in boosting the contribution of the maritime sector to Gross Domestic Product (GDP). This suggests that the more seriously these countries adopt sustainable economic policies, the greater the growth potential in their maritime sectors. In addition, the multicollinearity test shows that the independent variables do not have excessive interrelationship problems, meaning that each variable stands alone in explaining the influence on the dependent variable. This result corroborates the finding that green technology adoption and government regulation work independently but collectively support maritime sector growth. Equally interesting is the significant effect of government regulation, with a coefficient of 0.30, signaling that regulations that support innovation and sustainability can strengthen the relationship between technology adoption and maritime sector development. Governments that are more proactive in regulating sustainable maritime policies appear to be successful in driving improvements in operational efficiency and maritime economic growth. These findings underscore the importance of an integrated policy framework between innovation, economic policy and government regulation to maximize the potential of transforming the maritime sector through the blue economy and green technology.

5 Conclusion

This research has shown that the implementation of the blue economy has a significant influence on the growth of the maritime industry sector in developing countries in Southeast Asia, with the strongest coefficient of influence among other independent variables. The implementation of sustainable economic policies in the maritime sector is proven to increase the sector's contribution to Gross Domestic Product (GDP), in line with the literature that states that the blue economy can promote growth without damaging marine ecosystems [3]. The application of green technology has also been shown to play an important role in improving the efficiency and productivity of the maritime sector. This supports previous findings that emphasise the importance of technological innovation in the industrial transformation process [5, 8].

Government regulations that support sustainability and technological innovation have also been found to be significant in strengthening the relationship between the blue economy and maritime sector growth. Proactive government regulations that support environmental policies have been shown to promote more stable and

sustainable growth, in line with the literature that public policies play an important role in supporting sustainable development [12]. The results of this study provide important empirical evidence for policymakers to support the transformation of the maritime sector through the adoption of environmentally friendly and innovative policies.

However, this study has several limitations. Firstly, the use of secondary data limits the availability of consistent data across all sampled countries. In addition, this study only covers five countries in Southeast Asia and a relatively short time period, so the results may not be fully generalizable to other regions or over a longer period of time. Future research is recommended to expand the geographical coverage as well as consider other external factors, such as global market dynamics and international economic policies, which may also affect the maritime sector.

Overall, this research highlights the importance of an integrated approach involving technological innovation, economic policy and government regulation in supporting the transformation of the maritime sector through the blue economy. With the right policy framework, the maritime sector in developing countries can achieve more inclusive and sustainable growth, which not only supports the national economy but also preserves the marine ecosystem.

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