THE IMPACT OF FISH PRODUCTION, GOVERNMENT POLICY, CLIMATE CHANGE, AND MARINE BIODIVERSITY AS BLUE ECONOMY FACTORS ON FOOD SECURITY: A PANEL DATA ANALYSIS

A Thesis

Submitted to the Master's Study Program of Economics at the Faculty of Economics and Business in partial fulfillment of the requirements for the degree of

Master of Arts (M.A.)

by:

Azzam Robbani

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UNIVERSITAS ISLAM INTERNASIONAL INDONESIA

DEPOK

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ABSTRACT

Azzam Robbani
03212210013
azzam.robbani@uiii.ac.id
Economics
Universitas Islam Internasional Indonesia

This study explores the intersection between the blue economy and global food security, focusing on twelve Asia-Pacific countries from 2015 to 2021. As the blue economy becomes increasingly vital in sustainable development, particularly in regions reliant on marine resources, this research aims to quantitatively assess how key blue economy factors—such as fish production, government policies, marine biodiversity, and climate change—affect food security outcomes. Using a robust dataset sourced from reputable international organizations like the Food and Agriculture Organization (FAO) and the World Bank, the study applies panel data analysis using the Fixed Effects Model (FEM) based on the Hausman test, which confirmed FEM as the most appropriate model to account for country-specific characteristics and unobserved heterogeneity. Diagnostic checks for normality, heteroscedasticity, autocorrelation, and multicollinearity were conducted to ensure the robustness of the regression models. The findings reveal that climate change exerts a statistically significant and negative impact on food security, underscoring the vulnerability of food systems to environmental variability, particularly in regions where agriculture and fisheries depend heavily on natural rainfall and stable climatic conditions. Conversely, other blue economy factors—fish production, government policies, and marine biodiversity—do not show a significant direct influence on food security within the scope of this study. This suggests that while these areas hold potential, they may require more targeted and effective policy interventions to enhance their contributions to food security. The study emphasizes the need for policy recommendations that include the promotion of sustainable aquaculture and fisheries management, climate change mitigation strategies, and the development of comprehensive regulatory frameworks. Additionally, integrating urban planning into food security strategies and engaging local communities in the implementation of Marine Protected Areas (MPAs) are crucial for conserving marine biodiversity and supporting food security. The research also highlights the importance of diversifying blue economy activities to better integrate them into the broader economic system, thereby enhancing their contribution to food security.

Keywords**:** *blue economy, food security, climate change, sustainable fishery, panel data analysis*

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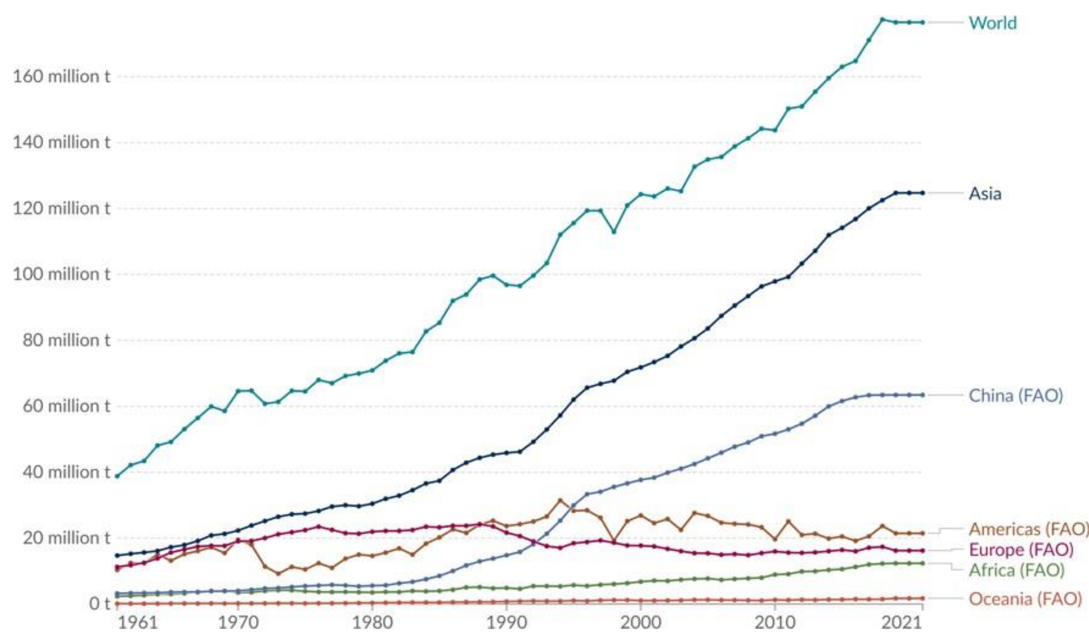
CHAPTER I : INTRODUCTION

1.1. Background

The world's oceans cover more than 70% of the Earth's surface and play a crucial role in supporting human life by providing sustainable economic opportunities. However, traditional exploitation has led to environmental damage, diminishing ocean biodiversity, and sustainable yields. In response, the Blue Economy concept emphasizes the sustainable use of ocean resources, integration, and inclusiveness. Introduced by Gunter Pauli in 2010, this model is based on natural principles and aims for economic growth while protecting the environment. Evolving from the Green Economy, the Blue Economy focuses on using ocean resources for economic development, creating jobs, and preserving ocean health. Acknowledged as an international organization at the United Nations Rio+20 Conference in 2012, it promotes sustainable economic activities in areas such as fisheries, aquaculture, shipping, renewable energy, and coastal tourism. Ecotourism, which prioritizes environmental protection and enhances the socio-economic well-being of local communities, aligns with the Blue Economy strategies. Therefore, addressing sustainability challenges in fisheries and aquaculture requires innovative solutions such as sustainable financing, technological advancements, and integrated planning, as suggested by Tegar & Gurning (2018) and Sanchez-Escalona (2023).

The latest SOFIA report highlights the potential for more effective and sustainable management of ocean resources through integrated and inclusive approaches. In this context, the Blue Economy emerges as a crucial tool. This emphasis becomes even more urgent as, for the first time, aquaculture production of aquatic animals has surpassed that of capture fisheries, underscoring the importance of the FAO's Blue Transformation initiative. The SOFIA 2024 report from the FAO marks a significant milestone, with global fisheries and aquaculture production in 2022 reaching 223.2 million tonnes — 4% increase since 2020. Of this total, 185.4 million tonnes were aquatic animals, and 37 million tonnes of fish were imported annually. Additionally, 8 million tonnes of algae are produced each year. FAO Director-General QU Dongyu stressed the need for further transformative and adaptive measures to enhance the performance, accessibility, stability, and sustainability of aquatic food systems. The Blue Transformation is essential for addressing hunger and poverty, supporting sustainable governance, and improving production, nutrition, environmental health, and people's quality of life, all while ensuring inclusivity and equit

Figure 1.1. Fish and seafood production

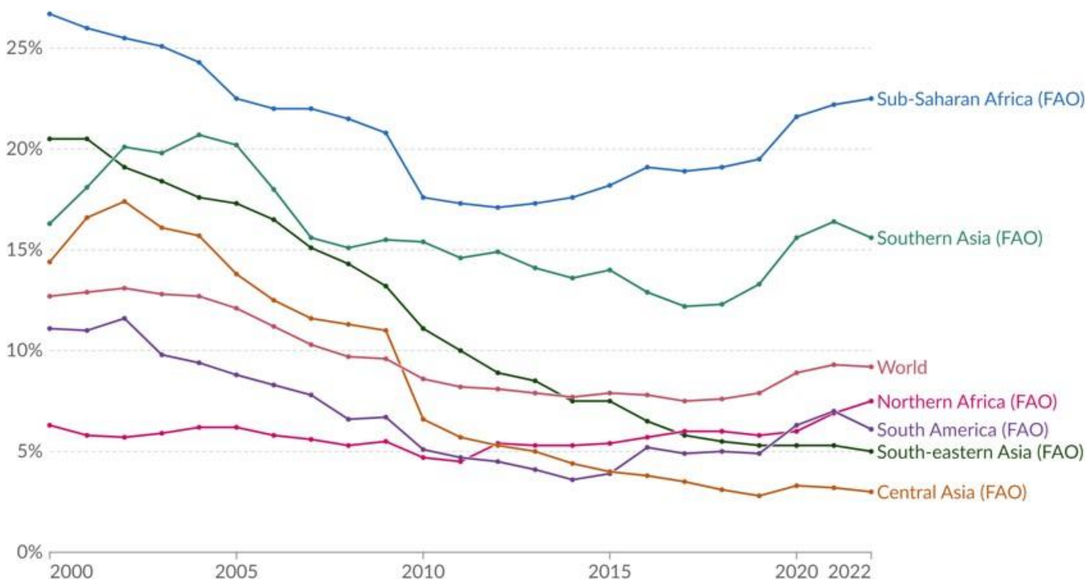


Data Source : Food and Agriculture Organization (2023)

The global fish and seafood production chart, 1961-2021, shows that global production has steadily increased from 40 million tonnes to over 160 million tonnes. Asia, especially China, has been behind this growth with Asian production increasing from around 20 million tonnes to over 120 million tonnes and Chinese production from the late 1970s to almost 70 million tonnes in 2021. The Americas produced around 30 million tonnes in the mid-1990s and has either plateaued or declined slightly since then. Europe has remained relatively constant between 10 and 20 million tonnes, Africa on the other hand has slowly increased to almost 10 million tonnes. Oceania, with the lowest production has shown the least growth, remaining below 5 million tonnes. Thus, the Asian region continues to lead the world in fish and seafood production levels while levels in other regions have remained relatively stable or increased at a slower pace. In addition, global aquatic food consumption has again increased with record production and the sector can play a role in addressing food insecurity and malnutrition. Thus, global real consumption of aquatic animal foods reached 162.5 million tonnes in 2021, growing at a rate almost two and a half times that of world population since 1961. Worldwide, annual per capita consumption increased from 9.5 million tonnes to 20.7 million tonnes in 2022. Thus, the share of total aquatic animal products produced that are directly consumed by humans is 89 per cent, indicating the importance of fisheries and aquaculture in feeding the world's population. The remainder is used for indirect or non-edible purposes, mainly in the form of fishmeal and fish oil. Promoting and increasing intakes from sustainable sources remains critical to improving global food consumption patterns and nutritional security as aquatic foods contain quality protein and other nutrients and contribute at least 20 per cent of the per capita protein supply from all animal sources globally. 2 billion people in 2021, and 2.3 billion people in 2024 (FAO, 2024).

Fish are an important source of protein; it stimulates the demand for seafood, and many countries have increased production, which has affected GDP. As for 2021, China tops the list with 58.8 million metric tons per year from aquaculture with modern fish farming methods. India follows, producing 9.05 million metric tons and contributing 6% of international sugar production and is an exporting country. Indonesia, with 6.1 million metric tons, which takes advantage of the Coral Triangle, which is rich in biodiversity. Fisheries in Peru have been a historical fish producer and currently, the country produces 5.85 million metric tons despite obstacles caused by illegal fishing cases. The US maintains the highest possible production quality at 5.36 million metric tons, due to its vast territorial waters. Among the most pressing issues of the contemporary world, it is possible to identify the problem of food security as one of the most significant ones, which is directly connected with the problem of undernutrition. A considerable portion of the global population faces the problem of low daily food consumption, which results in insufficient dietary energy to sustain a normal, active, and healthy life. This is so due to climate change, population growth, economic instability and unfair systems of food production and distribution.

Figure 1.2 Share of people that are undernourished



Data Source : Food and Agriculture Organization (2023)

A chart showing the proportion of the population that is undernourished is useful in presenting one aspect of the food security problem. The data show that over the past two decades the proportion of the population that is undernourished has been gradually decreasing in many regions, including Sub-Saharan Africa, South Asia and North Africa. However, malnutrition statistics have increased in recent times, particularly in Sub-Saharan Africa and South Asia due to factors such as high food price inflation. At the same time, global agricultural and cereal prices have been volatile; maize and wheat prices have experienced large year-on-year fluctuations and therefore affect the volatility of food security. In addition, the critical hotspots identified by FAO and WFP, including Mali, South Sudan and Gaza, remain in a phase of extreme food insecurity, with Gaza in a catastrophic phase due to ongoing conflict and limited humanitarian access. The Russia-Ukraine war has further exacerbated the global food crisis, with many countries adopting trade policies that result in bans on food and fertilizer exports to meet domestic demand, thus exacerbating the problem. The concerns raised by the AMIS Market Monitor about 2024/25 wheat production also show that global food security remains very weak, indicating the need for an integrated and sustainable approach to address this complex issue and strengthen the resilience of affected regions.

1.2. Problem Statement

The integration of the Blue Economy with food security is a critical yet often underexplored area of research. The Food and Agriculture Organization (FAO) in 2022 projects significant increases in both production and consumption of aquatic animal foods by 2032 which is called blue foods. This research aims to address the importance of blue foods in global food security and the necessity of sustainable practices to support this growth. Aquatic animal production is expected to rise by 10 % by 2032, reaching 205 million tonnes, while apparent consumption is projected to increase by 12 %, averaging 21.3 kg per capita. This blue food growth is driven by factors such as rising incomes, urbanization, and improvements in post-harvest practices. Blue foods, encompassing over 3,000 species of aquatic animals and plants, are vital to the global food system. They provide essential nutrition for over 3 billion people and livelihoods for hundreds of millions. Rich in essential micronutrients and offering lower risks of non-communicable diseases compared to other protein sources, blue foods are crucial for public health. However, many blue food systems have low environmental impacts, with some even enhancing the ecosystems they are part of. Despite their significance, blue foods are often marginalized in food system discussions, leading to missed opportunities for integration and sustainable development for economic, social, and environmental impact.

1.3. Research Questions :

Based on the background provided above, this study aims to address the following :

1. What are the key factors within the blue economy that will significantly effect food security?
2. How do policies and governance mechanisms within the blue economy framework impact food security?
3. What is current development in blue economy sector withn global scope?

1.4. Research Objectives :

To provide comprehensive responses to the research questions, this study outlines the following objectives :

1. To identify and analyze quantitatively the key factors within the blue economy that significantly impact food security

2. Investigate how policies and governance mechanisms directly and indirectly affect food security outcomes

3. To analyze current global blue economy developments in the policy advancements, sustainable fisheries, marine protected areas, and economy impacts

1.5. Research Hypothesis

The following hypotheses outline a clear and focused approach for studying the impact of blue economy factors on food security. To control variables and apply the four pillars of food security—availability, accessibility, utilization, and stabilization—these hypotheses address the complexity of food insecurity:

a. H_1 : Fishes Production has a positive effect on food security

b. H_2 : Government Policy has a positive effect on food security

c. H_3 : Climate Change has a negative effect on food security

d. H_4 : Marine Ecosystem has a positive effect on food security

These hypotheses aim to advance the research framework and form the basis for systematic and empirical questions and objectives.

1.6. Significance of The Study

The study of the impact of fish production, government policy, climate change, and marine biodiversity as blue economy factors on food security is of significance for several reasons:

1.6.1. Theoretical Significance

This research provides a substantial theoretical contribution by delving into the relationship between the Blue Economy and food security, a nexus that remains underexplored in existing academic literature. While the Green Economy has been extensively studied within the realm of environmental economics, particularly concerning its role in sustainable development, the Blue Economy has not received comparable scholarly attention. This study addresses this gap by offering a quantitative analysis that integrates key Blue Economy factors—such as fish production, government policy, climate change, and marine biodiversity—into the broader discourse on food security.

The theoretical contribution of this study can be seen from the fact that this study can add to the current body of knowledge on SDGs in the following ways, especially in the field of economics, this case can be associated with SDG 14 which is Life Below Water. Thus, this study contributes to the literature of environmental economics and argues for the inclusion of marine sustainability into the heart of economics by revealing how sustainable use of marine resources can feed the world. Thus, this research demands the dismissal of the traditional economic frameworks and the introduction of the Blue Economy concept that embraces the economic, social and environmental aspects. Furthermore, this study contributes to the theoretical body of knowledge to the effect that Blue Economy objectives can be attained alongside economic growth objectives without compromising on the marine resources. This paper gives a different perspective of the environment and the economy and reveals that the two are not mutually exclusive but are in fact harmonious if the appropriate policies and institutions are put in place. Consequently, this study offers the right platform for subsequent research to explore how the idea of the Blue Economy can be integrated into the mainstream economic theory and, in the process, enrich theoretical knowledge of sustainable development.

1.6.2. Practical Significance

Practically, this research has major implications for policymakers and other stakeholders in the management of marine resources and food security. Therefore, the research presents the findings of how Blue Economy factors influence food security and presents the decision-makers with the empirical evidence that is required to formulate policies that will foster economic growth and environmental conservation at the same time.

The practical significance of this research is the most valuable for enhancing the effectiveness of the measures aimed at the management of fisheries. In so doing, the research makes available policy relevant information that can be of value in the formulation of interventions that can assist in improving fish production in a way that supports food security. The recommendations of the study could be used in the development of policies that will ensure the sustainable utilization of fish resources, proper stocking and the promotion of fish farming as an additional source of food. These strategies are crucial in the provision of food security particularly to the regions that depend much on the sea produce. From the point of view of government policy, this research provides important data that can be used to enhance the correspondence of national policies to the principles of the Blue Economy.

The findings of the study can be used by the policymakers to develop and implement policies that are more sensitive to the economic, social and environmental sustainability. This includes the process of policies that in fact, bring MPAs into a wider system of marine management, so that these areas are useful for the protection of species and enhancement of food supply.

Finally, the study suggests that urban planning should take a more active role in the inscription of the food systems into the discourse of sustainable development. Therefore, regarding the urban planning concerns they should be directed to such provisions of the food systems as the support of the new urban fish markets, the improvements of the offshore processing and the development of the local production. These are useful not only in the given problem of food security but also can help work out new revenues, which in the given conditions of Urbanization might be drawn within the urban ecosystems hence acting as a plus in terms of sustainability of the Urban development.

1.7. Thesis Outline

The following is the plan of this thesis which is aimed at fulfilling the research objectives and at offering a synthesis of the Blue Economy components, especially fish production, government policy, climate change, and marine biodiversity on food security based on the panel data analysis. The thesis is divided into five chapters where each chapter is a logical progression from the other to give an easy to follow flow from the introduction of the topic and background information to the actual findings and conclusions.

The first chapter provides the background to the research and the rationale why analyzing the correlation between Blue Economy factors and food security is crucial. The problem statement, the research questions, and the specific research objectives of the research are defined in this chapter. The relevance of this study in the context of related literature is established to illuminate the need for the study that will aid in the development of policies. Last but not least, the present chapter offers a preview of all chapters to be presented in the thesis, so the reader gets oriented.

The second chapter also discusses the theoretical frameworks and literature review that apply to the study. Primarily, the study will analyze factors in the Blue Economy environment that influence food security in a theoretical context before determining the conceptual linkage between factors in the Blue Economy environment and food security. The chapter also presents a summary of a literature review done in other studies related to this chapter. Identify shortcomings that were noted in the previous studies which this current study aims to fill. In addition to positioning the study in the body of existing literature, this review also explains the rationale of the research methodology used.

The third chapter of the study identifies the methods used in the conduct of the study. This sub-section explains the research design in terms of why panel data analysis was employed and how data were collected. In this chapter, the author detail the meaning of the operational variables and how they are assessed in the framework of the investigation. This section also provides a detailed exposition of the analysis techniques used in carrying out the panel data analysis such as the Panel Corrected standard errors to correct for heteroscedasticity and cross-sectional dependence.

The fourth chapter of the research offers an analysis of the results of the empirical study discussed in detail. The first part of the current paper is devoted to the analysis of the current development of the Blue Economy, which is to establish the context for the subsequent statistical analysis. Frequency tables and simple percentages are then used to present the data; bivariant covariance is then used to determine the relationships between the variables. The chapter then outlines the findings of tests that check the suitability of estimating a panel data model, alongside diagnostic tests. Research questions are used to interpret the hypothesis test results in the view of analyzing the effect of Blue Economy factors concerning food security. This chapter will tie up all the loose ends that were submitted in the previous chapter, in a discussion that synthesizes the findings with the literature to demonstrate their theoretical contributions and real-world relevance.

In the last chapter, the authors provide an overview of all the conclusions that have been made in the course of the analysis. Some of the areas it covers include policy recommendations informed by the results towards improving food security through the possible management of Blue Economy resources. The chapter also provides an insight into the limitation of the study and other possible research direction that could expand on the result obtained in the study. This chapter is therefore the final chapter of the study and brings together the contributions of the study to scholarly knowledge and practice.

Consequently, every single chapter of this thesis is aimed to provide a specific piece of knowledge for constructing the overall picture of Blue Economy factors and food security and can be useful for academicians as well as for policy-makers.

CHAPTER II : LITERATURE REVIEW

2.1. Theoritical Framework

2.1.1. Food Security Theory

Food security in the existing meaning was developed based on earlier classifications of food shortage and its causes. Malthus (1798) observed that as people reproduce, the danger of shortage rises because of resource constraints. Although, with time, this theory has developed and seems to imply that increased population size will lead to the emergence of new techniques of obtaining food. In the present world, the food security theory has become a much broader theory that has been called the multidimensional theory in the consideration of food related problems in the present civilised society base on Boserup (1965). It is a modern concept that defines the economical, social and ecological approach to food security to qualify the food systems for eligibility for the needs of the increasing population.

2.1.1.1. Food Supply and Population Growth

The correlation between food and people has been one of the most debated and analyzed themes for centuries in the world among economists, politicians and scientists. The global population is growing daily and this means that the demand for food also rises and this exerts a lot of pressure on the agricultural sector to produce more food. This dynamic interaction brings two main questions; one is the ability of food production to meet the population growth rate and the other is the way of feeding the whole population. The earliest theory was by Thomas Malthus in the late eighteenth century and was a rather pessimistic view of this relationship as he claimed that while people would reproduce in greater numbers than food would be produced this would result to scarcity and famines. Malthus (1798) argued that population increases by geometrical progression and food by arithmetic progression and hence population will always outrun the food supply and therefore food scarcity, famine and social unrest. According to this theory, population grows in a geometric ratio while the resources specifically food increase in arithmetic ratio. Hence, in the absence of such checks as famine, disease or moral restraints, population will outgrow the capacity of the food production system thus creating a scarcity of food.

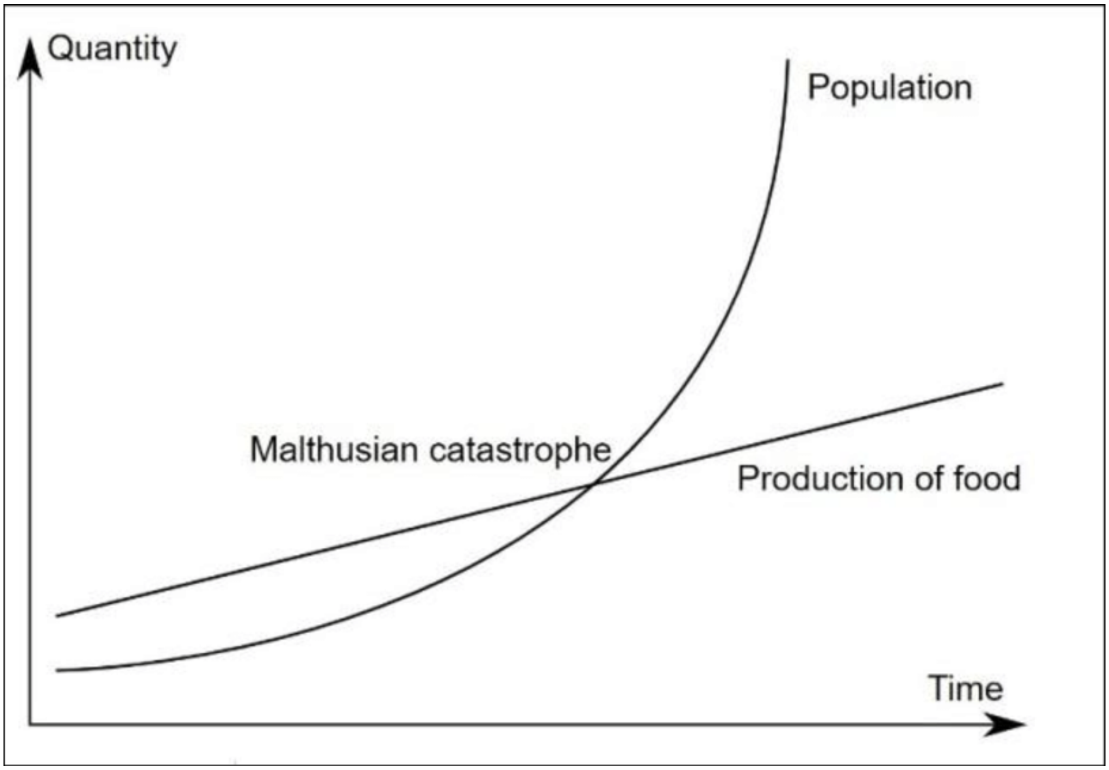


Figure 2.1 Malthusian Theory of Food Supply & Population

Malthus's primary argument centers on the concept that human populations tend to increase exponentially, while food production can only increase arithmetically. Mathematically, population growth can be expressed as

$$P(t) = P_0 \cdot (1 + r)^t \quad (2.1)$$

where P(t) is the population at time, P_0 is the initial population, r is the growth rate, and t is the time period. This is an exponential or geometric progression, meaning the population grows by a constant percentage over time, leading to a rapid increase (e.g., 1, 2, 4, 8, 16). Malthus argued that human reproduction follows a biologically exponential pattern in which each generation can produce more offspring than the previous generation. For example, if a couple has four children, and each of those children grows up to have four children of their own, the population will double with each generation, leading to exponential growth. In contrast, the growth in food production can be expressed as

$$F(t) = F_0 + k \cdot t \quad (2.2)$$

where F(t) is the food supply at time, F_0 is the initial food supply, and k is the constant increase in food supply per time period. This is an arithmetic progression, meaning that the food supply grows by a constant amount each time period, resulting in a linear increase (e.g., 1, 2, 3, 4, 5) because it is limited by factors such as land availability, soil fertility, and the limitations of agricultural technology. For example, a farmer may be able to increase his crop yield by a certain amount each year through improved techniques and improved seeds, but this increase is linear. If a farmer can grow 1,000 kilograms of wheat this year and, through improvements, can grow 1,100 kilograms next year, this is a linear increase of 100 kilograms per year. Malthus argued that because population grows exponentially while food production grows arithmetically, population will eventually outstrip food supply, leading to widespread shortages and potential crises.

Malthusian theory gives a negative outlook of population food relationship and how resource exhaustion is bound to happen when the population increases than the production of food. He forecasted that if population was given a chance to grow, free for all society would one day be in a position to lack food to feed the people. Malthus identified two types of checks to mitigate this risk: positive checks such as famine, diseases, war, etc that result to high rate of mortality and preventive checks such as moral restraints, late marriage, etc that result to low rate of birth. According to Malthus, these checks are essential in order to reduce the population to a point that can be supported by the available resources so as to avert the misery and anarchy associated with overpopulation. Even though some of the conclusions described by Malthus failed to occur due to the scientific and technological advancements, his theory can be applied to the contemporary discussions about sustainability and the need to prevent the population growth and the lack of resources to feed it from causing ecological and humanitarian disasters.

2.1.1.2. Agricultural Innovation and Population Growth

As the population of the world rises, the demand for food also rises and this has a lot of pressure on the farming sector. This factor has led to formation of a cycle of innovation and an increase in yield in agricultural production for the growing population. In the 1960s, Ester Boserup, an economist from Denmark, presented a counter view to Malthusian theory in her book 'The Conditions of Agricultural Growth' where she opposed the idea that population density hinders agricultural innovation and improvement. Boserup also argued that as the population densities rise, societies are compelled to devote more time and energy to the production of food and this will require the use of modern tools, efficient water control and the use of fertilizers. While Malthus predicted famine and low populations, Boserup believed that population density would be solved by human ingenuity. Her theory is that given the pressure of population there is always a change in agricultural practices and yields and that the low impact practices such as shifting cultivation will be replaced by high impact and high yields such as ploughing, terracing and irrigation. Also, Boserup noted that these changes are not only technological but also social, that is, new forms of organization and cooperation of farmers to meet the growing needs of the population.

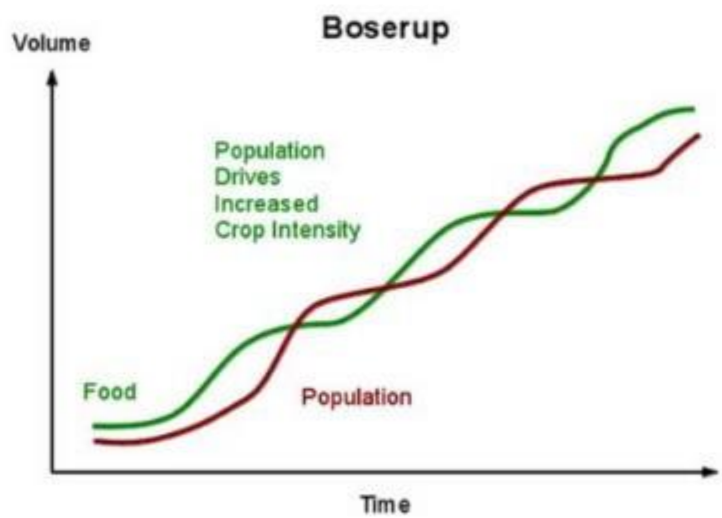


Figure 2.2 Boserup Theory of Food Supply & Population

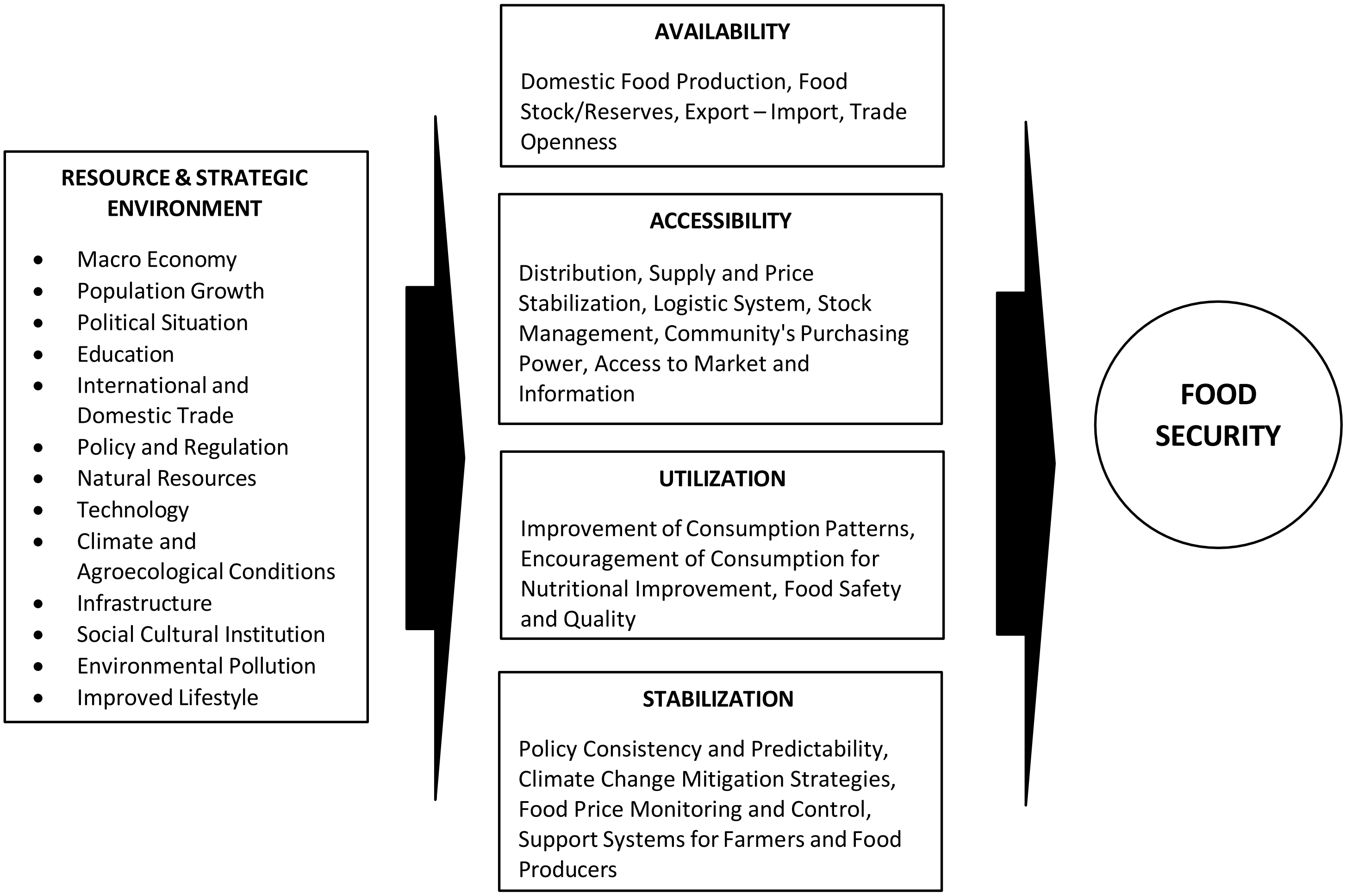
The hypothesis of Ester Boserup helps to understand the relationship between population density and the yield of the agricultural production, as it states that the increase of the population results in the innovations in the sphere of agriculture. The demand on the food resources also increases with the density of the population, so the societies have to produce more food on the same territory. This leads to time of surpluses where the rate of production of foods out competes the rate of increase in population through advancement in technology and farming methods. As put by Boserup, population density can be relieved through innovation and technological improvement thus establishing a cycle that shows that population pressure leads to development of better ways of practicing agriculture. This view is quite different from Malthusian prophecy of famine and resource depletion; on the contrary, it postulates that the pressure of the population on the land triggers the development of new farming technologies..

2.1.1.3. Sustainable Food Security

Food security as a policy concept was first formulated in early 1970s, but popularized after the world food conference of 1974 that was convened by the United Nations because of food shortage in the world. This conference can be said to be the turning point of the international debate on food security which was at first defined in relation to physical and economic access to staple foods at both the global and national levels (United Nations, 1974). In the recent past, food security has been defined to be not only the physical availability of food stocks but also the quality, accessibility and reliability of the food supply. This process was marked by the World Food Summit in 1996 and in which food security was described as the condition in which individuals have access to adequate, safe and nutritious food that is culturally acceptable and meets the dietary requirements for a healthy and active life (FAO, 1996). This fine-tuned definition stems from the broader idea of food security and its attainment, stability, and quality.

Hence, the development of the food security concept cannot be attributed to an individual theory by an individual scholar or an organization but it is the product of the discourse that has taken place internationally particularly by the FAO of the United Nations. The theory of food security has now moved to other areas including crop and livestock production diversification, food processing and impacts of climate change on the food chain (FAO, 2021). As highlighted in this research economic stability, social justice, environmental conservation and good governance should form part of the food security framework. These are fundamental in ensuring that every individual has a stable and adequate access to safe and nutritious food, thus affirming the fact that food security is global policy concern that is actually complex (FAO, 2021)..

Figure 2.3 Conceptual Model of Food Security



Source : (Author’s modification, 2024)

The diagram provides a comprehensive framework for understanding food security by highlighting four key components: Availability, Accessibility, Utilization, and Stabilization, often referred to as the four A’s of healthy population. Each of these components is influenced by various factors within the resource and strategic environment. Availability involves aspects such as domestic food production, food reserves, export-import dynamics, and trade openness, which are crucial in ensuring a consistent supply of food. Domestic agricultural production is particularly vital as it guarantees the local availability of food, while open trade policies help balance food deficits and surpluses, maintaining a steady supply (Pingali, Bigot, & Binswanger, 1987).

Accessibility concerns the distribution channels and networks, the fixed and administered prices, distribution and storage, the purchasing power of the community, and markets and information. Availability and price are two critical factors that determine the acquisition of food and distribution channels and pricing policies help to achieve these objectives. Transportation is important in getting food from producers to consumers, while stock control to avoid food stock out is important. Market information and purchasing power within the community is crucial in the purchase decision and therefore improving food security (Godfray et al. , 2010). Utilization focuses on the enhancement of consumption rates, and on the nutritional quality of foods as well as food safety and quality. Adherence to proper diets and high standards of food hygiene are also some of the ways that help in the improvement of the health of the people (Boserup, 1965). Stabilization includes policy stability, climate change, food price management and farmers and food producers. Policies that are stable and climate change measures that are implemented are important in maintaining the productivity of agricultural land, in addition to managing the food prices so that they do not fluctuate and remain affordable. Subsidizing farmers, and providing them with training or resources improves the food production capability (Hazell & Wood, 2008). Last of all is the Resource & Strategic Environment which defines the scope in which food security is attained through the macro economy, politics, education, trade policies, natural resources, technology, climate, infrastructure and socio-cultural institutions (Foley et al., 2011).

2.1.2. Blue Economy Theory

The Blue Economy is a holistic concept grounded in sustainability, expanding beyond traditional economic models that focus solely on growth by integrating social and environmental considerations. It emphasizes the importance of preserving marine and coastal ecosystems while pursuing economic development, making it a broader extension of the Green Economy by incorporating ocean-related sectors such as fisheries, aquaculture, marine tourism, renewable energy, and biotechnology. The Blue Economy also embraces circular economy principles, aiming to minimize waste and promote the use of recycled resources to mitigate environmental impacts. Understanding the Blue Economy requires considering its predecessors—sustainable, green, and environmental economies—which provide essential context for situating the Blue Economy within the broader framework of sustainable development.

2.1.2.1. Sustainable Economy

Sustainability, as currently understood, gained significant momentum with the 1987 report "Our Common Future" by the Brundtland Commission. This report provided a foundational definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). This principle has since become central to sustainability science and policy, integrating economic, social, and environmental considerations. Herman Daly, a pioneer in ecological economics, further contributed to this field with his theory of steady-state economics, which emphasizes the need for economic processes to remain within the planet's ecological limits (Daly, 1977). Daly's work, alongside the broader principles of resource efficiency, carbon emission reduction, and life cycle thinking, forms the core of sustainable economic development, aiming to balance growth with environmental stewardship (Britannica, 2024; SpringerLink, 2018).

The right measures and approaches in economic development must be adopted to improve the growth of the economy in order that all the people of the society will have an opportunity to be uplifted and to have a fair share in the growth. This aligns with E. F. Schumacher's humanistic economic theories that are evident in Small is Beautiful in which the author calls for development that enhances the ability of communities and places people first before money (Wu & Zhou, 2021). Another factor is the adoption of clean technologies which include cleaner production and efficient use of energy. These ideas are developed by Kate Raworth's Doughnut Economics that states that economic activities should not exceed the planetary boundaries and must also not violate the social contract of societies (Satija, 2013). Government policies like tax credit and subsidies are some of the fiscal policies that have demonstrated that policy intervention is feasible in the attainment of both economic and environmental objectives (Smulders et al. , 2011).

Social sustainability is the aspect that is made up of social justice and poverty reduction. Basic policies including employment diversification, access to basic services and wages for work are some of the policies that are relevant to economic inclusion. In Raworth's Doughnut Economics, the economic models that erase poverty and ensure that the ecological ceiling is not breached are presented (Varghese et al. , 2018). Green jobs that are linked with economic growth and environmental protection are essential in the developing countries as they offer sustainable employment with regard to ecological matters (Qian & Ji, 2022). Another factor is the citizen participation because if communities are involved in decision making then the measures concerning the sustainable development are more credible and efficient, this is in accordance with Schumacher's philosophy of localism and community based development (Ofreneo, 2015).

The environmental dimension of sustainability is therefore the conservation of the biological diversity and the ecosystems that are useful in supporting the activities. Ecosystems are sources of oxygen, water and fertile soil and thus their conservation is vital for the balance of the environment (Kostetska et al. , 2020). Environmental pollution control and recycling are also some of the considerations that assist in reducing the pollution of the environment and the optimization of the use of resources as per the circular economy model (Sun et al. , 2020). Climate change is therefore only manageable through mitigation measures such as reduction of emissions and enhancement of energy efficiency for the sustenance of international stability. From the literature review, one can deduce that there is a call for integrated climate approaches to tackle climate change and enhance sustainable development (Ravichandran & Roy, 2022). Therefore, based on these principles, societies can build a sustainable future that would adequately meet the needs of the present and future generations, with regard to Schumacher's and Raworth's works that advocate for people's economy that does not overexploit the Earth and society.

2.1.2.2. Blue Economy Framework

The Blue Economy, introduced during the 2012 United Nations Conference on Sustainable Development in Rio de Janeiro, represents a developing concept centered on utilizing ocean resources for sustainable income and wealth generation without compromising future generations (Commonwealth Secretary-General, 2016). This concept, linked to Gunter Pauli's work on nature-inspired technologies, focuses on sustainable economic development that meets essential human needs such as clean water, food, and housing (Pauli, 2010). Pauli's systematic literature review, which began with 2,231 peer-reviewed articles, ultimately identified 100 innovations capable of functioning like ecosystems, highlighting the dual origin of the Blue Economy: international recognition of the ocean's economic value and Pauli's project emphasizing nature-based technologies for sustainable development (Brears, 2021).

The Blue Economy encompasses a wide range of activities, from traditional industries like fisheries, marine transportation, and tourism to emerging sectors such as marine renewable energy, seabed mining, and marine biotechnology. It aims to utilize ocean resources sustainably, balancing economic, social, and environmental benefits while conserving resources for future generations. The Blue Economy incorporates circular economy principles to reduce waste and maximize resource efficiency, focusing on equitable and sustainable development supported by sound governance and international cooperation (Commonwealth

Secretary-General, 2016; Brears, 2021). This model promotes innovation, interdisciplinary approaches, and a commitment to social equity and environmental protection, providing a sustainable framework for current and future prosperity.

The Blue Economy is increasingly recognized for its potential to create significant economic opportunities while preserving the world's oceans and seas. It is seen as a major pillar for sustainable economic growth, as exemplified by the European Union's commitment to sustainable maritime resource exploitation (Biukšāne, 2022). Beyond its economic significance, the Blue Economy addresses global challenges such as unemployment, marine resource management, and climate change, making it central to the broader sustainable development agenda (Duarte, 2023). Local governments play a critical role in implementing Blue Economy policies, particularly in areas such as water quality, sanitation, and sustainable land use, which are vital for strengthening resilience against water-related risks (Romano, Lassman, & Laimé, 2023). Globally, the Blue Economy has the potential to contribute up to $1.5 trillion, emphasizing its importance in improving economic stability while ensuring sustainable resource use (Waruhiu, 2019).

In regions reliant on traditional sea-based industries like shipping and fishing, the Blue Economy promotes efficiency and best practices to ensure long-term profitability while preserving the environment. The emphasis on clean energy, sustainable fishing, and ecotourism reflects a global shift towards conservation as a key pillar of economic growth. The Blue Economy offers a promising pathway for balancing economic development with environmental protection, creating jobs, and safeguarding water resources for future generations. This approach provides countries with a roadmap to diversify income sources while addressing environmental degradation and climate change. The Blue Economy's theoretical foundation is further supported by recent studies highlighting its potential benefits and challenges, particularly in Africa. The African Union's Agenda 2063 recognizes the Blue Economy as a tool for regional cooperation and sustainable development, aligning with the need for context- specific policies to manage ocean resources and address climate change in the Global South (Nagy & Nene, 2021; Schot & Steinmueller, 2018). Through sustainable marine resource management and equitable benefit distribution, the Blue Economy aligns with the United Nations Sustainable Development Goals, particularly Goal 14, and serves as a policy reference for global efforts to achieve sustainable development for present and future generations.

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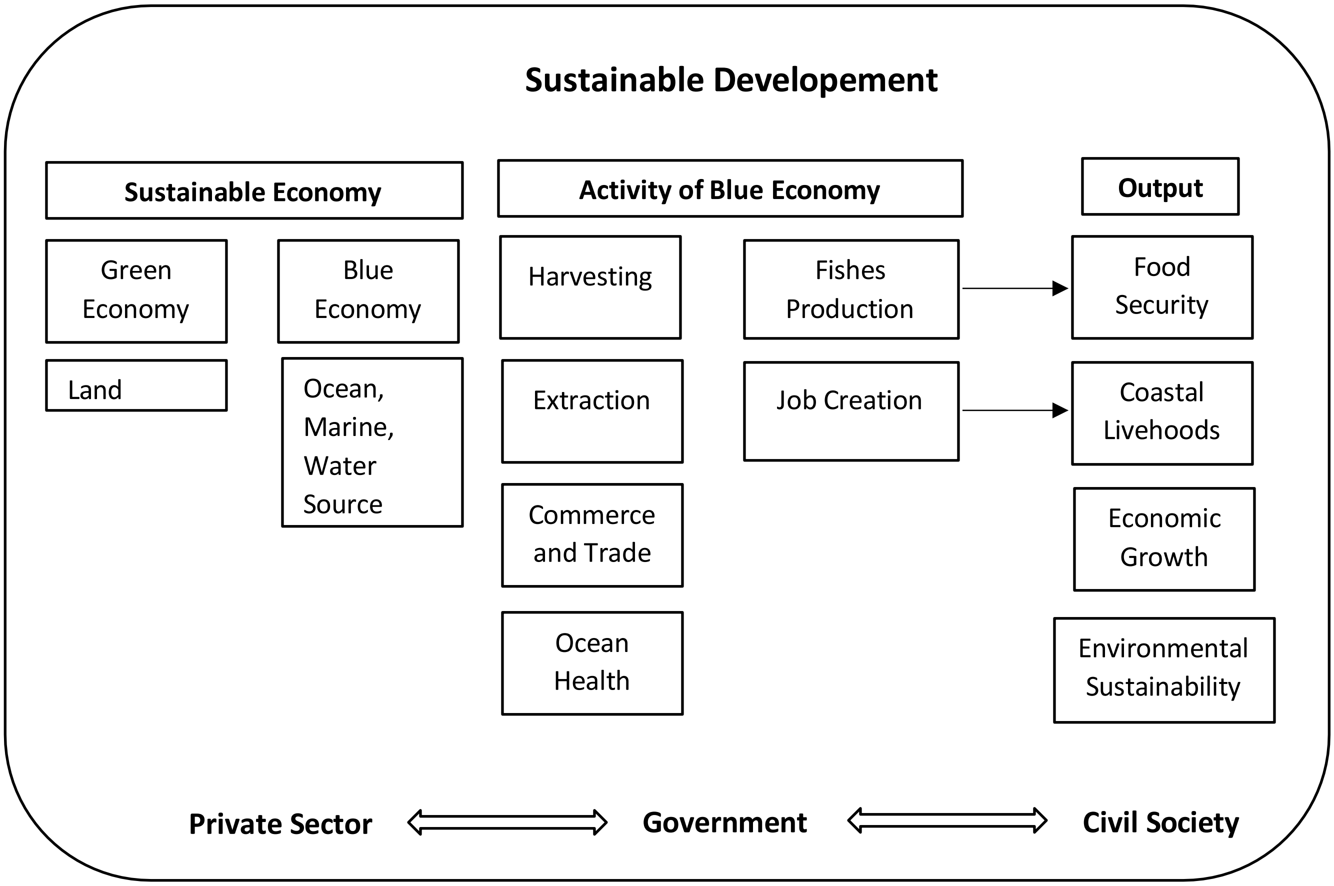
2.1.2.3. Integration of Blue Economy and Food Security

The Blue Economy and food security have been integrated and this has been shown through the following successful projects across the globe. In Bangladesh, the community-based fishery management systems have improved food security in the fishery-dependent households by increasing the fish stock, and thus, offering both the income and nutritional securities to the fishery communities (Islam et al. , 2020). In Norway, the integration of aquaculture and wild fishery is a balanced system of food production, including fish as a source of protein for the population without negative impact on the environment (FAO, 2018).

Likewise, in the Pacific Island states, the development of small scale fishery and introduction of mariculture, the farming of aquatic life for food have enhanced food security and income and is an example of the Blue Economy. Community based coastal resource management (CBCRM) initiatives in the Philippines have enabled the communities to manage the coastal resources. Measures such as mangrove planting and marine protected areas have improved fish yield, food supply, and community's ability to cope with disasters (Chen et al. , 2020).

The Blue Economy is well illustrated by the Seychelles' Marine Spatial Planning (MSP) where the concept of MSP shows that the conservation of marine species, enhancement of fish stock production and overall marine ecosystem can be achieved together with economic utilization. In Indonesia, integrated mangrove-aquaculture farming involves the restoration of mangroves together with sustainable aquaculture and leads to greater yields in aquaculture, better protection of the coast and better living standards for the people (Adiprayoga & Samiaji, 2021). These examples show that the sustainable marine management integrated with food production can solve the problems related to food security and provide positive economic and environmental impacts.

Figure 2.4 Framework for Sustainable Development through Blue Economy



Source : Author's Modification, 2024

The relationship between the Blue Economy and food security is based on the sustainable development agenda which seeks to unlock the wealth of the seas, oceans and water for human welfare. The main activities that are in the Blue Economy include fishing, fish farming, mining, trade and business and they are important in supporting food security. These sectors are useful in generating employment and improving the quality of living in the coastal regions thus enhancing economic growth and order. The sustainable management of these activities improves the health of the environment by the effective regulation of the extraction of resources and the conservation practices.

This framework thus calls for a coordination of effort among various players, the private sector, the government and the civil society in the implementation of the Blue Economy. Effective coordination and collaboration between these sectors are important for food security and enhancement of the progress in the context of SDGs. The Blue Economy supports food security in the sense that it promotes the utilization of sustainable practices that will enable the development of the economy and at the same time preserve the environment in such a way that future generations will benefit from the required ecosystems.

2.1.2.4. Fish Production

In the case of blue food, fish production which comes from fisheries capture and aquaculture has a significant importance in improving food security all over the world especially in the regions where fish forms the staple food. The term food security can therefore be understood in terms of its physical accessibility, both in terms of getting hold of food and the stability of those supplies, as well as the ability to make use of food in order to lead a healthy lifestyle. All these dimensions are provided by fish production and can be considered as sustainable source of protein, essential fatty acids, vitamins and minerals. This aspect shows that fish availability affects food security due to the regular provision of quality protein.

Fish contributes approximately to 17% of the animal protein consumed by the world’s population and over 50% in many of the least developed countries. Fish farming or aquaculture has thus become an important part of fish supply chain and has helped to make fish available all year round. This steady availability assists to bring order and stability in the food markets and decrease the reliance on seasonal fish harvest which is controlled by climatic and environmental changes. Fish is as vital as meat and grains and therefore its availability must also be ensured to its consumers. In many coastal and island countries fishing is not only a business but an occupation that has been inherited from one generation to another. Fish production creates a large producers’ surplus and stimulates other economic activities as millions of households are able to buy other food products and other necessities. Moreover, the advancements in fish preservation and transportation have made it possible to cover the fish products in the inland and urban areas which increases the coverage of this important food source.

Food security is affected by the stability of fish production since it reduces the risks that are likely to result from unstable food supply. There is a general threat of over fishing, losing the habitats of fish, and climate change, which are threats to wild fish stocks and food security. But, there are some improvements seen in the sustainable fishing, and the new techniques for aquaculture are useful for everlasting fish production. For instance, measures such as putting in place quotas for fishing, preserving the ecosystem that the fish exist in, and adopting sound methods of fish farming all help in the provision of sustainable supply of fish. Regarding the vulnerability to environmental changes, aquaculture has turned out to be less sensitive as compared to the wild fisheries. This makes it possible for aquaculture to avoid some of the natural fluctuations and shocks since it has full control over breeding, feeding, and harvesting. This stability helps in maintaining fish as a stable source of food in the adverse conditions and hence contributes to the food security.

The nutritive values of fish is paramount to food security. Fish is known to contains rich nutrients such as the omega-3 fatty acids that are important in the development of the brain and the heart. It also contains vitamins of D and B2 (riboflavin) and minerals including calcium, phosphorus, iron, zinc, iodine, magnesium, potassium. Fish consumption is a good preventative measure against malnutrition and deficiency diseases given that such diseases affect the young and pregnant women most. Some measures that have been taken to address the issue of utilization include:; the attempt to increase value added practices such as the minimization of post harvest loses and waste. To add value to the fish products, the industry should try and diversify in producing fish fillets, canned fish and fish based snacks, among others; this would help in expanding the shelf life of fish products hence catering for more consumers. Awareness campaigns regarding the health impacts of fish consumption should also change people's eating habits to healthier and better diversified diets.

It also helps in the economic diversification and employment opportunities in fisheries, aquaculture, marine tourism, and sectors that are directly related to them; thus, combating poverty and improving food security in the coastal areas (Sardan et al. , 2023). Mangrove and coral reefs are as important as they provide climate resistant measures including defense from sea level rise and extreme weather events, hence supporting fishery and aquaculture and guaranteeing food security (Bank et al. , 2022). Nevertheless, the following challenges need to be met for optimum exploitation of marine resources for food security. The challenges include; overfishing continues to be a real threat and this calls for proper management and control of fishing activities to avoid damaging the fish resources. Pollution of the seas, oil spills, plastics, and chemical leaks affect the marine environment and the quality of seafood, which calls for collective measures in the fight against pollution (Romano et al. , 2023). Climate change is the other threat that influences the climate of the seas, depth, water temperature, sea level and the marine life which in turn affects the productivity of fishery resources. There is therefore need to use adaptive measures that would help in the reduction of the impacts of climate change on the marine resources (Namany et al. , 2018). Governing and regulating are also important because poor regulation results in poor usage and exploitation of resources. Finally, there is a negative impact of social and economic inequalities in the coastal areas in terms of resource exploitation through the Blue Economy. Policy coherence measures and capacity development interventions are crucial for achieving equal opportunities and facilitating the harmony between the Blue Economy and food security (Choudhary et al. , 2021).

2.1.2.5. Income and Employment for Coastal Livehoods

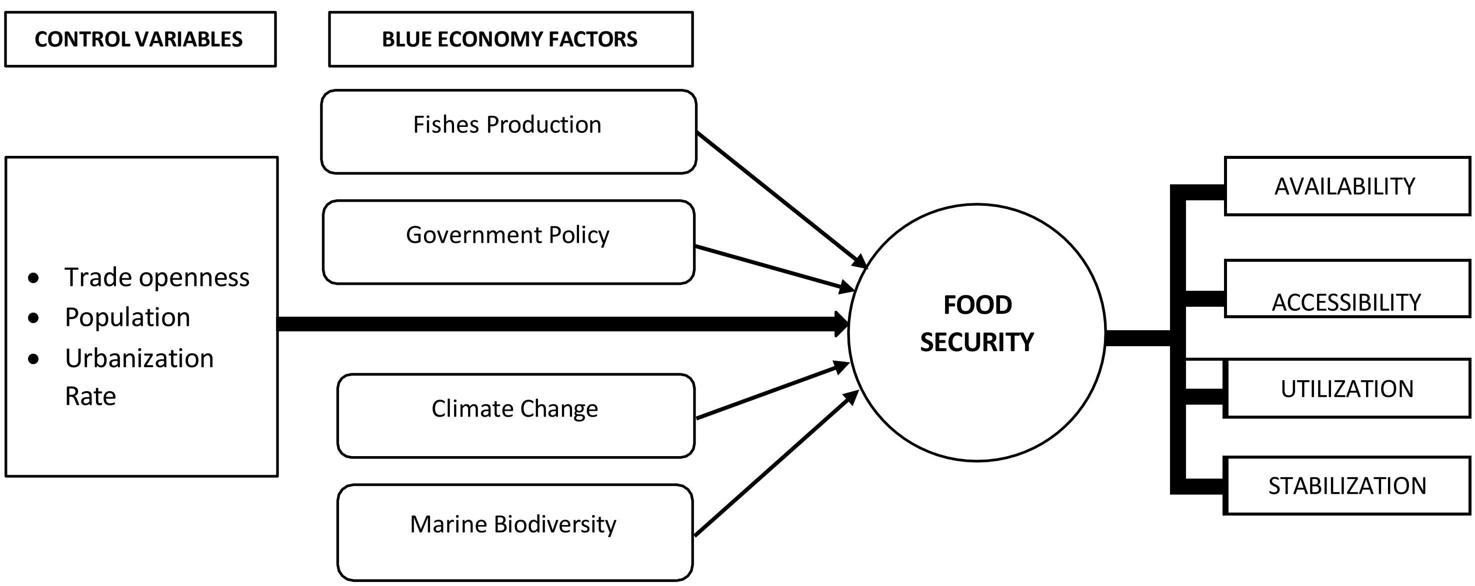
Fisheries and aquaculture are important for income and employment generating activities that support millions of people especially those in the coastal regions. These sectors are not only sources of direct employment in fishing and aquaculture operations but also create demand for various services including processing, transport and marketing. A study on marine fisheries employment profile projected that about 260 million people are employed in fisheries worldwide, of which a large number work in small-scale fisheries that are essential for local communities (Teh & Sumaila, 2013). In such areas like the Brazilian semi-arid, both fishery and aquaculture are important in the economy. Fisheries offer a more stable income and offer employment to more people in comparison to aquaculture even though the latter has higher revenues (Lopes et al. , 2018). Likewise, the culture-based fisheries in Laos have been proven to enhance the production and income in the long-run which is vital in terms of financial returns and food security for the communities (Phomsouvanh et al. , 2015).

These industries also have ripple effects in the economy other than just the employment of people. They allow communities to buy food and other basic needs, which in a roundabout way, improves food security and the quality of life. For instance, increased income from fish resources such as fisheries and aquaculture can increase the purchasing capacity of families to afford a range of and healthy foods (Kawarazuka & Béné, 2010). The fisheries and aquaculture are vital in creating employment and income especially in the coastal areas. These industries contribute to economic stability and food security; therefore, the sustainable management of these industries is crucial for their future sustainability and contribution to people’s livelihood. The management of these sectors is based on several principles such as ecosystem approach (Pauly et al. , 2002), zonal approach (Morales et al. , 2016), and the triple bottom line approach (Wurts, 2000).

2.2. Conceptual Framework

The conceptual framework for this study outlines the relationships and dynamics among the various factors influencing food security within the context of the blue economy. This framework is designed to guide the investigation of how fish production, government policy, climate change, and marine biodiversity contribute to food security, considering control variables and the four pillars of food security: availability, accessibility, utilization, and stabilization. The control variables included in this study are trade openness, population, and urbanization rate. These variables are essential for isolating the effects of the blue economy factors on food security. Trade openness influences the flow of food and resources across borders, population size impacts the demand for food, and urbanization rate affects the distribution and accessibility of food within regions.

Figure 2.5 Conceptual Framework



The blue economy factors examined in this study are fish production, government policy, climate change, and marine biodiversity. These factors are critical components of the blue economy, which emphasizes the sustainable use of ocean resources for economic growth, improved livelihoods, and job creation while preserving the health of ocean ecosystems. Fish production plays a significant role in food security as it directly contributes to the availability of protein and other nutrients. This study investigates how variations in fish production impact food security. Government policies related to fisheries management, environmental protection, and economic incentives play a vital role in shaping the blue economy. This study examines the influence of these policies on food security outcomes. Climate change poses a threat to marine ecosystems and fish stocks, affecting their productivity and distribution. This study explores the implications of climate change on food security through its impact on the blue economy. Biodiversity in marine ecosystems supports fish populations and overall ecosystem health. This study assesses how changes in marine biodiversity influence food security.

The four pillars of food security—availability, accessibility, utilization, and stabilization—provide a comprehensive framework for analyzing food security. Each pillar is considered in relation to the blue economy factors. Availability refers to the supply of food through production, distribution, and exchange. This pillar examines how fish production and marine biodiversity contribute to the availability of food. Accessibility involves the ability of individuals to obtain sufficient and nutritious food. This pillar investigates the impact of government policies on food accessibility. Utilization concerns the nutritional quality and safety of food, as well as individuals' ability to metabolize food nutrients. This pillar looks at how climate change and marine biodiversity affect food utilization. Stabilization addresses the stability of food supply over time, considering factors such as economic shocks and environmental changes. This pillar explores the role of government policies and climate change in stabilizing food security.

2.3. Previous Research

This lliterature review examines major studies on the effects of Blue Economy elements on food security with emphasis on fish output, government actions, climate change, and the marine environment. This research seeks to establish the degree to which these elements, described as subcategories of the Blue Economy, affect food security of people.

2.3.1. Fish Production and Food Security

Research has been carried out on the contribution of fisheries and aquaculture to food security and poverty and it has been found out that this sector is important and complex. In a comprehensive review of the dynamic interconnection between fishery, aquaculture, and poverty reduction, Béné et al. (2016) did. Their findings portray that despite the fact that fish is very vital in nutrition and food security the link between fisheries/aquaculture and poverty is still not well understood. They point out the lack of data in the literature and methodological differences between the studies, emphasizing the need for better conceptual models to evaluate the functions of fisheries at the national and household levels. In addition, Béné et al. (2016) stress that the methods used to study the impacts of fish trade are also quite diverse, and the primary drivers such as climate change and decentralization have been studied inadequately.

In the extension of the regional analysis, Elzaki (2023) also examined the relationship between fish production, economic growth and food security in the GCC countries. Elzaki used dynamic fixed effect estimators, cointegration tests, panel unit root tests and the pooled mean group method and found out that fish exports have a positive effect on GDP and fish imports have a positive effect on food security. Therefore, this research confirms that marine fish production plays a significant role in the food security of the GCC countries. However, Elzaki noted that there is a lack of research on other food security indicators and stressed the need for more research to have a comprehensive understanding of the effects of fish production on economic growth and food security especially with regard to panel data.

For instance, in the case of North East India, Singh et al. (2017) focused on fish production in food and nutritional security. Their National Sample Surveys, Gini coefficient, and various forecasting models such as ARIMA, Simple, Holt and Brown indicated a marked increase in fish production in the last one decade. Singh et al. have also highlighted on the huge potential of increasing fish consumption for improving the nutritional status in the region. But the research also shows that there are still gaps in the data gathered, and thus, more emphasis should be placed on the infrastructure, communication, technology, and transportation to enhance the fish production and consumption rates. This underlines the need to work on panel data analysis in order to have strong base for identifying patterns and making proper policy recommendations.

On this basis, Murshed-e-Jahan et al. (2010) looked at the impact of aquaculture on food security in Bangladesh. Based on the analytical framework of income, employment, and consumption and one-way ANOVA and t-tests, the study proved that employment, income, and consumption are positively impacted by aquaculture. Fish has been available and markets have been supplied hence increasing the supply hence the price has dropped hence enhancing food security. But the research discovers that there are some major limitations such as limited availability of quality fish seed, poor market information and weak negotiation power of fish producers. The study suggests that these problems should be addressed by adopting gender issues and decentralized seed production. This requires a panel data analysis that would include other characteristics of food security that could be impacted on by aquaculture.

Menasveta (1997) looked at the sustainable contribution of fisheries to food security in the South East Asia area. This paper is prepared based on the study under the FAO Regional Office for Asia and the Pacific's TSS-1 project and includes the current status and future trend of fish production and policy issues of fisheries. Menasveta's research shows that fisheries have a lot to offer in the food security and economic value in the SEA as the region is known to consume fish in large proportions. But the study reveals that there is a need to improve on the management of the fisheries, implementation of laws, data gathering and facilities for supporting sustainable fisheries. The studies stress the need to address problems like over fishing, pollution and introduction of measures to support the fisheries sector in enhancing food security.

All these various studies on fish production and food security therefore indicate that fisheries and aquaculture are central to the enhancement of food security and economic growth. However, the previous research has done this in a way that has not directly compared fish production and food security. The current literature review can be considered rather limited and does not include a sufficient number of theoretical and methodological papers with statistical analysis. To the author's knowledge, there is no other study that has used panel data analysis to assess the contribution of fish production to food security on a global context. This gap therefore requires more extensive and statistically sound studies that would assist in developing the trends of fish production within the context of the blue economy and its role in food security.

2.3.2. Government Policy and Food Security

The review of government policy issues concerning agriculture, fisheries and forestry on food security entails a broad research area that encompasses agricultural expenditure, budgetary policies, fisheries subsidies, EU policies, structural change and government expenditure and their relation to food security. Agricultural expenditure and food security in Sub-Saharan Africa: A Feasible Generalized Least Square (FGLS) and Panel Corrected Standard Errors (PCSE) analysis by Atabukum et al. (2021). According to their findings, public agricultural expenditure reduces food availability and utilization but domestic private agricultural expenditure and human capital enhance the food security. This study therefore stresses the importance of resource management and utilization since it has been established that aid does not enhance food availability but utilization. However, the research does not consider the country level heterogeneity and is more focused on the macro level factors and does not investigate the micro level processes.

In line with the budget distribution concept, Tonoa et al. (2022) analyze the budget policy for the food security development in East Nusa Tenggara Province. The content analysis and descriptive statistics used in their analysis show that the regions are highly financially dependent and have low levels of local financial autonomy, and inadequate and unlawful budgeting for food security. While the study is helpful in establishing the regional financial capacities, it does not include the efficiency or even the effectiveness of the financial allocations and does not take into account micro-level factors that affect food security. This focus on financial strategies is important as it lays the groundwork for understanding how the management of resources influences food security at the different levels of administration.

Transitioning from the budget policies to the sectoral policies, He (2022) analyses the Chinese public policy on the fisheries subsidies focusing on the trade, environmental and food security. According to the descriptive analysis and policy analysis of this study, it is found that China's fisheries subsidies have evolved from capacity expansion to ecological protection and quality improvement. This policy change seeks to solve the problems of trade and conservation of the environment and at the same time feed the nation. However, lack of quantitative data on the impact of subsidies for food security and lack of case and study based general policy analysis reduces the impact of the findings. This transition also proves that there is a difficulty in attaining economic, environmental, and social goals within policy settings.

Switching to the effects of the EU policies at the international level, Bureau and Swinnen (2022) look at the impact of the EU policies on the global food security. The policy review and descriptive analysis reveal that EU policies have various impacts on the bioenergy chain and food standards; however, agricultural and trade policies have contributed to reducing the negative impacts of bioenergy policies and food standards. The lack of case studies and the scarcity of quantitative data on all policy aspects in the study are the main weaknesses that hinder the comprehension of the EU policy impacts on food security. This broader analysis emphasizes the need to look at the international policy interactions and their interactions and effects on the global food security.

Continuing with the examination of the government interventions, Ebenezer et al. (2022) examine the impact of government expenditure on the agricultural productivity in South Africa using the Auto-Regressive Distributed Lag (ARDL) model. They obtain a long-run increase in agricultural productivity due to government expenditure but the current expenditure does not suffice to create the short-run impact. This research shows that the government has a small budget for the agriculture sector, poor management of resources, and low priority as the main issues. This paper aims to focus on how the governmental financial obligations can affect the sectoral productivity and therefore food security.

Moreover, Ngobeni and Muchopa (2022) also examine the relationship between government expenditure and the value of agricultural production in South Africa with the help of the following variables: government expenditure, average annual rainfall, consumer price index, food import value and population. The long-run relationship of the variables is established via the use of the VAR model, Johansen cointegration test, and Granger causality test; the results show that government expenditure, rainfall, and population have a positive effect on agricultural production, while the CPI and FIV have a negative impact. The study also suggests that for the government to enhance on the productivity of agriculture and food security there is need to increase on the spending on agriculture and ensure proper utilization of the available resources. This paper gives a general outlook of the factors that influence the productivity of agriculture, therefore, stressing the need for a multi-faceted approach to policy formulation.

The literature review reveals that food security is a multifaceted phenomenon and depends on the parameters like agricultural expenditure, budgetary measures, subsidies to fisheries, and government expenditure. However, there are still some voids that can be distinguished, particularly referring to the empirical research on the impact of specific policies and micro-level factors. In addition, the previous quantitative researches on the government policies have mainly focused on the relationship between the budgetary expenditure for agriculture and food production without exploring their impact on food security which is a theoretical construct encompassing various dimensions and is usually limited to the analysis at the regional level. This study aims at filling these gaps through employing a panel data analysis to assess the impacts of the government policy on agriculture, fisheries and forestry on food security and a more elaborate analysis on how sustainable management of ocean resources can enhance food security.

2.3.3. Climate Change and Food Security

Numerous papers have examined the impacts of climate change on food security in the different areas of the world using different models and approaches. East African Community (EAC) region and climate change and food security research was conducted by Walaa Mahrous in 2022. In the same manner, by employing the pooled fixed effects model the study found that temperature has a negative impact on food security and on the other hand, precipitation and increase in area under cereal production has a positive impact on food security. However, the study was limited to a particular region and the researcher was equally limited in developing an appropriate food security index due to the data gathered. This research therefore tries to make a start in showing how specific climatic factors influence food security in the EAC region and as such lays a foundation for future research.

Expanding the spatial dimension, Allah Ditta et al. (2021) investigated the climate change, energy consumption, and urbanization impacts on food security in the chosen developing countries. In this study, the panel ARDL approach was employed to reveal that climatic changes improve food security in the long-run due to extended growing periods. Whereas, energy consumption and rate of urbanization were also affirmed to have negative impacts. The limitation of the study was that the authors only focused on a few developing countries in South Asia, and other factors that affect the food security other than climate change were not taken into account. Following Mahrous's work, this paper incorporates other variables such as energy consumption and urbanization that are correlated with climatic factors influencing food security.

From these works, Giulio Fusco (2022) examined the impact of climate change on the food security status of Northern and Eastern African regions in relation to average protein and average dietary energy supply adequacy. The study employed the fixed effects (FE) and random effects (RE) panel data analysis and realized that climate change has a negative effect on food security in the mentioned regions. That is, the rainfall is beneficial to food security while the temperature is detrimental. The study was limited to the availability of data for the year 2000-2012 and excluded all the factors that affected food security. Fusco's work extends regional effects by pinpointing rainfall and temperature in several African contexts, thereby contributing to the literature on climatic influences on food security.

Jintian Wang (2010) provided a quantitative evaluation of the factors that would impact food security in China through variables such as per capita disposable income, food retail price index, agricultural disaster area, sown area and residents' savings. The paper used SYS-GMM as the dynamic panel data analysis method and found that climate change is positively and significantly affecting food security in the current year, but food prices do not have a similar impact in the short run. The research also highlighted on the fact that the agricultural disaster areas should be targeted to improve on food security. Nevertheless, it only involved 27 provinces in China and did not include sub-provincial divisions and other factors that influence food security. Wang's study adds an economic component to the climatic impacts on food security in a way that presents a complete picture of the issues that are likely to emerge as the world seeks to attain food security.

Based on the above synthesis of the climate variables and food security, Raïfatou Affoh et al. (2022) further expanded the analysis by considering rainfall, temperature, and CO2 emission and food security, availability, accessibility, and utilization in SSA. The paper used PMG, panel ARDL, FMOLS, and DOLS approaches and found that rainfall has a positive effect on all the three dimensions of food security. Temperature, on the other hand, has a negative impact on food access and utilization while CO2 emissions have a positive impact on food access and utilization but not on the food utilization. The food stability indicator was not used because data was unavailable for some of the countries, and this study focused mainly on cereal crops on 25 SSA countries. The study by Affoh et al. is a comprehensive work that looks at the various facets of food security; thus, the authors' conclusions provide a more nuanced view of how climate factors affect different aspects of food security.

In total, the above-stated works paint the picture that climate change is highly sensitive to food security and therefore, there is a need to come up with strategies depending on the region to minimize the effects and enhance the outcome on food security. The approaches and conclusions of these studies provide a general view of the complex relationship between climate characteristics and food security in different areas, and therefore provide valuable insights to the discussion of sustainable development and climate change adaptation. However, previous quantitative research on the impact of climate change on food security has shown some gaps especially on the impact of climate change on fish production. Most of the studies have focused on impact of climate change on crop production while the same climate change impacts fish production in one or the other due to similar climatic conditions. Moreover, the previous studies have been conducted with regard to the regional contexts with specific characteristics, primarily in the African countries. However, there is a plethora of quantitative data available, however, there is a severe lack of guidance in the researches conducted on the economic aspect of the marine and aquatic life. This study aims at filling these gaps by providing a more extensive and elaborate analysis of the blue economy and its relation to food security in the context of climate change.

2.3.4. Marine Biodiversity and Food Security

Marine diversity encompasses the full range of species found in marine and coastal ecosystems, including fish, crustaceans, mollusks, and marine plants. This biodiversity plays a vital role in maintaining ecosystem services essential for human survival, such as providing food, water, and climate regulation. Examples of marine biodiversity include coral reefs and their associated fish species, mangroves, seagrass beds where many fish species breed, and the pelagic zone, which serves as feeding grounds for large migratory species like tuna and whales.

MPAs have been an area of interest in blue economy especially in the context of food security. Gill et al. (2017) offered a comprehensive assessment of the literature to demonstrate that most of the MPAs have no positive social and ecological impacts even as the global coverage is increasing. Here, they used cross-sectional random forest and linear mixed-effects models to find out that staff and budget capacities are positive predictors of MPA effectiveness. However, they did not have a global sample and counterfactors to estimate what the state of conservation would be if there were no MPAs. In this paper, the foundation for the assessment of specific designs of MPAs that would improve food security is established.

On this basis, Cabral et al. (2019) analyzed the design of MPAs for food security on open access fish stocks. Their study which was based on a bioeconomic model incorporated biological and economic parameters such as growth rate of fish stock, fish movement, fish price, and fishing cost. They concluded that the optimal size of MPAs depends on economic variables: Large MPAs produce the highest catch of valuable, inexpensive species, while small MPAs or no closures produce the highest catch of inexpensive, valuable species. Species with high and low mobility are conserved and migration may not always be density dependent and open access. This study provides a better understanding of how MPAs can be adopted with a view of the economic environment.

Likewise, Aswani and Furusawa (2007) tried to determine the association between MPAs and human nutrition and health by conducting a cross-sectional survey on villages in Roviana, Solomon Islands. The cross-sectional data collection instruments used by them were questionnaires, food diaries, and body size measurements. The study revealed that the consumption of energy and protein was positively associated with effective MPAs, therefore, no-take reserves pose no threat to food security. However, the absence of longitudinal data and the possible influence of other confounding socioeconomic variables are the study's limitations, which highlight the need for improved biological monitoring. This work also seeks to appeal for the inclusion of human health in MPA research.

Expanding on the socioeconomic impacts, Mascia et al. (2010) deliberated on the impacts of MPAs on fishing communities and on human welfare, food security, rights to resources, employment, community structure, and income. They found out that the food security did not deteriorate or even improved in the older and smaller MPAs and the resource rights improved with MPA zoning and compliance. Some of the limitations of the study include small sample sizes and absence of statistical tests on some of the indicators, therefore, the need to document social impacts better. As it is evident from the analysis of this paper, there are other social values of MPAs other than ecological and nutritional.

Based on the reviewed literature, it is evident that there is a complex relationship between the factors of the Blue Economy and food security. The effectiveness of Marine Protected Areas (MPAs) in enhancing food security and preserving biological diversity largely depends on management practices, economic conditions, and community involvement. Marine biodiversity, which can be assessed through the extent of MPAs and the variety of food sources, plays a critical role in improving food security (Gill et al., 2017). Future research should address several gaps, including the lack of long-term data, insufficient focus on the influence of socioeconomic factors, and the inadequacies in enforcement measures concerning the Blue Economy's impact on food security. Additionally, there is a need for global research on the challenges facing marine biodiversity, particularly concerning the economic dimensions of marine and aquatic ecosystems. More studies are required to assess the contribution of marine diversity to global food security.

CHAPTER III : RESEARCH METHODOLOGY

3.1. Research Design

The study employs a quantitative research method to assess the effects of Blue Economy factors on food security across various countries using secondary data. This research gathers panel data consisting of annual variables related to the Blue Economy, including fisheries production, government policies on fisheries, marine biodiversity conservation measures, and the impacts of climate change. It also examines various food security measures, including food availability, access, utilization, and stability.

3.2. Data Collection

This research focuses on twelve countries—China, Japan, New Zealand, Australia, South Korea, Malaysia, Indonesia, Thailand, Cambodia, Sri Lanka, Bangladesh, and Pakistan—from 2015 to 2021. These countries were selected from the 23 Asia-Pacific nations based on their representation as a sample. The Asia-Pacific region's geographical and economic diversity makes it ideal for assessing Blue Economy factors' impact on food security. This region is a major producer of fisheries and aquaculture products, contributing 70% of global production, with China, Indonesia, India, and Vietnam as leading producers.

The methodology involves secondary data analysis, collecting quantitative data from reputable international databases and reports on Blue Economy and food security indices. Food security indicators are sourced from the Economist Intelligence Unit, fish production data from FAO Statistics, government policies, and climate change data from the World Bank Climate Change Knowledge Portal, and population, trade openness, and urbanization rates from the World Bank Development Indicators. These data sources ensure high-quality and reliable data for the analysis.

3.3. Operational Definitions of Variables

This study incorporates several variables, including the dependent variable (Y) and independent variables (X). The independent variables are further divided into main variables and control variables. The operational definitions of these variables are outlined in the following table:

Table 3.1 Variables of Research

No	Variable	Type	Indicator	Unit	Time Period	Source
1	Food Security (Y)	Dependent	Global Food Security Index	Score 1-100	2015 – 2021	The Economist Intelligence Unit (https://impact.economist.com)
2	Fishes Production (X_1)	Independent	Total annual marine capture and aquaculture	Metric tons	2015 – 2021	FAO Statistics (https://www.fao.org/faostat/en/#data)
3	Government Policy (X_2)	Independent	The ratio of the share of government spending on agriculture, forestry, and fishing to the share of agriculture in the country's GDP	Ratio	2015 – 2021	FAO Statistics (https://www.fao.org/faostat/en/#data)
4	Climate Change (X_3)	Independent	The ratio of annual precipitation to the optimal precipitation level for food production, which is 500 mm	Ratio	2015 – 2021	World Bank Development Indicators (https://databank.worldbank.org)
5	Marine Biodiversity (X_4)	Independent	Marine protected areas of territorial waters	%	2015 – 2021	World Bank Development Indicators (https://databank.worldbank.org)
6	Population (X_5)	Control	Population Growth	%	2015 – 2021	World Bank Development Indicators (https://databank.worldbank.org)
7	Trade openness (X_6)	Control	The sum of exports and imports of goods and services measured as a share of gross domestic product	%	2015 – 2021	World Bank Development Indicators (https://databank.worldbank.org)

8	Urbanization (X_7)	Control	Percentage of Population Living in Urban Areas	%	2015 – 2021	World Bank Development Indicators (https://databank.worldbank.org)

Table 3.1 presents the variables employed in the study, their types, indicators, units, time periods, and data used in the study. It consists of dependent and independent variables, which are food security, fish production, government policy, climate change, and marine biodiversity, control variables, population growth, trade openness, and the urbanization rate. Information for these variables is obtained from credible institutions such as The Economist Intelligence Unit, FAO Statistics, and World Bank Development Indicators for the year 2015-2021.

Food security, the dependent variable is the Global Food Security Index (GFSI) from The Economist Intelligence Unit which considers affordability, access, quality, and regulatory standards of food. Fish production is the independent variable which is the total weight of fish produced per year, an important input in the food basket as other studies have pointed out the nutritional and economic value of fish. Government policy is measured by the Agricultural Orientation Index (AOI), which is a ratio of government expenditure on agriculture to GDP, which shows the influence of policy on performance of agriculture. Climate change is measured in terms of the actual annual precipitation divided by the ideal amount of precipitation for food production affecting both crop and fish farming. Marine diversity is expressed in terms of the %age of MPA in the territorial waters of a country is crucial for the protection of marine life forms. Other control variables are population growth rate, trade openness which is total exports and imports as a percentage of GDP and the urbanization rate which is the proportion of people living in urban areas. The study uses secondary data and only sources that are credible and reliable hence providing a rich and comprehensive analysis on the selected countries.

These variables are important for the panel data analysis as they cover the aspects like food security, fish production, government policy and climate change, marine ecosystem, population, trade openness and urbanization for the period of 2015 to 2021 across the countries. Compared to cross-sectional data, panel data takes into account variations between sections and over time and therefore, the results generalize the relationships between these factors. Panel data is cross sectional and time series data; it increases variation and efficiency hence improves the statistical estimates. It enables the application of country fixed effects to control for other individual characteristics that may be other influential variables (Wooldridge, 2002). Also, the time dimension in panel data is important in determining the effects of policies and changes in the environment on food security. It also helps to avoid multicollinearity between the explanatory variables hence improving on the reliability of the estimates.

3.4. Panel Data Analysis

3.4.1. Types of Panel Data Models

Panel data models are used to analyze data that involves multiple entities observed across multiple time periods. The main types of panel data models include the Common Effects Model, Fixed Effects Model, and Random Effects Model. The choice of model depends on the nature of the data and the assumptions about the individual-specific effects.

3.4.1.1. Fixed Effects Models

Fixed effects models are important in analysing panel data because they control for the effect of other variables that are not included in the model. As per Gujarati (1999), these models are capable of capturing entity-specific fixed effects due to the constants incorporated in the models. This approach uses the idea that there can be fixed individual effects that do not vary with time and can affect the dependent variable and are associated with the regressors. Fixed effects models are especially helpful when the researcher is interested in the impact of the variables that may differ within the entity, for instance, a country, while controlling for the variables that do not change. Wooldridge (2002) observes that these models are applied when characteristics unique to the individual with regard to the explanatory variables are not captured in the model. This method can also be used to control for bias from time-invariant characteristics thus making them disappear.

Mathematical formulation of the fixed effects model is represented as

$$Y_{it} = \alpha_i + \beta X_{it} + \epsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

where:

- Y_{it} is the dependent variable for individual i at time t
- α_i represents the individual-specific intercept
- β is the vector of coefficients for the explanatory variables
- ϵ_{it} is the error term

In this formulation, α_i captures all the time-invariant characteristics of the individuals, thus controlling for unobserved heterogeneity.

3.4.1.2. Random Effects Models

Random effects models assume that individual-specific effects are independent of the independent variables. According to Gujarati (1999), these models treat individual-specific effects as random variables from a larger population, allowing the inclusion of time-invariant variables among the regressors, unlike fixed effects models. Random effects models are suitable when individual-specific effects are expected to be random and independent of other variables. Wooldridge (2002) suggests using random effects models when the sample includes a large number of individuals selected from a population, with the aim of generalizing the results to the population level. These models are also appropriate when between-individual variation is large compared to within-individual variation.

Mathematical formulation of the random effects model is represented as:

$$Y_{it} = \alpha_i + \beta X_{it} + u_i + \epsilon_{it} \quad (3.2)$$

where:

- Y_{it} is the dependent variable for individual i at time t
- α is the overall intercept
- β is the vector of coefficients for the explanatory variables X_{it}
- u_i is the random individual-specific effect
- ϵ_{it} is the error term

In this model, u_i is assumed to be uncorrelated with X_{it} and ϵ_{it}.

The choice between fixed and random effects models depends on the relationship between individual-specific effects and covariates. The Hausman test determines which model to use. If the test indicates differences, the fixed effects model is preferred for consistent estimates. If the random effects estimator is consistent, it is used for its efficiency and ability to include time-constant variables. Fixed effects models control for individual characteristics related to explanatory variables, while random effects models are suitable when these characteristics are unrelated and the goal is to generalize the results.

3.4.2. Estimation Techniques

OLS is a simple estimation method that can be applied in econometric analysis of panel data and other techniques, to estimate models that minimize the squared residual of the dependent variable. It is popular because it does not involve any complex computations and it is ease to compute. However, OLS is biased and inconsistent in case of the existence of unobserved heterogeneity or when the errors are serially correlated. In such cases, higher levels of thinking is required. GLS is an extension of OLS that can accommodate heteroscedasticity and autocorrelation in the error terms, and hence is more efficient and less biased. GLS is particularly useful in panel data when the random effects models are used because it enhances the efficiency of the models in the event of non-spherical disturbances. In cases where the form of heteroscedasticity or autocorrelation is unknown, the Feasible GLS (FGLS) is applied whereby the parameters are estimated in a iterative manner with a view of making them more accurate.

3.5. Analysis Techniques

3.5.1. Econometric Models

Based on the data examining the impact of Blue Economy factors on Food Security, this study models Food Security as the dependent variable with various independent and control variables. For panel data analysis, either a Fixed Effects or Random Effects model is used, depending on the data specifics and assumptions about unobserved heterogeneity. Given the data characteristics, the Fixed Effects model is likely appropriate. A basic representation of a Fixed Effects model is as follows:

$$Y_{it} = \alpha_i + \beta \log(X_{1it}) + \beta X_{2it} + \beta X_{3it} + \beta X_{4it} + \beta X_{5it} + \beta X_{6it} + \beta X_{7it} + \epsilon_{it} \ldots (3.3)$$

where:

- Y_{it} : Food Security for country i at time t
- $\log(X_{1it})$: Log of Fish Production for country i at time t
- X_{2it} : Government Policy for country i at time t
- X_{3it} : Climate Change for country i at time t
- X_{4it} : Marine Biodiversity for country i at time t
- X_{5it} : Population for country i at time t
- X_{6it} : Trade Openness for country i at time t
- X_{7it} : Urbanization for country i at time t

- ϵ_{it} : Error term

In this model, α_i represents the country-specific intercept, β_1, β_2, β_3, β_4, β_5, β_6, β_7 are the coefficients of the respective independent variables, and ϵit is the error term. This specification accounts for individual country differences by allowing for unique intercepts for each country, thereby controlling for unobserved heterogeneity.

3.5.2. Model Specification and Diagnostic Tests

3.5.2.1. Hausman Test

The Hausman test is a fundamental test in panel data analysis to decide between fixed or random effects models. It checks if the unique errors, or individual-specific effects, are related to the regressors. As noted by Gujarati (1999), the Hausman test assesses the consistency of the random effects estimator. For the test to be performed, both fixed and random effects models must be identifiable on the same sample. A significant test statistic indicates that random effects are related to the independent variables, thus supporting the use of the fixed effects model.

The hypotheses for the Hausman test in condition are:

- Null Hypothesis (H_0): The random effects model is preferred
- Alternative Hypothesis (H_1): The fixed effects model is preferred

3.5.2.2. Lagrange Multiplier Test

The LM test, or Breusch-Pagan test, assesses the null hypothesis of random effects in a panel data model. According to Gujarati (1999), it determines if the variance of the individual-specific error term is different from zero. This test is particularly useful when starting with a pooled OLS model to decide if a random effects model is more appropriate. A high LM test statistic suggests that the random effects model is superior to the pooled OLS model.

The hypotheses for the Lagrange Multiplier (LM) test in condition are:

- Null Hypothesis (H_0): The variance of the individual-specific error component is zero (no random effects)
- Alternative Hypothesis (H_1): The variance of the individual-specific error component is greater than zero (presence of random effects)

3.5.2.3. Chow Test for Model Selection

The Chow test is used to check for structural shifts or to compare the goodness of fit of two models. Chow test can be applied in the panel data to test whether the regression should be performed separately on different sub-samples, for instance, different time periods or groups. As pointed out by Gujarati (1999), the test entails the computation of the sum of squared residuals of the restricted model which is the combined sample with those of the unrestricted model which is the two samples. A high Chow test statistic means that there is a structural break, which means that it is appropriate to use different models for different sub-samples..

The hypotheses for the Chow test in equation form are:

- Null Hypothesis (H_0): There is no structural break, and a single combined model with fixed effects is suitable
- Alternative Hypothesis (H_1): There is a structural break, so separate models for different sub-samples with fixed effects are needed

3.5.3. Diagnostic Tests

3.5.3.1. Normality Test

The normality tests are used in order to check if the residuals of the regression model are normally distributed. This assumption is essential in the use of many statistical tests and construction of confidence intervals. Gujarati (1999) identifies several normality tests such as the Jarque-Bera test that is based on the skewness and kurtosis of the residuals. The normality of the residuals can be checked to see if there are problems with the model specification or outliers.

3.5.3.2. Heteroskedasticity Test

Heteroskedasticity is a situation where the variance of the error terms is not equal across the observations and this leads to inefficient estimate and invalid standard errors. As stated by Gujarati (1999), it is necessary to check the heteroskedasticity by using the test known as Glejser test. These tests entail performing a regression of the squared residuals on the explanatory variables and comparing the results. The problem of heteroskedasticity indicates that the model should be modified, for instance, by applying robust standard errors or transforming the variables. The Heteroskedasticity Test seeks to identify whether there is a variation inequality of the residuals from one observation to another in the regression model. The Glejser test is one of the most used tests to check for heteroskedasticity. This test entails performing a regression of the absolute values of the residuals on the independent variables by applying the regression equation :

$$|\boldsymbol{U_t}| = \boldsymbol{\alpha} + \boldsymbol{\beta X_t} + \boldsymbol{u_t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\boldsymbol{3.4})$$

In this equation, $|U_t|$ represents the absolute value of the residuals, α is the intercept, β is the coefficient of the independent variable X_t and u_t is the error term. The significance level used for this test is typically $\alpha = 0{,}05$, which is commonly adopted in research. If the coefficients of the independent variables in this regression are statistically significant, it indicates the presence of heteroskedasticity in the model.

Consequently, adjustments may be required, such as using robust standard errors to correct for heteroskedasticity.

3.5.3.3. Autocorrelation Test

Autocorrelation or serial correlation is a type of correlation that exists between the error terms in different time intervals. This can result in the biased standard errors and inefficient estimates in the case of panel data. Durbin-Watson test is one of the widely used methods to check the autocorrelation in time series data. However, for panel data, Gujarati (1999) suggests tests such as the Gujarati test for autocorrelation in panel data which is based on the residuals from the first-differenced regression. Autocorrelation is a common problem that must be addressed in order to make proper inferences from the model. The autocorrelation test is used to test whether there is a correlation between the error terms in period ttt and the error terms in period $t - 1$ of a linear regression model. If such a correlation is present then it means that an autocorrelation is present in the system. Autocorrelation occurs due to the fact that the observations made over time are dependent. In this study, Durbin Watson (DW) test will be employed to check for autocorrelation. The Durbin-Watson test checks for autocorrelation by looking at the residuals of the regression model.

Durbin-Watson statistic varies between 0 and 4; a value of 2 suggests no autocorrelation, values close to 0 suggest positive autocorrelation, and values close to 4 suggest negative autocorrelation. More specifically, if the DW statistic is equal to approximately 2, then there is no autocorrelation. If the DW statistic is less than 2, it means that there is positive autocorrelation while if it is greater than 2, it means that there is negative autocorrelation. To draw the conclusions it is necessary to compare the results at a significance level of 0. 05 the DW statistic is then compared to the critical values from the Durbin-Watson table. If the DW statistic is less than the lower critical value (dL), then it can be concluded that positive autocorrelation exists. If the DW statistic is less than the lower critical value (dL), then the data exhibits positive autocorrelation while if DW > dU, then there is no evidence of positive autocorrelation. If the DW statistic is between dL and dU then the test is said to be indeterminate. If the DW statistic is significantly different from 2, then the results imply the existence of autocorrelation, thus, the use of robust standard errors may be required.

3.5.3.4. Multicollinearity Test

This is a situation where two or more independent variables in the model are correlated and this results in large standard errors and imprecise coefficients. According to Gujarati (1999), multicollinearity can be established using either the VIF or the condition index. High VIF values are generally above 10 that show the presence of serious multicollinearity. To deal with multicollinearity, one may eliminate one of the correlated variables, aggregate them into a single index, or use the principal component analysis (PCA) to decrease the dimensionality.

In conclusion, proper model specification and diagnostic testing are critical in the analysis of panel data. The choice of the right model is facilitated by methods like the Hausman test, the Lagrange Multiplier test, and the Chow test, while checking for normality, heteroskedasticity, autocorrelation, and multicollinearity of the model guarantees the accuracy of the estimated model.

CHAPTER IV : RESULTS AND DISCUSSIONS

In this chapter, the findings and discussions of the study are presented. The current developments of the blue economy are highlighted, emphasizing policy advancements, fisheries production and marine protected areas. Statistical results are analyzed to provide a quantitative understanding of these developments. The discussion integrates these findings, exploring their implications and how they contribute to the broader context of the blue economy.

4.1. Current Development of Blue Economy in Global Context

4.1.1. History of Policy Advancements

The history of the ocean governance and the development of the Blue Economy began in the mid of the twentieth century when the international society began to understand the need for collective management of the oceans. Prior to this period, ocean governance was based on freedom of the seas principle which allowed nations unfettered right to go to the seas and exploit the sea and the sea resources. But as the use of marine resources intensified and the impact of such use on the marine environment observed, there was a call for international collaboration and control. The single most important development in ocean governance was the adoption of the United Nations Convention on the Law of the Sea in 1982 although the process of its negotiation started in the 1950s. UNCLOS established the legal framework for the oceans of the world defining rights and responsibilities of states in the use and protection of the seas and their resources. The convention also made some of the important ideas such as the EEZ which provides a country with 200 nautical miles exclusive rights over the resources in the sea and the common heritage of mankind which applies to the deep sea bed. As the legal basis for the management and conservation of the marine resources, the UNCLOS was the milestone in the ocean governance and created the environment for the following policies and the establishment of RFMOs for the marine conservation.

The public consciousness regarding the environment and the state of the marine environment in particular and the over exploitation of the marine resources was on the rise in the 1980s and 1990s. At the same time, the idea of integrated ocean management was introduced, which is the complex of actions that make it possible to address the diverse and interconnected challenges of the ocean space with the help of a single list of measures. The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 also raised international concern on environmental and also that of the oceans. Another success of the Earth Summit was signing of the Agenda 21 which is an action plan for sustainable development. Chapter 17 of the Agenda 21 was on the protection of the oceans, seas and coastal areas and was focused on the sustainable use of the marine and coastal resources through the implementation of the integrated management strategies. Another significant event in this period was the United Nations Fish Stocks Agreement of 1995 which was signed in order to provide for the long term conservation and management of the straddling fish stocks and highly migratory fish stocks. UNFSA established measures for the protection and sustainable utilization of these fish stocks for example the precautionary principle and science based management. In the early 1990s, most of the countries started developing national ocean policies that embraced integrated ocean management, sustainable development and in most cases ecosystem based management.

The shift to linking ocean governance with sustainable development in general was at the start of the 21st century. During this period the concept of 'blue economy' was developed which was based on the economic utilization of the sea but at the same time emphasized on the rational use of the sea resources. The WSSD held in Johannesburg in 2002, followed up the commitments made in the Earth Summit and called for establishment of MPAs and adoption of the ecosystem approach to management of fisheries. The summit also underlined the importance of the international cooperation in addressing the international challenges among which those concerning the oceans. The Blue Economy was further advanced during the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012 where it was stated that oceans are the key to sustainable development. In the outcome document of the conference known as "The Future We Want," the importance of the protection and management of the oceans was recognized and the call for the development of sustainable Blue Economy strategies was called for. The integration of the United Nations Sustainable Development Goals (UN-SDGs) in year 2015 was a significant move towards the integration of ocean governance into the development agenda. The 14th SDG is 'Life Below Water' which is aimed at the conservation and sustainable use of the oceans, seas and marine resources for sustainable development, goals of which include reducing marine pollution and protecting and restoring marine and coastal ecosystems, and ensuring sustainable fishing and increasing the benefits to be derived from the sustainable use of ocean resources.

Given the increasing importance of the Blue Economy, most countries and regions have developed policies for the development of the blue economy as well as the conservation of the marine environment. The EU's Blue Growth Strategy adopted in 2012 is a comprehensive policy framework that identifies the strategic sectors for growth in the marine and maritime economy including offshore renewable energy, aquaculture, and marine biotechnology with the emphasis on the sustainable use of the marine resources. The countries like Canada, Australia, Indonesia, and Norway have developed marine plans at the national level that aim at the sustainable use of the marine resources, climate change, and the conservation of the marine ecosystem. These plans may also contain components of the ecosystem-based management, the integrated ocean management, and the stakeholder participation, which is evidence of the change in the management of the oceans and the growing recognition of the Blue Economy as the source of sustainable development.

4.1.2. Global Fisheries Production

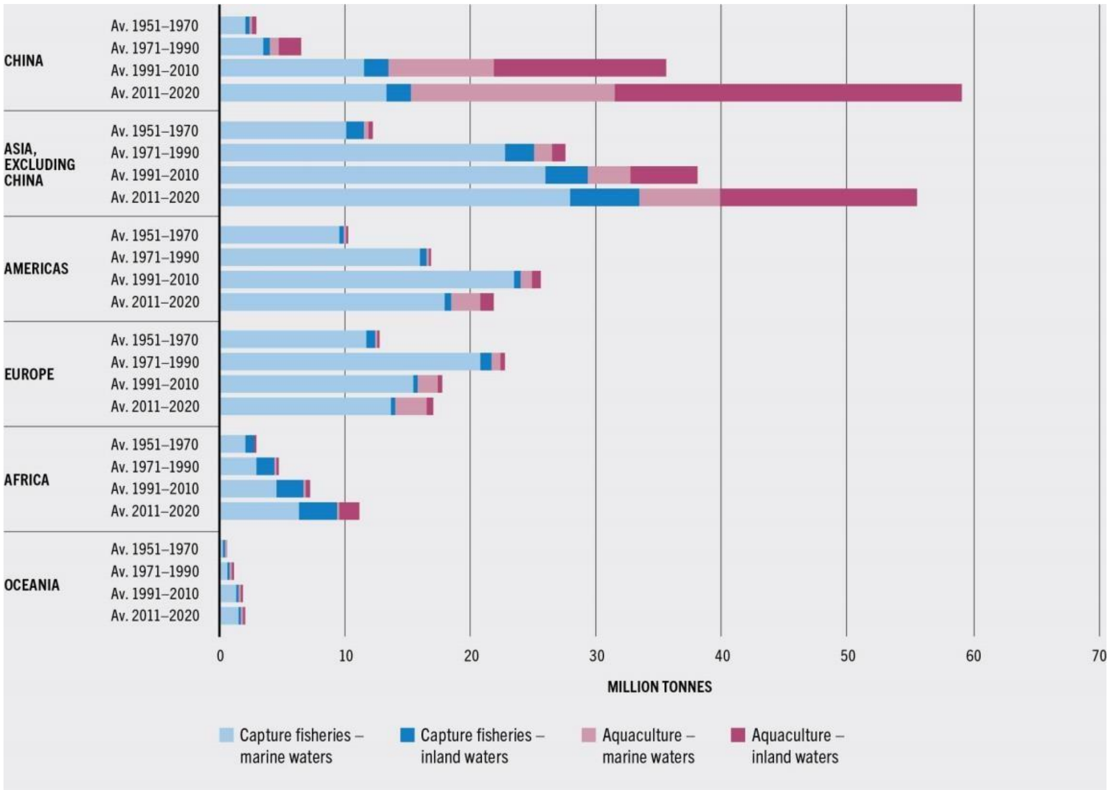
The current development of world fisheries and aquaculture is a combination of a number of factors that are both positive and negative. The world production of fish has remained high especially due to the growth in aquaculture that currently supplies about 48% of the world's fish. This growth has been occasioned by increased technology, better management practices and growing consumption of seafood. The aquaculture sector has also witnessed attempts to increase sustainability, including the minimization of environmental effects, better feed conversion rates, and better farming practices. These developments are important for food security, economic development and environmental conservation but also point to the need for further innovation and good governance of fisheries and aquaculture to optimize on the opportunities and minimize on the risks. FAO has provided forecasts of fisheries production up to 2030, which contains useful forecasts that can be used for planning and decision making for the sustainable development of the sector in the future years.

The world's fisheries and aquaculture production for the last seven decades has shown a gradual increase and recent oscillations. It has risen from a production level of 19 million tonnes in 1950 to 179 million tonnes in 2018, with an annual growth rate of 3%. But the sector declined in the following years mainly because of the decline in capture fisheries and the effects of external conditions including COVID-19. Nonetheless, aquaculture has persisted to grow and is now a significant source of the total fisheries yield, contributing to almost half of the overall production. This shift reveals the new trends within the industry and stresses the importance of aquaculture for future development when the environmental and economic conditions change.

The global fisheries and aquaculture sector has large differences in the production and economic contribution across the continents, regions, and countries. In 2020, Asia was the largest producer with 70% of the total world production, the Americas with 12%, Europe with

10%, Africa with 7%, and Oceania with 1%. All continents have experienced the augmentation of production during the last decades but Europe and Americas are characterized by fluctuations connected with variations in the catches of anchoveta and other factors. Africa and Asia for instance have nearly doubled their production over the last twenty years. Nevertheless, the COVID-19 outbreak affected the production of cars in Africa and Oceania and reduced it in 2020. China continued to dominate the production and supplied 35% of the total world production followed by India, Indonesia, Viet Nam, and Peru. The economic importance of the sector has gradually extended to the LMICs, which currently contribute 87% of the global production with UMICs such as China in the forefront. These differences indicate that the international fisheries and aquaculture are not static and are changing due to regional factors and development.

Figure 4.1 World Capture Fisheries and Aquaculture Production



Source : Food and Agricultural Organization (2022)

Over the last 70 years, Asia particularly China has become the world's largest producer mainly because of a growth in aquaculture in sea and fresh water bodies. This tremendous increase in Asia is quite different from what has been seen in other regions such as Europe and Americas where the capture fisheries in the marine waters have been more conventional but the aquaculture has not demonstrated such a rapid increase. Africa and Oceania, which produce less than other regions, have also increased at a somewhat higher rate. The variations in production from these regions could be attributed to a number of factors such as; level of development, fishery and aquaculture polices, climate and availability of species. Among the most significant trends of the present day world aquaculture it is possible to point to the fact that Asia is the leading continent in this sphere. In the year 2020, Asia contributed to the production of aquatic animals from inland waters in the production of aquaculture fish accounting for nearly a third of the global production. This was followed by the Pacific Northwest with 22% and the Western Central Pacific with 10%. This is a departure from the 1950s when more than 40% of the oil demand was supplied from the Atlantic Basin. Regarding the Pacific Ocean, it has been the leading production area since 2020, with the share of 40%, while the Atlantic Ocean's share is only 13%. The economic development of the region has also boosted the growth of aquaculture because the demand for fish products rises within the region and in the export markets..

These regional differences in production are influenced by a range of factors, including the level of development in the surrounding countries, the implementation of fisheries and aquaculture management practices, the prevalence of illegal, unreported, and unregulated (IUU) fishing, the status of fishery stocks, and the quality and availability of inland waters. For example, regions that rely heavily on capture fisheries, especially those targeting small pelagic fish like anchoveta in the Pacific Southeast of South America, often experience greater fluctuations in production due to climatic variability and other environmental factors. The diversity of species harvested also varies significantly by region. In 2020, finfish dominated the total production of aquatic animals, comprising 76 % of the global output. Marine fishes made up 51 % of the total finfish production and 39 % of the total aquatic animal production. Freshwater fishes, which are central to the aquaculture sector in many Asian countries, represented 43 % of total finfish production and 33 % of the total aquatic animal output. This study of current development of global fisheries production underscores the complexity and regional specificity of global fisheries and aquaculture production, driven by both natural factors and human interventions. Although production continues to increase, it is accompanied by significant variability in growth rates across different regions, with some areas experiencing rapid expansion due to advancements in aquaculture and economic development, while others face challenges related to environmental sustainability, fluctuating fish stocks, and the impacts of illegal, unreported, and unregulated fishing.

The significant expansion in global fish production from 101.3 million tonnes in the 1990s to 185.4 million tonnes in 2022 highlights the increased economic activity within the blue economy. This growth has been driven primarily by the rapid development of aquaculture, both inland and marine, which has seen inland production more than quadruple to 50.1 million tonnes and marine production rise substantially to 35.3 million tonnes by 2022. The increased production has resulted in greater availability of fish for human consumption and non-food uses, contributing positively to economic growth in many coastal and rural communities.

Table 4.1 Fisheries and Aquaculture Trends at Glance

	1990s	2000s	2010s	2020	2021	2022
	Average per year					
	(million tonnes, live weight equivalent)					
Production						
Capture fisheries:						
Inland	7.1	9.3	11.3	11.5	11.4	11.3
Marine	81.9	81.6	79.8	78.3	80.3	79.7
Total capture fisheries	**88.9**	**90.9**	**91.1**	**89.8**	**91.6**	**91.0**
Aquaculture:						
Inland	12.6	25.6	44.8	54.5	56.4	59.1
Marine	9.2	17.9	26.7	33.2	34.7	35.3
Total aquaculture	**21.8**	**43.4**	**71.5**	**87.7**	**91.1**	**94.4**
Total world fisheries and aquaculture	**110.7**	**134.3**	**162.6**	**177.5**	**182.8**	**185.4**
Utilization*						
Human consumption	81.6	109.3	143.1	157.4	162.5	164.6
Non-food uses	29.1	25.0	19.5	20.1	20.3	20.8
Per capita apparent consumption (kg)	14.4	16.9	19.5	20.2	20.6	20.7
Trade**						
Exports – in quantity	39.3	51.2	60.8	63.8	67.8	70.0
Share of exports in total production (%)	*35.4*	*38.3*	*37.5*	*35.8*	*36.9*	*37.6*
Exports – in value (USD billion)	46.6	76.4	141.8	151.0	176.6	192.2
Employment (millions of people)***						
Aquaculture	12.1	15.9	21.9	22.2	22.3	22.1
Fisheries	24.4	29.1	31.9	34.3	33.4	33.6
Unspecified	7.2	6.8	7.0	6.3	6.1	6.1
Fishing fleet (millions of vessels)****						
Motorized and non-motorized vessels	4.5	4.7	5.0	5.3	5.1	4.9

Source : FAO (2024)

In 2022, the global workforce in the primary sector of fisheries and aquaculture was estimated at 61.8 million full-time, part-time, and occasional workers, a slight decrease from 62.8 million in 2020. Of this workforce, 54 % were employed in fisheries, 36 % in aquaculture, and the remaining 10 % were not specified by subsector. Asia dominated the sector's employment landscape, employing 85 % of the global workforce, followed by Africa (10 %) and Latin America and the Caribbean (4 %). Europe, Oceania, and Northern America combined accounted for just 1 % of the workforce. Within the aquaculture sector specifically, Asia employed 95 % of the workers, while Africa and Latin America and the Caribbean accounted for 3 % and 2 %, respectively. In the fisheries sector, Asia employed 77 % of the global workforce, with Africa and Latin America and the Caribbean employing 16 % and 5 %, respectively. Data disaggregated by sex, which covered 66 % of the workforce, showed that women made up 24 % of fishers and fish farmers (28 % in inland fisheries) and 62 % of processing workers. However, gender disparities persist, with women facing issues such as wage gaps, insufficient recognition of their contributions, and gender-based violence. Notably, 53 % of women in the sector were employed on a full-time basis, compared to 57 % of men.

The utilization and processing of aquatic products have continued to advance, with 89 % of the global production of aquatic animals (185.4 million tonnes) in 2022 being used for human consumption. The remaining volume was allocated for non-food purposes, primarily for the production of fishmeal and fish oil. The largest share of aquatic animals for human consumption (43 %) was distributed in live, fresh, or chilled form, followed by frozen (35 %), prepared and preserved (12 %), and cured (10 %). In high-income countries, the trend is toward more processed aquatic foods, and traditional preservation methods are increasingly being replaced by value-adding processes. Additionally, by-products of aquatic animals, traditionally discarded as waste, are now increasingly utilized to prepare both food and non-food products. In 2022, 34 % of global fishmeal production and 53 % of total fish oil production were derived from by-products, reflecting a more efficient use of resources within the industry.

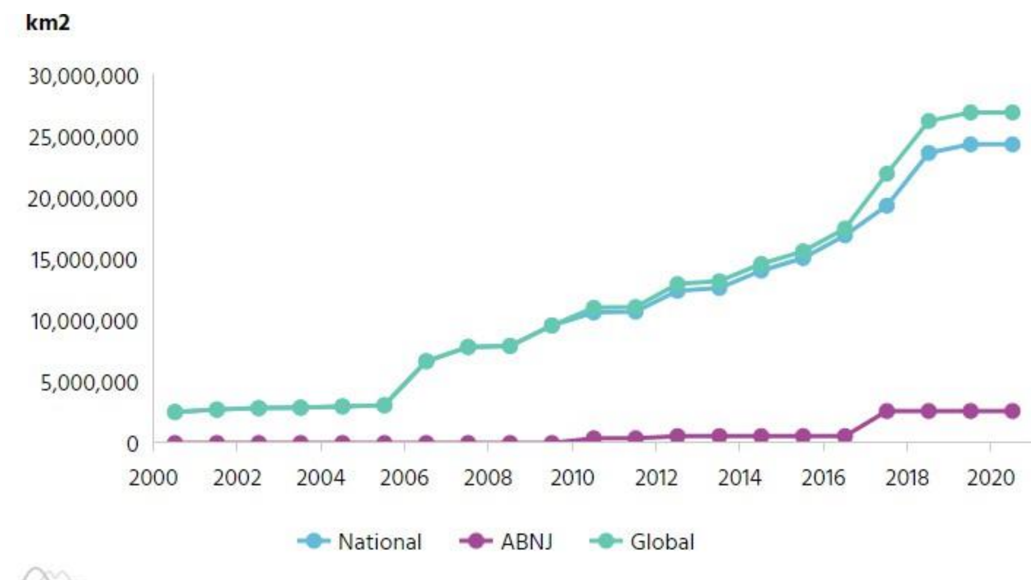
4.1.3. Marine Protected Areas

Marine Protected Areas (MPAs) that are currently being developed are a clear indication of the increasing concern across the world in the conservation of marine biodiversity and the sustainable use of the ocean resources. In the last few decades, the number and size of MPAs have increased due to global conventions - the CBD and the SDGs especially the 14th with a target of protecting at least 10% of coastal and marine areas by the year 2020. According to the latest statistics, MPAs span about 8 percent of the world’s ocean area. 35 percent of the total ocean area of the world. They are set up to conserve important habitats such as coral reefs, mangroves, seagrass and fish breeding grounds from fishing, destructive practices and other human related activities that are damaging to aquatic life. MPAs have been most actively developed in such areas as the Pacific and the Caribbean where large scale MPAs have been established. For instance, large MPAs in the Pacific including the Papahānaumokuākea Marine National Monument in Hawaii and the Pitcairn Islands Marine Reserve are good progress towards the protection of marine life.

The oceans of the world are split into the National Waters, which are waters under the jurisdiction of a country, and the Areas Beyond National Jurisdiction (ABNJ), which are waters that are not under the jurisdiction of any country. The establishment of MPAs within National

Waters is relatively easier because it has legal framework as well as government authority. As a result, 19. National Waters, which are 39% of the global ocean, are protected in 17% of their extent. However, the establishment of MPAs in ABNJ is relatively more complicated because of the numerous and often fragmented legal arrangements of these regions. Consequently, only 1. 44% of the ABNJ that constitute the other 61% of the world's ocean are protected. Understanding this discrepancy, the international community continues the work on the creation of the mechanisms that would facilitate the establishment of MPAs in ABNJ to improve the protection of these important but frequently endangered marine spaces.

Figure 4.2 Marine Protected Area Coverage



Source : Protected Planet Report, 2020

The following chart depicts the trends in the MPAs from the year 2000 to the year 2020 and the coverage of MPAs in the National Waters, ABNJ and globally. In this period, it is possible to identify a substantial increase in MPA coverage, particularly in the National Waters, where the establishment of large MPAs has been mainly accountable for this growth. It shows a sharp increase from around 2008, a sharp increase from 2014, in parallel with the creation of massive MPAs of over 100,000 km². As per the data, National Waters have recorded the biggest rise in the protection of areas which is in line with the efforts of the USA and the Cook Islands to protect huge portions of sea territory within their countries. These large MPAs have been instrumental in the global MPA expansion where 20 largest MPAs cover a large portion of the global area protected.

Nevertheless, the expansion of MPAs in ABNJ has been much slower, primarily due to the legal and practical challenges associated with the protection of areas in the high seas. But there has been a slow and progressive increase in the number of MPAs in ABNJ, particularly from 2014, which indicates that the protection of these areas is increasingly being acknowledged. The findings also reveal that there is poor management of MPAs within the large MPAs in National Waters and this has implications on the set conservation goals; but the commitment to the conservation of the marine environment is evident. The analysis of the rate of growth of National Waters and ABNJ proves that the issues of increasing the protected areas in the high seas are still urgent and deserve further consideration.

4.2. Descriptive Statistics

The descriptive statistics give an overview of the data collected and the basic features of the data collected such as measures of central tendency and variability. In general, descriptive statistics such as mean, median, mode, standard deviation, and Jarque-Bera are computed to determine the distribution and dispersion of the variables in the given data set. The mean is the sum of all the scores divided by the number of the scores and gives the measure of central tendency of the data. The median is another measure of central tendency that is less affected by extreme values as compared to the mean. The mode gives the value that is most often repeated in the given set of values.

Table 4. 2 Descriptive Statistics

	Food Security	Log of Fishes Production	Government Policy	Climate Change	Marine Biodiversity	Population	Trade Openness	Urbanization
Mean	63.22500	14.64288	0.872976	3.319130	8.313856	0.891393	62.90111	58.43850
Median	64.35000	14.59807	0.405000	3.366220	2.969939	1.067196	43.66106	56.68850
Maximum	83.80000	18.26926	4.150000	7.503800	44.33664	2.246032	134.0189	91.86700
Minimum	34.60000	12.36706	0.060000	0.483980	0.070000	-0.459952	24.70158	18.25600
Std. Dev	13.32192	1.613040	0.992389	1.777585	12.75681	0.626929	37.38743	24.91094
Jarque-Bera	4.292789	8.245964	44.98506	2.611597	52.87666	2.049963	13.67453	7.057948
Observations	84	84	84	84	84	84	84	84

Source : Author's estimation, 2024

The table 4.2 shows the descriptive statistics of the variables used in a study relating to Blue Economy factors and food security. The dependent variable is food security (Y) while the independent variables are fish production (X_1), government policy (X_2), climate change

(X_3) and marine biodiversity (X_4). Other independent variables are population (X_5), trade openness (X_6), and urbanization rate (X_7). This is a cross-sectional study and the dataset contains 84 observations. The descriptive statistics include mean, median, maximum, minimum, standard deviation for each of the variables. The mean value for the food security is 63.23, meaning the level of food security is moderate according to the observations made. Fish production in the selected countries has a mean of 14.64, while the mean value of the variable government policy is 0.87, which suggests that while being low, policy measures are present in the countries. Climate change and marine biodiversity have means of 3.32 and 8.31, respectively, which indicates that these factors have been affected in a rather uneven manner.

The results of the Jarque-Bera test for most of the variables show normality with probabilities greater than 0.05, but those of fish production, government policy and marine biodiversity are showing probabilities of non-normality. The standard deviations are high for both food security (13.32) and trade openness (37.39), which means that the observations differ greatly. The mean, median, and standard deviation reveal the nature of distribution and variability of the data and the associations between the factors and food security in the Blue Economy context. As a result, this analysis creates a foundation for more advanced inferential statistics to examine the hypothesized effects and interaction more closely.

The data provided for marine biodiversity, represented by the percentage of marine protected areas (MPAs), and government policies across various countries show notable disparities between the mean and median values, suggesting a skewed distribution for both variables. This skewness highlights significant differences in marine conservation efforts and policy implementation across different countries, as well as the presence of outliers. Marine biodiversity, as represented by the percentage of marine protected areas, refers to the proportion of a country's marine territory that is legally designated for conservation purposes to protect biodiversity and maintain ecosystem services. A higher percentage of MPAs indicates that a country is dedicating more of its marine environment to protection from harmful activities, which is crucial for maintaining the health and diversity of marine life.

The mean value for marine biodiversity across the data set is significantly higher than the median. For instance, the overall mean was around 8.31%, while the median was much lower at approximately 2.97%. This large discrepancy is primarily due to the presence of countries like Australia and New Zealand, which have exceptionally high percentages of MPAs, exceeding 40% and 30%, respectively. These countries have large and diverse marine ecosystems, and their significant conservation efforts result in higher biodiversity values, which in turn pull the mean upwards. Conversely, many other countries have much lower percentages of marine protected areas, often below 1%, as seen in Cambodia, Sri Lanka, and Pakistan. These lower values suggest that a smaller portion of their marine environments is under protection, potentially leading to lesser biodiversity and a higher risk of ecosystem degradation. The result is a skewed distribution where the mean is influenced by a few countries with extensive MPAs, while the median reflects the more modest protection levels common among the majority of countries.

A similar pattern is observed with government policies. The mean value for government policy is higher than the median, indicating that while a few countries have very proactive policies (as shown by values close to or above 3 in countries like New Zealand and Australia), the majority have lower levels of policy engagement. New Zealand and Australia, for example, demonstrate much higher government policy values, reflecting more comprehensive or effective marine conservation policies. In contrast, countries like Thailand and Malaysia have much lower policy engagement, with values often below 0.5. This disparity suggests that the implementation of government policies related to marine biodiversity conservation varies widely across different countries. A few countries, likely those with greater resources or more significant environmental pressures, have implemented strong policies, skewing the mean upwards. However, the median remains low because many countries have either less comprehensive policies or are in earlier stages of policy development.

The fluctuation in marine species and governments' policies in different countries shows the ecological and policy differences around the world. It is also important to note that the countries with higher proportions of MPAs and therefore more developed marine conservation policies are those countries with large coastlines and diverse marine life, for example Australia and New Zealand. These countries' values are high and as such, they raise the mean of the overall statistical measures. However, the countries with short coastlines, less number of marine resources, or different economic and environmental concerns like Cambodia, Sri Lanka, and Pakistan have lower biodiversity and policy values. Such countries may lack the capability or the imperative to enforce stringent marine policies or may be preoccupied with other developmental concerns. The large variability in the values of both marine protected areas and government policies for marine conservation lead to the large difference between the mean and median values for both variables. Some countries that have very high percentage of MPAs and sound policies distort the mean and make it higher than the median because most countries have lower values. The fact that the distribution is skewed in this way means that there is a need for differential conservation approaches that take into account the fact that the level of biodiversity and policy involvement may not be the same in all countries, and that all nations should be able to play a role in the conservation of the world's marine resources.

4.3. Covariance Analysis

Covariance test for panel data also known as Panel Data Covariance Analysis is a statistical tool that is used in the analysis of more than two variables in different cross sections at different time periods. This method allows the researchers to control for individual heterogeneity because the data used in the analysis is in the form of cross sectional data that contain observations on several entities over time. In the case of the panel data model, the correlation of the variables has to be established in order to determine the stability of the model. Another criterion that is widely used is that the multicollinearity of independent variables should not be very high, usually the Variance Inflation Factor (VIF) should not be greater than 10, which in turn means that the correlation coefficient (R) should not be greater than 0. 9 to reduce the issue of multicollinearity. Moreover, the study shows that the covariance is significant, which helps in determining the associations between variables so enhancing the model's performance in explaining the data. This method is particularly applied in econometrics for assessing the economic data since the covariance does not change with time and entities hence providing a more complex perspective of the relationships between the variables.

Table 4.3 Covariance Test

Correlation	Food Security	Log of Fishes Production	Government Policy	Climate Change	Marine Biodiversity	Population	Trade Oppenness	Urbanization
Food Security	1.000000	-	-	-	-	-	-	-

Log of Fishes Production	-0.066861	1.000000	-	-	-	-	-	-
Government Policy	0.507449	-0.476298	1.000000	-	-	-	-	-
Climate Change	-0.230657	0.287474	-0.390542	1.000000	-	-	-	-
Marine Biodiversity	0.589709	-0.422769	0.761554	-0.343499	1.000000	-	-	-
Population	-0.159543	-0.444004	0.255325	-0.010450	0.340007	1.000000	-	-
Trade Oppenness	-0.068611	-0.162578	-0.174165	0.2748.40	-0.250013	0.042405	1.000000	
Urbanization	0.886737	0.065574	0.434243	-0.060137	0.562769	-0.126721	-0.074108	1.000000

Source : Author’s estimation, 2024

The correlation matrix presented in Table 4.3 shows a measure of the correlation between the level of food security and the independent and control variables. The relationship between food security and fish production is negative but very weak (-0. 066861) this indicates that although fish production may be increased, it does not necessarily improve food security as observed in the dataset. Government policy has a significant positive relationship with food security = 0.507449, which means that good governmental policies and intervention have a positive effect on the food security status. Climate change, however, has an inverse relationship (-0. 230657) with food security meaning that climate variability is detrimental to food security indicators. Food security also has a positive relationship (0. 589709) with marine protected areas and this could mean that well managed marine resources improve the food security status.

The relationships of the control variables with food security were as follows. Population size has a negative coefficient (-0. 159543) with food security, this indicates that large population may have some difficulties in fulfilling the requirements of food security. Trade openness has a relatively higher negative coefficient (-0. 086611), which means that food security may decrease with higher levels of trade openness, because of reliance on markets and fluctuations. Highly positively correlated with food security at 0. 886737, urbanization could mean that urbanization is in some way connected with food security since the development of urban areas may lead to better food accessibility. These correlations give a basic perspective on how various variables are connected in the framework of food security and create the premise for the subsequent regression analyses to examine these relations further.

4.4. Model Specifications Test

A specification model test for panel data determines whether a Fixed Effects (FE) or Random Effects (RE) model is appropriate. The FE model accounts for entity-specific factors related to independent variables, while the RE model treats these factors as random and unrelated. The Hausman test helps choose between them, with other tests like the Lagrange Multiplier (LM) and Chow Test further guiding model selection to ensure accurate estimates.

4.4.1. Lagrange Multiplier (LM) Test

The LM test, or the Breusch-Pagan test when done on panel data, is used to test whether Random Effects model is more suitable than the basic pooled OLS model. The LM test aims at testing the null hypothesis to see if the entities are heterogeneous hence the choice of Random Effects. The first major conclusion that can be derived from this test is the presence of entity specific effects, which support the Random Effects model over the pooled OLS model.

Table 4.4 Lagrange Multiplier Test

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	43.38206 (0.0000)	0.020093 (0.8873)	43.40216 (0.0000)

Source : Author's estimation

Table 4.4 shows the result of the Lagrange Multiplier (Breusch-Pagan) Test used to test the random effects in the panel data model. The test is carried out for cross-section, time, and both dimensions. The cross-section component reveals a test statistic of 43 in the test. 38206 with the p-value of 0.0000, which suggests that there is a highly significant cross-sectional random effect. This implies that there are huge uncontrolled cross-sectional unit heterogeneities that influence food security status.

4.4.2. Chow Test

The Chow Test is used to check the null hypothesis of structural shifts or different regression coefficients in different groups or at different time periods. In the analysis of panel data, it can be used to compare the fit of the model across the different entities or at different time point, in order to determine whether the data can be pooled or whether separate regression should be performed. The test in fact determines if the coefficients of the regression are significantly different across the given groups, and therefore if the data cannot be pooled.

Table 4.5 Chow Test

Effects Test	Statistic	d.f.	Prob.
Cross-section F	15.546936	(11,65)	0.0000
Cross-section Chi-square	108.319143	11	0.0000

Source : Author's estimation

Table 4.5 provides the results of Chow Test that is used to check whether the panel data model should be estimated under the assumption of pooled OLS or if different equations are required for different groups, that is, Fixed Effects Model or Random Effects Model. The Chow Test is performed for the cross-section and time dimensions. When it comes to the Chow Test for the cross-section, the F-statistic is equal to 7.493 and the p-value corresponding to this is equal to 0.0000. This means that there is variation across the cross-sectional units and therefore one should use the FEM instead of the pooled OLS model. The large F-statistic means that the effects of individual cross-sections (e g., countries) are not the same and should be taken into account in the model.

4.4.3. Hausman Test

The Hausman Test is employed to test for the right model to use namely Fixed Effects or Random Effects. It tests the null hypothesis that the individual effects are unrelated to the other independent variables. If the null hypothesis is rejected, then it means that the use of Random Effects model will give biased estimates hence the Fixed Effects model should be used. However, if the null hypothesis is not rejected, the Random Effects model is applied because of its efficiency.

Table 4.6 Hausman Test

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	37.323875	7	0.0000

Source : Author's estimation

Table 4.6 shows the findings of the Hausman Test which is used to choose between the Fixed Effects Model (FEM) and the Random Effects Model (REM) in panel data analysis. The test examines if the unique errors (u_i) are related to the regressors; the hypothesis is that they are not related (in favor of REM). The test summary shows that Chi-Square statistic is 37. 323875 with 7 degrees of freedom and p<0. 0000. The calculated Chi-Square statistic being greater than the Chi-Square critical value and the p-value being less than 0.05, it can be concluded that the null hypothesis can be rejected, hence there is correlation between the individual effects and the regressors. This means that the Random Effects Model is not suitable for the data and the Fixed Effects Model should be used. The dismissal of the REM in favor of the FEM means that the individual-specific effects should be removed because they are related to the explanatory variables, thus achieving more accurate and less biased estimates in the panel data analysis.

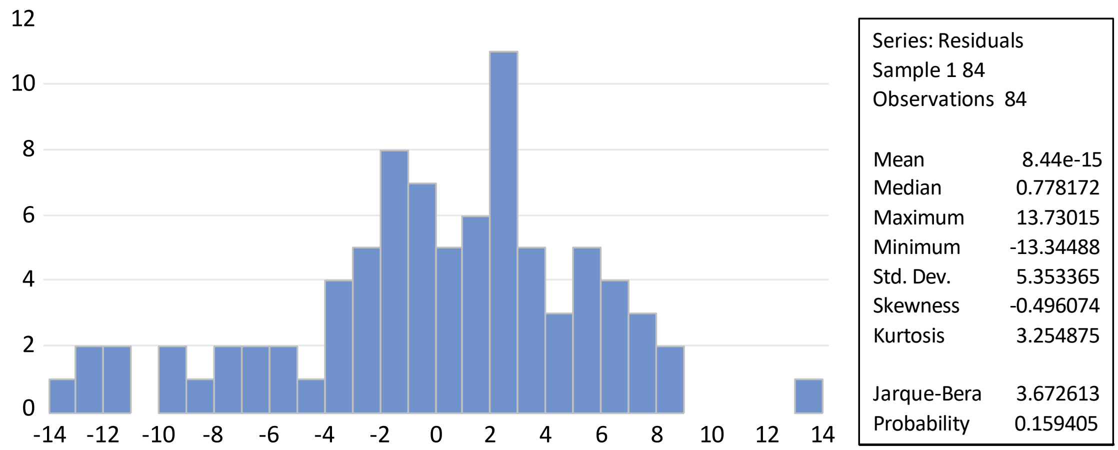
4.5. Diagnostic Tests

The diagnostic tests for panel data entail checking the basic assumptions of regression models to determine the credibility of the estimated results. Such tests include; multicollinearity test which checks the correlation between the independent variables, heteroscedasticity test which checks for constant variance of the error terms across entities or time, autocorrelation test which checks for correlation of the error terms across time periods and normality test which checks for normality of the error terms.

4.5.1. Normality

The normality test in the case of panel data analysis is performed to check whether the residuals (error terms) of the regression model are normally distributed. This is a common assumption in most statistical models since normality of errors determines the reliability of the statistical tests for coefficients. Jarque-Bera test is some of the techniques that are frequently used to check normality. In this test, the null hypothesis is that the residuals are normally distributed. A small p-value, usually less than 0. 05, means rejecting the null hypothesis which in this case is that the residuals are normally distributed and this may call for data transformation or use of robust statistical methods. Normality is very important in parameter estimation, hypothesis testing and the overall validity of the model’s conclusions.

Figure 4.3 Normality Test



Source : Author's estimation, 2024

Table 4. 6 displays the p-value of normality test for the residuals of the regression model and histogram of the residuals. The descriptive statistics also show that the mean value of the residuals is very close to zero (8. 44e-15), which is a good property in regression analysis because it means that the errors of the model are distributed around the mean value of zero. The median value of 0. 778172 and the standard deviation of 5. 353365 give additional information on the dispersion of the residuals across the different districts. The Jarque-Bera test statistic is 3. 672613 with the probability (p-value) of 0. 159405. Since the p-value is greater than 0. 05 we are not in a position to reject the null hypothesis of normality. This means that the residuals do not depart much from the normal distribution hence affirming the regression model's assumptions. The normality of residuals is very important for hypothesis testing and constructing confidence intervals to guarantee that the inferential statistics derived from the model are accurate and valid.

4.5.2. Heteroscedastisity

The heteroscedasticity test is a statistical test used to check if the variance of the residuals of a regression model is constant for all values of the independent variables which is one of the assumptions of OLS regression. Heteroscedasticity is a condition where the variance of the residual or error term is not constant and this makes the estimates inefficient and the inference invalid. For this study, Glejser test is used to check for heteroscedasticity. In these test, the null hypothesis is that the variance of the residuals is constant, or, in other words, homoscedasticity. A low p-value, often below 0. 05, is an indication that the model under test has heteroscedasticity meaning that the model's assumptions have been violated If the data has homoscedasticity, hypothesis testing and construction of confidence intervals in regression analysis are valid.

Table 4.7 Heteroscedastisity Test

Variable	t-Statistic	Probability
C	2.046590	0.0442
Log of Fishes Production	0.033942	0.9730
Government Policy	0.726562	0.0883
Climate Change	1.264864	0.2098
Marine Biodiversity	1.634495	0.1063
Population	-0.843235	0.4017
Trade Openness	-1.669967	0.0990
Urbanization	-5.150046	0.0000

Source : Author's estimation, 2024

Table 4. 7 reports the result of the heteroscedasticity test, namely the Glejser test, which tests whether the variance of the residuals of a regression model is constant across different levels of the independent variables. The Glejser test is therefore very important in checking the assumption of homoscedasticity which is an important component of the OLS regression. Heteroscedasticity is a condition whereby the variance of residuals is not constant and this makes the parameter estimation to be inefficient and also the inference to be invalid. The null hypothesis of the Glejser test is that the residuals are homoscedastic or they have equal variance. If the p-value is less than 0. 05, this would mean that there is heteroscedasticity hence violating this assumption.

The implication of these findings is very significant for model reliability. Variables with p-values less than 0. 05 like the constant and Urbanization show high levels of heteroscedasticity and hence violate the assumption of homoscedasticity. On the other hand, the variables with p-value > 0. 05, like Log of Fish Production and Population, there is no issue of heteroscedasticity in the data. To correct for heteroscedasticity, it is recommended to use

GLS methods like FGLS because it involves modification of the error variance-covariance matrix from data.

4.5.3. **Autocorrelation**

An autocorrelation test checks for correlation between residuals in a regression model, especially in time series data, where this can lead to inefficient estimates and biased inferences. The Durbin-Watson test is commonly used, with values close to 2 indicating little to no autocorrelation, while values near 0 or 4 suggest positive or negative autocorrelation, respectively.

Table 4.8 Autocorrelation Test

Test Statistic	Value
Durbin-Watson stat	1.967609

Source : Author's estimation, 2024

The Durbin-Watson statistic is 1 in this study. The value of 967609 is almost 2 and thus, there is very little sign of autocorrelation in the residuals. The DW statistic is an index ranging between 0 and 4 and a DW value of 2 indicates no autocorrelation while DW values less than 2 indicate positive autocorrelation and DW values above 2 indicate negative autocorrelation. Since the statistic is close to 2, it means that the residuals are almost uncorrelated in time and there is no serious problem with autocorrelation. Hence, despite the fact that the DW statistic is within the range where the results are indeterminate if compared with the critical values from the Durbin-Watson table, its value of 1.93 is close enough to 2 to support the model's assumption of residual independence. Therefore, it can be concluded that the estimates of the regression model are accurate and no significant correction for auto correlation is mandatory. However, it is advised to perform other diagnostic tests to validate the findings of the study.

4.5.4. Multicollinearity

A multicollinearity test is used to check whether there is collinearity and the degree of collinearity between independent variables in a regression model. This is a situation where two or more predictor variables are highly correlated and this can cause issues whereby accurate estimation of the regression coefficients is not possible. This poses a problem when one wants to establish the unique contribution of each predictor towards the dependent variable and can result in high standard errors of the coefficients, which hampers the making of valid statistical inferences.

The two commonly used techniques to identify multicollinearity include the use of the Variance Inflation Factor (VIF) and the tolerance levels. VIF values above 10 (or below 5 in some cases) indicate high multicollinearity because each of the predictor variables is highly influenced by the others' variance. Likewise, the measure of tolerance which is the reciprocal of VIF should be above 0. 1 suggest that the level of multicollinearity is high. Another measure is the condition index where values greater than 30 are taken to mean that the problem is severe in the sense of multicollinearity. The following actions can be taken when multicollinearity is identified; one can either delete the variables that are related or merge them, standardize the variables, or employ methods like ridge regression or PCA. To enhance the stability and the interpretability of the regression model, multicollinearity should be solved as it leads to the distortion of the coefficients of the independent variables.

Table 4.9 Multicollinearity Test

Variable	Centered VIF
Fishes Production	1.989958
Government Policy	2.713194
Climate Change	1.370401
Marine Biodiversity	3.911527
Population	1.526303
Trade Oppenness	1.343430
Urbanization	2.161140

Source : Author's estimation, 2024

Table 4. 9 displays the multicollinearity test for the regression model, including the uncentered and the centered VIFs for the variables. The VIF tells the extent to which the variance of a regression coefficient is increased because of multicollinearity. Another rule of thumb is that when VIF is greater than 10, then there is high multicollinearity and corrective action may be required.

From the table, all the centered VIF values are below 10 and the highest one is 3. 911527 for the variable "Marine Protected Areas. " This means that multicollinearity is not a serious issue in this model. The values of the VIF test that are less than 1 for most of the independent variables imply that there is no high linear relationship among the independent variables that would affect the estimation of their coefficients. However, the uncentered VIF values are relatively higher as compared to the centered VIF values and these include; Fish Production 167. 9516, Urbanization 14. 19769. However, the values are higher in the uncentered VIF and the centered VIF gives a better idea of the multicollinearity and it can be concluded that the model is not much affected by multicollinearity.

4.6. Hypothesis Test Results

Hypothesis tests play a crucial role in determining the appropriate model to use and ensuring the soundness of panel data analysis. To address violations of classical assumptions, such as heteroscedasticity and autocorrelation, the Fixed Effect Model with cross-section weights is employed. This method mitigates cross-sectional heteroscedasticity by applying different weights to various cross-sections, thereby stabilizing the variance of the residuals. Consequently, the Fixed Effect Model enhances the efficiency and accuracy of parameter estimates, which in turn strengthens the credibility of the inferences drawn from the panel data model. This robust approach ensures that the conclusions derived from the analysis are reliable and firmly grounded in statistical theory.

Table 4.10 Fixed Effect Model Estimation Result

Dependent Variable : Food Security (Y)

Variable	**Symbol**	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-	-194.2540	99.93828	-1.943740	0.0563
Fihes Production	X_1	7.780320	6.960064	1.117852	0.2677
Government Policy	X_2	-0.956111	1.393440	-0.686152	0.4951
Climate Change	X_3	-1.818900	0.913991	-1.990063	0.0508
Marine Biodiversity	X_4	0.006113	0.255623	0.023914	0.9810
Population	X_5	4.695786	1.495344	3.140271	0.0025
Trade Openness	X_6	0.073447	0.093492	0.785591	0.4350
Urbanization	X_7	2.422514	0.377135	6.423462	0.0000

Source : Author’s estimation, 2024

Based on the obtained results from the Fixed Effect Model (FEM), the regression equation for food security (Y) can be represented as follows:

$$Y = -194.2540 + 7.780320 log(X_1) - 0.956111X_2 - 1.818900X_3 + 0.006113X_4 + 4.695786X_5 + 0.073447X_6 + 2.422514X_7 + \epsilon \quad (4.1)$$

In the context of regression analysis using the Fixed Effect Model (FEM), it is crucial to differentiate between the main independent variables and the control variables, as each plays a distinct role in explaining the observed phenomenon.

The main independent variables in this analysis include Fisheries Production (X1), Government Policy (X2), Climate Change (X3), and Marine Biodiversity (X4). The discussion of these variables focuses on their direct causal relationship with the dependent variable, which is Food Security (Y). The primary objective is to understand the extent to which each of these key variables influences food security, assuming that changes in these variables will directly impact the level of food security. Although the coefficient for Fisheries Production is positive (7.780320), it is not statistically significant ($p = 0.2677$), indicating that fisheries production may not have a strong or consistent impact on food security within the scope of this model. The negative coefficient for Government Policy (-0.956111) and lack of statistical significance ($p = 0.4951$) suggest that government policy, as measured in this model, does not have a significant effect on food security. With a negative coefficient for Climate Change (-1.818900) and marginal statistical significance ($p = 0.0508$), climate change appears to negatively impact food security, though the strength of this influence is borderline in terms of statistical significance. The near-zero coefficient for Marine Biodiversity (0.006113) and lack of significance ($p = 0.9810$) imply that marine biodiversity does not have a strong relationship with food security within the context of this model.

The control variables, including Population (X5), Trade Openness (X6), and Urbanization (X7), are used to account for other factors that may influence the relationship between the main independent variables and the dependent variable. By including these control variables, the analysis can more accurately isolate the effects of the main independent variables on food security. The positive and significant coefficient for Population (4.695786, $p = 0.0025$) suggests that an increase in population is positively associated with improved food security, possibly due to the potential for increased food production and more efficient distribution systems. Despite the positive coefficient for Trade Openness (0.073447), the lack of statistical significance ($p = 0.4350$) indicates that trade openness may not have a significant impact on food security within this model. The positive and highly significant coefficient for

Urbanization (2.422514, p = 0.0000) indicates that urbanization is strongly associated with improved food security, likely due to enhanced infrastructure and better access to food in urban areas.

In this context, the distinction between main independent variables and control variables is made depending on the function of these variables in the research. The main independent variables are the main subject of interest of the analysis just because they are posited to have a direct effect on the dependent variable which is food security in this study. These variables are chosen because there is some theoretical or empirical support that indicates that they are causally connected. As a result, the study aims at determining the level to which the above variables; Fisheries Production, Government Policy, Climate Change, and Marine Biodiversity do or do not affect food security. The coefficients and the significance levels of these variables explain the degree and the nature of impact of the independent variables on the dependent variable. On the other hand, the control variables are of great methodological importance in the sense that they help to control other factors that might affect the relationship between the major independent variables and food security. These variables are then included in the model in an attempt to ensure that the major independent variables are not endogenised by other variables such as Population, Trade Openness and Urbanization. Therefore the analysis can establish the extent to which the main independent variables affect the outcome controlling for the effects of other factors. This approach enhances the internal validity of the study and minimizes the chances of arriving at wrong conclusion on the effects of the main independent variables on food security because of OVB. In other words, the actual relationships in the field and the general conclusions of the study are improved by means of control variables.

Two tests that are used in the evaluation of efficiency and accuracy of a regression model include F-test and coefficient of determination or R-squared. The F-test of overall significance tests the hypothesis that the regression equation is not significant or in other words, whether the equation is significant at all, that is, whether it is better than the model with no predictors. It rejects the null hypothesis of all the regression coefficients being equal to zero which implies that the predictors are not related to the dependent variable. The p-value less than 0. The results of the analysis showed that 05 means that the model has the ability of explaining the variance of the dependent variable and hence the null hypothesis is rejected.

R-squared coefficient (R^2) is the measure of the degree of how well the independent variables explain the variation in the dependent variable and it ranges between 0 and 1. An R^2 of 0. 5 From this it can be seen that the model fits the data better than what is depicted by the

R^2 of 0. 3. For instance, an R^2 of 0. 7 indicates that the model can explain 70% of the variation of the dependent variable. In sum, the F-test and R-squared are a correct pair of tests that allow the check of the model and make decisions according to the results of regression analysis.

Table 4.11 F-Statistic Test and R Square

R-Square	Adjusted R-Squared	F-Statistic	Prob(F-Statistic)
0.955527	0.943212	77.58762	0.000000

Source : Author's estimation, 2024

The results presented in Table 4.11 indicate a strong model fit and significant predictive power for the regression analysis. The R-squared value of 0.955527 suggests that approximately 95.55% of the variance in the dependent variable is explained by the independent variables included in the model. The Adjusted R-squared, which accounts for the number of predictors, remains high at 0.943212, indicating that the model is robust even after adjusting for the number of variables. The F-statistic of 77.58762, with a corresponding p-value of 0.000000, confirms that the overall regression model is statistically significant and superior to a model without predictors. This result strongly rejects the null hypothesis that all coefficients are zero, demonstrating the model's effectiveness in explaining the variance in the dependent variable.

4.7. Discussion

This section discusses the findings from the research. The results were analyzed through descriptive statistics, covariance analysis, model specification tests, diagnostic tests, and hypothesis test to understand the relationship between the Blue Economy factors and food security. The following subsections elaborate on the effects of fish production, government policy, climate change, marine biodiversity, population, urbanization, and effective policies within the Blue Economy framework on food security.

4.7.1. The Effect of Fish Production on Food Security

Fish production is one of the most strategic interventions towards the achievement of food security in the world. Fish is regarded as a lean protein, Omega-3 fatty acids, vitamins and minerals that are essential to the human body. Fish is a common food in most of the developing nations and it has a very significant role on the diet of many people especially the vulnerable groups who may not afford other source of animal protein. It is now well known that fish is a food packed with nutrients. Fish is particularly endowed with omega-3 fatty acids which are essential in the formation of and functioning of the brain, heart and as an anti-inflammatory nutrient. Incorporation of fish in the diet can help in alleviation of malnutrition and diseases associated with it among children and pregnant women hence improving the public health. Thus, improving the availability of fish through production can help improve the nutritional status and food security in many regions (Golden et al. , 2016; Béné, 2016).

In this study, the effect of fish production on food security was analyzed using a panel data regression model. The coefficient for fish production (X1) was found to be positive (7.780320), indicating a potential positive relationship between fish production and food security. However, the t-statistic for this variable (1.117852) and the associated probability value (0.2677) suggest that the effect is not statistically significant at conventional significance levels (e.g., 5% level). The lack of statistical significance implies that, within the scope of this study, fish production does not have a strong direct impact on food security when controlling for other variables such as government policy, climate change, marine biodiversity, population, trade openness, and urbanization. This result could be due to several factors, including the complexity of food security as an outcome influenced by a multitude of factors beyond just the production of fish. It may also reflect the varying roles that fish production plays in different regions or contexts within the panel data, where other factors like distribution networks, access to markets, and socio-economic conditions could mediate the impact of fish production on food security.

The contribution of agriculture to food security is even more pronounced than that of fish production. Food crops, for instance staple foods, are a direct input to the energy requirements of populations and are at the center of most food adequacy policies (Smith et al. , 2013). Also, there is usually well-developed physical framework and policy backing for agriculture in many areas, which might increase its potential in contributing to food security than fisheries. The fact that agriculture products can be produced, stocked and supplied in large quantities can help to offer a more reliable food supply than that which is offered by fish farming which is affected by seasonal and environmental changes (Jones & Tarp, 2015). Hence, even though the findings of the study show a positive correlation between fish production and food security, the non-significance of this relationship means that fish production cannot on its own guarantee food security. Policy makers should therefore look at a wider basket of options that are available and include but not limited to increasing fish production for the desired food security gains. Including agricultural production in these strategies might provide better and more reliable results for food security in the world.

4.7.2. The Effect of Government Policy on Food Security

This study used a panel data regression model where government policy was captured by the Agricultural Orientation Index (AOI) to evaluate the effects of government policy on food security. The coefficient for government policy (X2) was negative (-0. 956111) which imply that the government policy is negatively related with food security. However, the t-statistic (-0. 686152) and the probability value (0. 4951) suggest that this is not the case.

The Agricultural Orientation Index is an index that is used in comparing the level of expenditure on agriculture by the government in relation to the contribution of this sector to the economy. A higher AOI means that a government is spending more of its budget on agriculture than the proportionate share of agriculture in GDP and therefore can be interpreted as a higher policy commitment to the agricultural sector. This negative coefficient in this regard could therefore mean that a higher AOI does not necessarily lead to better food security outcomes. This can happen when the funds invested in agriculture have been spent unappropriately or when the policies supported by such allocations do not respond to the issues of food insecurity such as availability, access, market or nutrition.

The following might explain why the AOI does not have a more profound impact on the food security. First, the efficiency of agricultural spending is not only the amount of money that is spent but the quality of that money. Investment on agriculture could however enhance food security depending on the effectiveness of the investment on the process of allocation, corruption or policy. If the government spending is more on large scale commercial farming than small holder farms it may not reach the food insecure groups of people (Fan, S. , & Rao, N. , 2003). Second, the AOI does not include the other policies which impact on food security including trade policies, social protection policies or the policies on the environment. If there has to be an appropriate strategy towards food security it cannot be a mere funding on agriculture but a funding on social sectors including agriculture but also other sectors like health, education, infrastructure among others. The non-significant correlation between the

AOI and food security in this study may therefore imply that there is more policy incoherence required. Also, the AOI is linked to the shares of government expenditure rather than the levels of investment or results. A high AOI does not therefore mean that a country spends a lot of money on agriculture since the size of the GDP can be small; the effect of its policies on food security may be small. On the other hand, the country with lower AOI but with higher total spending will be more efficient in policies towards food security.

With these in mind, the findings of the present study reveal that although the Agricultural Orientation Index may offer some information about what the government regards as priorities, it may not necessarily reveal how effective the government policy is in boosting food security. The authors could make future research more useful if they pay attention to the quality of agricultural investment, the targeting of the investment and the interaction between the investment and other policies. Hence, the conclusion of this study is that the Agricultural Orientation Index as a policy instrument is not a significant determinant of food security in this study. This implies that there could be other variables that affect the government agricultural spending and food security and which are not included in the AOI. The policymakers should develop a wider approach that would link the agricultural investments with other policies that would enhance the food security status.

4.7.3. The Effect of Climate Change on Food Security

In this study, the effect of climate change on food security was examined through a panel data regression model. The coefficient for climate change (X3) was negative (-1.818900), indicating that as the impacts of climate change increase, food security tends to decrease. The t-statistic (-1.990063) and the associated probability value (0.0508) suggest that this relationship is statistically significant at the 5% level, albeit marginally. This is in compliance with literature that has postulated that climate change is unfavorable to agriculture and food systems (Helms, 1996; Fróna et al. , 2021). Irregular rainfall patterns, whether in the form of droughts or excessive rainfall, can severely disrupt crop cycles, leading to reduced yields, crop failures, and ultimately food shortages. This negative relationship between precipitation variability and food security underscores the vulnerability of food systems to changes in climate patterns, especially in regions where agricultural practices are closely tied to natural rainfall (Lobell et al., 2008). Mahrous (2019) in his study on the East African Community (EAC) region found out that rainfall and temperature variations had significant effects on food production indices; thus, providing the much-needed support to the relationship between climate variability and food insecurity.

The impacts of alterations in precipitation on food security are very much negative. This is so because rainfall plays a very important role in making water available for agriculture and as climate change continues, the rainfall is unpredictable and this implies that water and therefore crops and food are also unpredictable. This can lead to huge food deficits particularly in the regions where agriculture is rain-fed agriculture has been noted to have been affected by both drought and excessive rainfall in the EAC region thereby worsening the food insecurity situation in the region (Mahrous, 2019). Thus, the measures stimulating the better water management and making the agriculture less vulnerable to the mentioned impacts are essential to minimize these effects and enhance the food security. Effective water resource management policies at the national and regional levels are crucial for mitigating the risks posed by precipitation variability (Rockström et al., 2010). The findings from this study suggest that as climate change continues to alter precipitation patterns, food security will increasingly be at risk, particularly in vulnerable regions. Policymakers should prioritize investments in climate adaptation strategies that focus on stabilizing agricultural and fishery production in the face of unpredictable rainfall. This could involve not only the implementation of technological innovations but also the enhancement of institutional frameworks to effectively manage water resources and provide farmers with the necessary support to adapt to evolving climatic conditions.

4.7.4. The Effect of Marine Biodiversity on Food Security

In this study, the impact of marine biodiversity on food security was analyzed using a panel data regression model. The coefficient for marine biodiversity (X4) was positive (0.006113), suggesting a potential relationship between higher marine biodiversity and improved food security. However, the t-statistic (0.023914) and the associated probability value (0.9810) indicate that this relationship is not statistically significant. The non-significant relationship observed in this study could also reflect the challenges of quantifying marine biodiversity's impact on food security. Biodiversity benefits are often long-term and indirect, contributing to ecosystem stability rather than immediate food production. While high biodiversity can enhance the resilience of fish stocks, this effect might only become evident over extended periods and in the face of environmental disturbances. Additionally, the benefits of biodiversity might be more pronounced in specific contexts, such as in regions heavily dependent on artisanal fisheries, where diverse ecosystems support livelihoods and local food security (Cardinale et al., 2012).

The first issue of MPAs implementation is that there is little funding allocated for management and enforcement. For instance, Gill et al. (2017) noted that there is a severe limitation in the capacity of MPAs to recruit staffs and sufficient funding which undermines their efficiency in meeting the conservation and social goals. If there is no adequate supervision and participation from the locals, the MPAs fail to deliver the expected outcomes of replenishing the fish stock and enhancing the ecological status. Furthermore, the effectiveness of MPAs has a relation with social-economic factors such as people’s living standards and household wealth (Darling, 2014). Another fact is that in many countries people rely on fishing activities and MPAs result in economic and social vulnerability. Aswani and Furusawa (2007) noted that while MPAs may increase fish stocks, food security might either improve or worsen depending on the situation on the ground.

Therefore, several biological and economic factors are needed to be understood so that the goal of food security can be improved. Cabral et al. (2019) argue that the large MPAs can enhance the fish catch to the level that the species of high economic value can be conserved and the small MPAs are beneficial for the slow growing and less mobile species. However, some limitations are still observed in the conservation of the biological diversity with special reference to food security of the fish stock in the areas of high fishing activities. Jefferson et al. (2022) have concurred with the opinion that the protection of 30% of the ocean can solve several goals including feeding the planet, conserving marine life, and saving endangered species. But this success is subject to the global coordination and management that is sensitive to the local needs. Policy management should be done to identify recommendations, which can enhance the MPAs management to contribute to the solution of the global problems of food shortage and the loss of biological diversity.

4.7.5. The Effect of Population, Trade Openness, and Urbanization on Food Security

This study sought to establish the impact of population growth, trade openness and urbanization on food security and this was done by employing a panel data regression model. The coefficients of population (X5) trade openness (X6) and urbanization (X7) were positive with a value of 4. 695786, 0. 073447, and 2. 422514, respectively. These positive coefficients imply that food security rises with a rise in the size of the population, trade and the level of urbanization. The significance of these relationships is however mixed whereby population and urbanization are highly significant and positively related to food security while trade openness is non-significant.

The coefficients for the regression equation are as follows: t-statistic of 3.140271 with the p-value of 0. 0025 for population growth and food security, this indicates that population growth has a positive impact on food security as defined in this study. This may be so since population growth leads to economic development, improved production of crops and food chains. If population increases especially in the third world there may be increased efforts to invest in capital in structures technologies and markets for food security (Boserup, 1981). But this positive influence may not be welcomed by all regions for instance the developing world and regions with poor infrastructure may be negatively impacted on by overloaded food chains (Godfray et al. , 2010).

The coefficient for trade openness is 0. 073447 and positive which could imply that higher level of openness to trade could be a sign of better food security. However, the t-statistic (0.785591) and p-value (0.4350) suggest that this relationship is insignificant in the context of this research. Trade openness in theory can enhance food security because countries can source food that cannot be produced locally hence enhance stability of supplies and prices of food. It also leads to productivity in the production and provision of food because countries can make goods that they are most effective in (Dollar & Kraay, 2004). The non-significant results in this study could be interpreted to mean that the effects of trade openness on food security may vary with the development, infrastructure and ability to trade internationally. However, the impact of trade openness can improve the food security of the countries with sound trade relations and trade facilities but the result in the countries with high trade restrictions, trade infrastructure problems or other factors that may limit them from reaping from the benefits of the international markets will be less (Gouel, 2013).

Urbanization is positively associated with food security with a coefficient of 2.422514, t-statistic of 6. The obtained score of 423462 and the p-value of 0. 0000. This implies that as the size of the urban areas increases, then the food security is also expected to increase. It has been observed that there is a positive relationship between the level of urbanization and better incomes, better services and better diversified food systems all of which are indicative of improved food security. People in urban areas are normally in a better position to access a number of foods including the nutrient dense foods from supermarkets and other markets. Also, urbanization has a positive effect on infrastructure like transport and storage which assists in reducing wastage during the distribution of food and other crops (Tacoli, 2017). Urbanization also affects the kind of foods consumed and there is a shift from traditional foods to convenience foods. Although this may at times have adverse effects on the health of the people such as increased cases of obesity it can in one way or the other help in the achievement of food security through provision of foods. The positive and significant correlation that has been established in this study therefore means that where infrastructure and economic base is well developed, urbanization can go a very long way in the improvement of food security.

Urbanization also affects food systems in a manner that it boosts the demand for different foods especially processed foods that in turn boosts the evolution of improved food distribution networks and other modern approaches to food retailing thus improving food availability and access. Proper infrastructure in the urban areas for instance in the transport sector and proper storage infrastructure for perishable produce helps in minimizing post harvest losses and in the distribution of the food. Nevertheless, urbanization has its drawbacks: the additional stress on rural agriculture, resources, and the possibility of developing food injustice zones where the poor cannot afford quality foods. To overcome these challenges, it is necessary to improve and facilitate the sustainable and equitable food systems in the urban areas by improving the physical facilities, producers, and nutrition and food waste policies. The policy makers have to mainstream the food systems into other city development policies in order to ensure that everyone has food security and food resilience (Reardon & Timmer, 2012; Tacoli, 2017; Popkin, 2014).

4.7.6. Effective Policies and Governance Mechanisms within The Blue Economy Framework to Impact Food Security

Effective policies and governance mechanisms within the Blue Economy framework are crucial for enhancing food security. The Blue Economy emphasizes the sustainable use of ocean resources for economic growth, improved livelihoods, and the preservation of marine ecosystems. To impact food security positively, policies must focus on sustainable fisheries management, including the implementation of sustainable harvest and yield policies that ensure the long-term health of fish stocks while meeting current demands (Shelton & Sinclair, 2008). To promote sustainable capture fishing, several key policies should be adopted. Integrating fishery resources into broader food chains, as emphasized by Thilsted et al. (2016), can enhance global diets and food quality. Sustainable fisheries management requires the development of sustainable harvest and yield policies, as outlined by Shelton and Sinclair (2008).

Aligning fisheries management with Sustainable Development Goal 14 (SDG 14) on life below water improves policy coherence and sustainability, as demonstrated by Farmery et al. (2019) in Australia. Combating Illegal, Unreported, and Unregulated (IUU) fishing through legal reforms and technological advancements is crucial, as seen in China's recent fisheries law update (He & Zhang, 2022). Garcia and Staples (2000) highlight the importance of sustainability indicators and reference systems for tracking progress. The Ecological, Economic, Social, and Institutional (EESI) approach underpins sustainable fisheries, as applied in Canada's fisheries management (Stephenson et al., 2019). Effective fisheries policies should minimize environmental and social impacts, incorporating regulations and environmental charges, as suggested by Lam (2012). For small-scale fisheries, robust institutional and legal frameworks are essential to support both social and ecological sustainability (Mattos & Wojciechowski, 2018). By addressing critical issues such as Illegal, Unreported, and Unregulated (IUU) fishing, policy coherence with Sustainable Development Goals (SDGs), and the need for robust institutional and legal frameworks, governments can advance the sustainable development of fisheries and the communities that depend on them..

Another part of the blue economy is also sustainable aquaculture, which is all about the improvement of the fish farming industry with the least harm possible to the environment. This also assists in obtaining a good source of protein that is quality assured and does not exert pressure on the wild fish stock hence being part of the solution to the food security challenge. Other stakeholder groups include certification programs such as the Aquaculture Stewardess Council which also play a role of providing check points on ecological and social responsibility this puts pressure on the actors in the industry to embrace sustainability (Bush et al., 2013). Cash subsidies and tax incentives are critical in influencing sustainable practices through the provision of subsidies for green technologies (March et al., 2023). The improvement of technology in infrastructure such as the construction of proper aquaculture structures and proper water management systems enhances the growth of the industry while at the same time minimizing the impacts on the environment (Boyd et al., 2020).

Legal systems are important in the promotion of sustainable practice because issues like water pollution, habitat destruction and over fishing among others are well handled through policies and laws (Bush et al. , 2013). Community participation assists in engaging the people in the community in decision making concerning practices that are friendly to the environment and the community. It is beneficial in the creation of trust and is a more viable approach in the long run (Campbell et al. , 2020). Also, Marine Protected Areas (MPA) are established to conserve species and habitats and for fisheries management. Although MPAs has the possibility of increasing the fish stock after sometime they close areas to traditional fishing grounds and in the short run they may be detrimental to food security if other income generating activities are not carried out.

This study has shown that the diversification of blue economy policies which includes fisheries sector, urbanization, modernization, and food production and processing are important in improving food security. The combination of fisheries with other sectors of the economy offers the society with food security, nutrition and economic stability. The policies that are related to capture fisheries and aquaculture are central to the enhancement of food security and nutrition since these two sectors are key players in the global and national food supply chains (Thilsted et al. , 2016). Indonesian blue economy policy as a good example of government intervention to achieve rational use of marine and fisheries resources for long-term economic gains (Sari & Muslimah, 2020). Further, measures like increasing the areas of commercial fishing, improving the processing facilities, and reducing post-harvest losses are important for increasing the marine food production and contribute to the economic diversification (Sharifuzzaman et al. , 2019). In this regard, urban planning is instrumental in incorporating fisheries into local economy through activities such as fish markets and onshore fish processing that are new income sources and help in food security (Keen et al. , 2017). Improving the food production systems and food processing systems through the use of technology in farming and fishing is a central way of improving production and sustainability. The development of the blue economy also requires the support of local communities and cooperation between the stakeholders in the coastal areas including Sumatra to enhance the national food security (Adiprayoga & Samiaji, 2021).

CHAPTER V : CONCLUSION

5.1. Summary and Conclusion

The blue economy is now one of the key sectors of sustainable development, the achievements in the field of fisheries production, MPAs and the policy for the use of marine resources. In the whole world, the development of aquaculture has improved the production of fish and fishery products to feed the growing population, and as a source of protein. Moreover, creation of MPAs is an indication of growing concern towards the marine organisms and the need to protect some important habitats. However, as it will be demonstrated in this study, the determinants of the blue economy such as fishery production, government policy and marine bio-diversity did not have any correlation with food security in the sense used in this study. This means that while these factors are key in the blue economy, their effects on food security will be somehow counteracted by other factors like socio-economic status, efficiency in resource utilization and policies.

Another of the most important threats described in this work is the threat of climate change for food security. The findings showed that climate change particularly precipitation influenced food security in a significant and negative manner. It also leads to erratic and severe weather patterns that hamper crop and fish production in the seas and oceans hence a reduction in food production. This has been observed to impact on food systems and has brought out the fact that climate variability is a real issue when it comes to food systems and therefore there is need to find ways of mitigating the impacts. Some of these strategies include water conservation, sustainable farming and protection of marine and coastal ecosystems as some of the measures that can be used to stabilize food production and therefore food security in the face of climate change.

The findings of this study underscore the need for a more strategic and systematic approach to the stewardship of the blue economy that, besides the concern with sustainability, would address the issues of food insecurity. The blue economy has a great potential in the food security but more effective approach to the resources, better policies and more attention to the socio-economic conditions of the implementation of these measures are required. Because climate change is still a significant threat to food security in the future, it is important for future activities in the blue economy to be more in line with environmental and social goals.

5.2. Policy Recommendation

Improving the efficiency of the blue economy in the delivery of food security there is need to address the following policy areas. Firstly, the sustainable aquaculture and fisheries should be promoted because they can be the source of food and income in the future. The governments and the stakeholders should promote the use of eco-friendly methods in farming fish that affects production. These practices should be backed with research and development to know how they should be practiced in the region and how they can enhance food security.

Another important issue which should be solved is climate change. Because climate change poses a threat to food security, there should be policies that will help in mitigating the impacts of climate change on food production in the sea and on the land. This includes practices like resilient agriculture, water, and coastal ecosystems. Governments should also pay attention to mainstream climate change in the quest for the blue economy and guarantee that all aspects of the blue economy are climate proofed. It is also important to establish and build on the set of rules that will govern the blue economy in order to benefit from the resources without exploiting the future generations. This includes formulation of policies on sustainable fishing, protection of MPAs and control of environmentalism. The right regulations will assist in the achievement of the goals of economic development and at the same time protect the sea resources for future food security.

Urban planning should be used as a tool of increasing the production of food especially in the coastal and island regions that rely on fishing. This is why it is only when food security is considered in the planning of the urban environment that it is possible to plan for the right infrastructure and services that will support sustainable food systems. This could include; enhancement of local fish markets, enhancement of transport infrastructure for food vending, mainstreaming food security in disaster risk reduction and management. Local community should participate in the implementation of MPAs because this is vital for their success. The involvement of the people in the management of the MPAs is very important because the areas are well managed and at the same time the people feel that the area belongs to them. The governments can improve the efficiency of MPAs in the protection of the marine environment and the sustainable use when people of the community are engaged in the decision making process.

Finally, the increase in the number of activities in the sphere of the blue economy is crucial for its inclusion into the system of economic activities. This can be done through searching for other sources or products, this will help in diversification of the blue economy and hence reducing on the shocks that may be encountered when relying on one source or product. Thus, the governments should promote development of as many sectors of the blue economy as possible including tourism, renewable energy so that the blue economy could contribute to food security and development in various ways.

5.3. Limitation of the Study

This study has some limitations that have to be noted: The first of these was the question of availability of some of the data of the variables that were used in the analysis. The study was conducted through the use of secondary data from international organizations and this sometime led to some gaps or inconsistency. This means that the findings of this study are dependent on the validity and the amount of information that is obtained from these institutions. Also, the study used models from literature and there is need to improve and advance these models especially in the blue economy and its effects on food security. The blue economy is a branch of the green economy and as such is relatively new and the inputs are sometimes perceived as relatively small. This perception could in turn affect the policies on the blue economy for food security and how it will be rolled out.

For the future research, the authors suggest that more country-level approach should be used to get a better picture of the situation. This would explain why it is possible to get a different set of characteristics and context for different nations. Even more could be achieved if more detailed time series data was used by employing more complex econometric models such as VECM and VAR which could give the long-run and short-run properties of the blue economy.

Investigating other frameworks to understand how the blue economy supports the four dimensions of food security: More beneficial would be the terms of accessibility, availability and stability of the infrastructure as well as the usage of the infrastructure. What is required is such analysis to understand how the blue economy has affected food security.

The study in the blue economy also has to be more sensitive to the country-specific conditions, understanding that not all countries have enough marine area to build a proper blue economy. Qualitative research could supplement quantitative research by describing the geographical locations and usage channels of blue foods to provide a better and inclusive account of their contribution to food security.

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APPENDIX

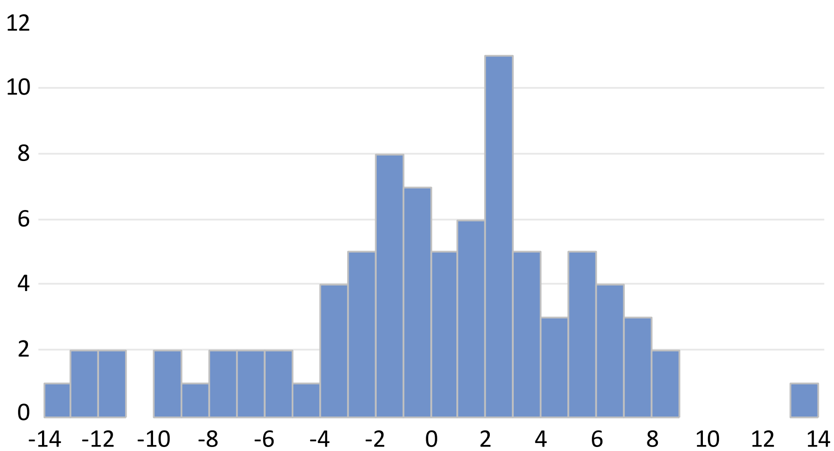
Appendix 1 : Statistics Descriptive

	FOOD_SEC...	FISHES_P...	GOVERNM...	CLIMATE_C...	MARINE_P...	POPULATION	TRADE_OP...	URBANIZAT...
Mean	63.22500	14.64288	0.872976	3.319130	8.313856	0.891393	62.90111	58.43850
Median	64.35000	14.59807	0.405000	3.366220	2.969939	1.067196	43.66106	56.68850
Maximum	83.80000	18.26925	4.150000	7.503800	44.33664	2.246032	134.0189	91.86700
Minimum	34.60000	12.36706	0.060000	0.483980	0.070000	-0.459952	24.70158	18.25600
Std. Dev.	13.32192	1.613040	0.992389	1.777585	12.75681	0.626929	37.38743	24.91094
Skewness	-0.227398	0.763881	1.597419	0.392788	1.777822	-0.033677	0.882022	-0.168904
Kurtosis	1.990212	2.851903	4.626618	2.640777	4.570038	2.237657	2.108286	1.620710
Jarque-Bera	4.292789	8.245964	44.98506	2.611597	52.87666	2.049963	13.67453	7.057948
Probability	0.116905	0.016196	0.000000	0.270956	0.000000	0.358803	0.001073	0.029335
Sum	5310.900	1230.002	73.33000	278.8069	698.3639	74.87703	5283.693	4908.834
Sum Sq. Dev.	14730.30	215.9576	81.74136	262.2642	13507.10	32.62232	116019.0	51506.06
Observations	84	84	84	84	84	84	84	84

Appendix 2 : Covariance Test

Correlation	FOOD_SEC...	FISHES_P...	GOVERNM...	CLIMATE_C...	MARINE_P...	POPULATION	TRADE_OP...	URBANIZAT...
FOOD_SECURITY	1.000000							
FISHES_PRODUC...	-0.066861	1.000000						
GOVERNMENT_P...	0.507449	-0.476298	1.000000					
CLIMATE_CHANGE	-0.230657	0.287474	-0.390542	1.000000				
MARINE_PROTEC...	0.589709	-0.422769	0.761554	-0.343499	1.000000			
POPULATION	-0.159543	-0.444004	0.255325	-0.010450	0.340007	1.000000		
TRADE_OPPENN...	-0.068611	-0.162578	-0.174165	0.274840	-0.250013	0.042405	1.000000	
URBANIZATION	0.886737	0.065574	0.434243	-0.060137	0.562769	-0.126721	-0.074108	1.000000

Appendix 3 : Normality Test



Series: Residuals
Sample 1 84
Observations 84

Mean	8.44e-15
Median	0.778172
Maximum	13.73015
Minimum	-13.34488
Std. Dev.	5.353365
Skewness	-0.496074
Kurtosis	3.254875
Jarque-Bera	3.672613
Probability	0.159405

Appendix 4 : Heteroskedastisity Test

Heteroskedasticity Test: Glejser
Null hypothesis: Homoskedasticity

F-statistic	5.845499	Prob. F(7,76)	0.0000
Obs*R-squared	29.39786	Prob. Chi-Square(7)	0.0001
Scaled explained SS	28.97349	Prob. Chi-Square(7)	0.0001

Test Equation:
Dependent Variable: ARESID
Method: Least Squares
Date: 07/25/24 Time: 18:05
Sample: 1 84
Included observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.712144	4.256908	2.046590	0.0442
LOG_FP__X1_	0.009246	0.272407	0.033942	0.9730
GP__X2_	0.892652	0.517011	1.726562	0.0883
CC__X3_	0.259465	0.205133	1.264864	0.2098
MPA__X4_	0.078933	0.048292	1.634495	0.1063
POP__X5_	-0.517597	0.613823	-0.843235	0.4017
TO__X6_	-0.016126	0.009657	-1.669967	0.0990
UR__X7_	-0.094668	0.018382	-5.150046	0.0000

R-squared	0.349975	Mean dependent var	4.136230
Adjusted R-squared	0.290104	S.D. dependent var	3.368084
S.E. of regression	2.837791	Akaike info criterion	5.014321
Sum squared resid	612.0322	Schwarz criterion	5.245828
Log likelihood	-202.6015	Hannan-Quinn criter.	5.107385
F-statistic	5.845499	Durbin-Watson stat	1.275536
Prob(F-statistic)	0.000019		

Appendix 5 : Autocorrelation Test

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	21.73126	Prob. F(2,74)	0.0000
Obs*R-squared	31.08100	Prob. Chi-Square(2)	0.0000

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 07/25/24 Time: 22:10
Sample: 1 84
Included observations: 84
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_FP__X1_	0.061131	0.432827	0.141236	0.8881
GP__X2_	0.251683	0.824795	0.305146	0.7611
CC__X3_	-0.140996	0.327300	-0.430784	0.6679
MPA__X4_	-0.068346	0.079611	-0.858495	0.3934
POP__X5_	0.613125	0.992412	0.617813	0.5386
TO__X6_	0.002629	0.015319	0.171597	0.8642
UR__X7_	0.015535	0.029547	0.525774	0.6006
C	-1.657391	6.780609	-0.244431	0.8076
RESID(-1)	0.638157	0.115598	5.520501	0.0000
RESID(-2)	-0.029452	0.120825	-0.243761	0.8081

R-squared	0.370012	Mean dependent var	-9.07E-15
Adjusted R-squared	0.293392	S.D. dependent var	5.353365
S.E. of regression	4.500038	Akaike info criterion	5.957392
Sum squared resid	1498.526	Schwarz criterion	6.246775
Log likelihood	-240.2105	Hannan-Quinn criter.	6.073722
F-statistic	4.829170	Durbin-Watson stat	1.967609
Prob(F-statistic)	0.000044		

Appendix 6 : Omitted Random Effects – Lagrange Multiplier

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided
(all others) alternatives

	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	43.38206	0.020093	43.40216
	(0.0000)	(0.8873)	(0.0000)
Honda	6.586506	-0.141749	4.557131
	(0.0000)	(0.5564)	(0.0000)
King-Wu	6.586506	-0.141749	3.798945
	(0.0000)	(0.5564)	(0.0001)
Standardized Honda	12.07420	0.001251	3.010137
	(0.0000)	(0.4995)	(0.0013)
Standardized King-Wu	12.07420	0.001251	1.919404
	(0.0000)	(0.4995)	(0.0275)
Gourieroux, et al.	--	--	43.38206
			(0.0000)

Appendix 7 : Redundant Fixed Effects – Likelihood Ratio

Redundant Fixed Effects Tests
Equation: Untitled
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	15.546936	(11,65)	0.0000
Cross-section Chi-square	108.319143	11	0.0000

Cross-section fixed effects test equation:
Dependent Variable: FS__Y_
Method: Panel Least Squares
Date: 08/11/24 Time: 08:35
Sample: 2015 2021
Periods included: 7
Cross-sections included: 12
Total panel (balanced) observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	50.50194	8.392145	6.017763	0.0000
LOG_FP_X1	-0.618651	0.537028	-1.151990	0.2529
GP__X2_	0.789380	1.019245	0.774475	0.4411
CC__X3_	-0.945856	0.404402	-2.338899	0.0220
MPA__X4_	0.080664	0.095203	0.847288	0.3995
POP__X5_	-2.887812	1.210102	-2.386420	0.0195
TO__X6_	0.017319	0.019037	0.909762	0.3658
UR__X7_	0.428593	0.036239	11.82698	0.0000

R-squared	0.838519	Mean dependent var	63.22500
Adjusted R-squared	0.823646	S.D. dependent var	13.32192
S.E. of regression	5.594472	Akaike info criterion	6.371828
Sum squared resid	2378.657	Schwarz criterion	6.603334
Log likelihood	-259.6168	Hannan-Quinn criter.	6.464891
F-statistic	56.37784	Durbin-Watson stat	0.386707
Prob(F-statistic)	0.000000		

Appendix 8 : Correlated Random Effects – Hausman Test

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	37.323875	7	0.0000

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
LOG_FP_X1	7.780320	-0.035254	46.637185	0.2524
GP__X2_	-0.956111	-0.233926	0.447615	0.2804
CC__X3_	-1.818900	-1.722668	0.320131	0.8649
MPA__X4_	0.006113	-0.026466	0.036731	0.8650
POP__X5_	4.695786	1.775110	0.541449	0.0001
TO__X6_	0.073447	-0.007869	0.006662	0.3191
UR__X7_	2.422514	0.567986	0.134422	0.0000

Cross-section random effects test equation:
Dependent Variable: FS__Y_
Method: Panel Least Squares
Date: 08/11/24 Time: 08:37
Sample: 2015 2021
Periods included: 7
Cross-sections included: 12
Total panel (balanced) observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-194.2540	99.93828	-1.943740	0.0563
LOG_FP_X1	7.780320	6.960064	1.117852	0.2677
GP__X2_	-0.956111	1.393440	-0.686152	0.4951
CC__X3_	-1.818900	0.913991	-1.990063	0.0508
MPA__X4_	0.006113	0.255623	0.023914	0.9810
POP__X5_	4.695786	1.495344	3.140271	0.0025
TO__X6_	0.073447	0.093492	0.785591	0.4350
UR__X7_	2.422514	0.377135	6.423462	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.955527	Mean dependent var	63.22500
Adjusted R-squared	0.943212	S.D. dependent var	13.32192
S.E. of regression	3.174643	Akaike info criterion	5.344219
Sum squared resid	655.0932	Schwarz criterion	5.894046
Log likelihood	-205.4572	Hannan-Quinn criter.	5.565245
F-statistic	77.58762	Durbin-Watson stat	1.467046
Prob(F-statistic)	0.000000		

Appendix 9 : Common Effect Model (CEM) Estimation Result

Dependent Variable: FS__Y_
Method: Panel Least Squares
Date: 08/11/24 Time: 08:39
Sample: 2015 2021
Periods included: 7
Cross-sections included: 12
Total panel (balanced) observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	50.50194	8.392145	6.017763	0.0000
LOG_FP_X1	-0.618651	0.537028	-1.151990	0.2529
GP__X2_	0.789380	1.019245	0.774475	0.4411
CC__X3_	-0.945856	0.404402	-2.338899	0.0220
MPA__X4_	0.080664	0.095203	0.847288	0.3995
POP__X5_	-2.887812	1.210102	-2.386420	0.0195
TO__X6_	0.017319	0.019037	0.909762	0.3658
UR__X7_	0.428593	0.036239	11.82698	0.0000

R-squared	0.838519	Mean dependent var	63.22500
Adjusted R-squared	0.823646	S.D. dependent var	13.32192
S.E. of regression	5.594472	Akaike info criterion	6.371828
Sum squared resid	2378.657	Schwarz criterion	6.603334
Log likelihood	-259.6168	Hannan-Quinn criter.	6.464891
F-statistic	56.37784	Durbin-Watson stat	0.386707
Prob(F-statistic)	0.000000		

Appendix 10 : Fixed Effect Model (FEM) Estimation Result

Dependent Variable: FS__Y_
Method: Panel Least Squares
Date: 08/11/24 Time: 08:47
Sample: 2015 2021
Periods included: 7
Cross-sections included: 12
Total panel (balanced) observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-194.2540	99.93828	-1.943740	0.0563
LOG_FP_X1	7.780320	6.960064	1.117852	0.2677
GP__X2_	-0.956111	1.393440	-0.686152	0.4951
CC__X3_	-1.818900	0.913991	-1.990063	0.0508
MPA__X4_	0.006113	0.255623	0.023914	0.9810
POP__X5_	4.695786	1.495344	3.140271	0.0025
TO__X6_	0.073447	0.093492	0.785591	0.4350
UR__X7_	2.422514	0.377135	6.423462	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.955527	Mean dependent var	63.22500
Adjusted R-squared	0.943212	S.D. dependent var	13.32192
S.E. of regression	3.174643	Akaike info criterion	5.344219
Sum squared resid	655.0932	Schwarz criterion	5.894046
Log likelihood	-205.4572	Hannan-Quinn criter.	5.565245
F-statistic	77.58762	Durbin-Watson stat	1.467046
Prob(F-statistic)	0.000000		

Appendix 11 : Random Effect Model (REM) Estimation Result

Dependent Variable: FS__Y_
Method: Panel EGLS (Cross-section random effects)
Date: 08/11/24 Time: 08:48
Sample: 2015 2021
Periods included: 7
Cross-sections included: 12
Total panel (balanced) observations: 84
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	35.60358	20.30488	1.753449	0.0836
LOG_FP_X1	-0.035254	1.343619	-0.026238	0.9791
GP__X2_	-0.233926	1.222317	-0.191379	0.8487
CC__X3_	-1.722668	0.717808	-2.399899	0.0188
MPA__X4_	-0.026466	0.169152	-0.156462	0.8761
POP__X5_	1.775110	1.301770	1.363613	0.1767
TO__X6_	-0.007869	0.045598	-0.172565	0.8635
UR__X7_	0.567986	0.088367	6.427554	0.0000

Effects Specification

	S.D.	Rho
Cross-section random	6.176947	0.7910
Idiosyncratic random	3.174643	0.2090

Weighted Statistics

R-squared	0.391779	Mean dependent var	12.05640
Adjusted R-squared	0.335759	S.D. dependent var	4.607238
S.E. of regression	3.754944	Sum squared resid	1071.570
F-statistic	6.993519	Durbin-Watson stat	0.848075
Prob(F-statistic)	0.000002		

Unweighted Statistics

R-squared	0.771640	Mean dependent var	63.22500
Sum squared resid	3363.810	Durbin-Watson stat	0.270162