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Blue Economy: Potential of Sustainable Fisheries Growth in Cape Verde Economy

João Antonio F. Brito
University of Cabo Verde
Praia, Cabo Verde
Joao.brito@docente.unicv.edu.cv

Supervisors:

Thanh Viet Nguyen, University of Akureyri: thanh@unak.is
Daði Már Kristófersson, University of Iceland: dmk@hi.is

ABSTRACT

Estimated fish stocks in Cape Verde range from 35,000 to 43,000 tonnes, and fresh fish is the main animal protein consumed by Cape Verdeans. The purpose of this study is to analyse the biological and economic sustainability of the fisheries sector in Cape Verde. Applying the Gordon Schaefer model to the data of fishing effort and harvest in the period between 1993 and 2021, the reference points of equilibrium, Effort at Maximum Sustainable Yield (E_{MSY}), Maximum Sustainable Yield (MSY), Effort at Maximum Economic Yield (E_{MEY}), Maximum Economic Yield (MEY), Effort at Open Access Equilibrium (E_{BE}), and Open Access Equilibrium (BEY), are analysed. The Input-Output model is used to compute the output and employment multiplier of the fisheries sector, assuming that the fisheries are in the maximum economic yield. The results point out that at the current situation, in 2021, the level of effort and harvest is higher than the level that guarantees the maximum sustainable yield, so it is necessary to reduce the fishing effort by 17 percent, and the harvest by 9 percent, to ensure sustainable growth at the biological level of the fisheries in Cape Verde. The results of the Input-Output model indicate that the output multiplier for the fishing sector is 1.743 and the employment multiplier is 1.265. Considering the hypothesis in analysis, the results suggest that, if the objective of policy makers is to increase the output multiplier effect, they should seek to increase the number of industrial vessels, but if they want a higher employment multiplier, promoting the artisanal vessels is the best solution.

Keywords: Bio-economic model; Input-Output model; Fisheries; Cape Verde

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1 INTRODUCTION

1.1 Problem Statement and Theme Presentation

The Food and Agriculture Organisation report (FAO, 2020) points out that global fish consumption increased at an average annual rate of 3.1 percent from 1961 to 2017, a rate almost twice that of annual world population growth (1.6 percent) for the same period, and higher than the rate of all other animal protein foods (meat, dairy, milk, etc.), which increased by 2.1 percent per year. The per capita fish consumption grew from 9.0 kg in 1961 to 20.5 kg in 2018, by about 1.5 percent per year. The United Nations (United Nations, 2022) argues that 40 percent of the world's population live near coastal areas, more than 3 billion people utilize the oceans for their livelihood, and 80 percent of world trade is achieved using the seas. The oceans, seas and coastal areas contribute to food security and poverty eradication.

According to (European Commission, 2021), in 2018, the European Union Blue Economy employed close to 4.5 million people and generated around €650 billion in turnover (which is 13 percent increase compared to 2009), €176 billion in gross value added (which is 5 percent increase compared to 2009), €68 billion in gross profit (which is 14 percent increase compared to 2009) and €24,020 in average annual salary (which is 14.2 percent increase compared to 2009). This impressive development in the blue economy has been driven by a combination of population growth, rising incomes, urbanization, strong expansion of fish production and more efficient distribution channels, (FAO, 2014).

(FAO, 2014) pointed out that Small Island Developing States (SIDS) has specific physical, biological, social and demographic diversity, and limitations to economic development, that increase the importance of oceanic, coastal, and freshwater fisheries and aquaculture for the economic development and government revenue of these countries. Besides, the specific characteristics of SIDS provide opportunities for fisheries, aquaculture, livelihoods, and food systems economic growth.

The report from (UNCTAD, 2016), points out that the fish sector plays a substantial multifunctional role in SIDS. The contribution of international trade flows in fish (exports + imports) in Gross Domestic Product (GDP) is bigger in SIDS (about 3 percent) compared with Least Developed Countries (LDCs) (about 0.4 percent), Developing Economies, excluding LDCs and China (about 0.3 percent), Developed Economies (about 0.2 percent) and Transition Economies (about 1 percent).

Also, (UN-OHRLLS, 2020), consider that SIDS have the potential to utilise the coastal and marine resources under their control to ensure food security through sustainable fisheries, aid in poverty eradication by creating sustainable jobs and livelihoods, and through effective conservation measures to mitigate the impacts of climate change on their societies. The SIDS through their Exclusive Economic Zones (EEZs), control some 30 percent of all oceans and seas, (UN-OHRLLS, 2020).

SIDS must protect, restore, and improve the health, productivity and resilience of oceans, coastal and inland ecosystems, and maintain their aquatic biodiversity, in the sense of sustainably using and managing aquatic resources for present and future generations, (FAO, 2014). However, SIDS face, sometimes, lack of expertise and institutional capacities, along with a lack of financial support to derive a full benefit from the ocean and its resources in sustainable ways, and in addition, SIDS are among the most vulnerable countries to natural disasters and climate change, (UN-OHRLLS, 2020).

(UN-OHRLLS, 2020) pointed out that the fisheries and aquaculture sector in the Pacific SIDS provide income and food for more than 200 million people across the region, and accounts for 84 percent of the global labour force employed in the region, in addition to being the primary generator of public revenue for governments in the region. The report indicated too, that the production and export of tuna is the primary catalyst of the fishing sector for Pacific SIDS, where some country's tuna fisheries can provide more than 10 percent of national GDP and make up 50 percent of exports. About 1.5 million metric tonnes of tuna (this amount represents 30 percent of the global tuna market) are caught each year in the waters surrounding Pacific SIDS.

Nonetheless, according to (UN-OHRLLS, 2020) measures are needed to enhance food security to lessen the impacts of external shocks including climate change. Whereby, the governments in SIDS face great challenges to improve the fisheries sector management system and increase their contribution to GDP, to government revenue, and to economic development.

Cape Verde is a SIDS with an Economic Exclusive Zone of around 800,000 km^2. Estimated fish stocks in Cape Verde range from 35,000 to 43,000 tonnes. Fresh fish is the main animal protein consumed by Cape Verdeans. Various development programmes (as: *II Plano Nacional de Desenvolvimento, 1986-1990; Plano Nacional de Desenvolvimento - 2002-2005; Programa do Governo, VII Legislatura 2006-2011; Plano Estratégico de Desenvolvimento Sustentável 2017/2021)* in Cape Verde, define objectives for the development of the fisheries sector, but the data, demonstrate that the announced investments and efforts have been reflected in a greater national fishing capacity (in terms of value of fisheries sector in GDP, it is decreasing, from around 10 percent in 1980 to less than 1 percent in 2020, and the amount of fish catches by national vessels, range from an average of 11,200 tons in the period 1980-85 to an average of 11,130 tons in the period 2015-2020).[1] According to (Ferreira, 2011) and (World Bank, 2018) the fisheries sector in Cape Verde faces many challenges, mainly lack of professionalization and entrepreneurial vision of artisanal fishermen, deficient communication between institutions with poor management of the fisheries sector, and limited access to high-value markets.

The development of a sustainable fisheries sector included in the blue economy is identified in Cape Verde's development plan (Plano Estratégico de Desenvolvimento Sustentado, 2017-2021) as very important and necessary sector to bring diversity to the economy, reduce the country's vulnerability and thus contribute to greater robustness of the economy and increased social well-being. Citing the (World Bank & United Nations, 2017), blue economy means a sustainable exploration of the oceanic resources, so it is pertinent to carry out an analysis of the potential of sustainable growth of the fisheries sector in Cape Verde and its impact on economic growth, measured by GDP.

However, reviewing the existing bibliography, there is a shortage of recent studies that analyse the potential of the fishing sector in Cape Verde (such as the study carried out by (Evora, 2016) and (Fortes, 2019)). Thus, this present study, intends to go further, and use the "Standard" Bio-Economic Models (The Gordon-Schaefer Fisheries Model) to estimate the potential for an ecological sustainable growth of the fishing sector in Cape Verde, and thereby analyse the sector's direct and indirect contribution to GDP growth and employment, by using the Input-Output model. This study intends, also, to use benchmark analysis to propose policies that can boost the fishing sector in Cape Verde, considering the best practices that exist in peer countries.

[1] The data is from FAO (2021); INE (2015;2017;2021;2022)

From the above information, the intention is for the present study to be relevant and pioneering, however, this topic has a large field of investigation that needs to be covered.

1.2 Goals and specific objectives

The main goal of this research is to answer these starting questions: Is the growth of the fisheries sector in Cape Verde sustainable? What is the total effect of the fisheries sector on GDP growth?

Specific objectives

The specific objectives are outlined below:
- Bibliographic survey on the blue economy and fisheries sector;
- Analyse the current state of the fisheries sector in Cape Verde;
- Determine and analyse the potential of sustainable fisheries sector growth in Cape Verde;
- Determine and analyse the total contribution of fisheries sector to GDP growth in Cape Verde;
- Propose recommendations for the improvement of fisheries sector in Cape Verde.

1.3 Structure

This paper starts in the first chapter with an introduction, where the problem statement and presentation of the theme, the objectives, and the structure of the paper are described. The second chapter presents a literature review, focusing on the blue economy, the development of a sustainable fisheries sector and on the direct and indirect contribution of the fisheries sector to GDP. The third chapter provides an evolutionary analysis of the fisheries sector in Cape Verde. The fourth chapter is dedicated to the methodology, the “Standard” Bio-Economic Model, the Input-Output Model, and the data used in the empirical study. Chapter five estimates the model and analyses the results. The conclusion and recommendation of this paper is to be found in chapter six.

2 LITERATURE REVIEW

The key themes to be presented here are the concept of blue economy, and the role of the fishing sector in the blue economy, mainly in Small Island Developing States (SIDS). A literature review is carried out on the sustainable growth of the fisheries sector, and on analyses of the fisheries sector impact on economic growth using input-output model.

2.1 Blue Economy - Concepts and an Overview

The term ‘Blue Economy’ first emerged during the 2012 United Nations Convention on Sustainable Development (UNCSD), or “Rio+20 conference”, however, its roots lie in the earlier 1992 Rio Earth Summit, (Voyer, Quirk, McIlgorm, & Azmi, 2018). According to (Voyer, Quirk, McIlgorm, & Azmi, 2018) quoting (Silver, Gray, Campbell, & Gruby, 2015) and (Whisnant & Reyes, 2015), it was in response to an international push to ‘green’ on global economy, that SIDS began emphasizing the importance of the ocean and marine economy, promoting the concept of a Blue Economy. And, since that time there has been increasing interest in the Blue Economy around the world.

In the current literature, there are several concepts/views/definitions of Blue Economy. (UNCTAD, 2014) defined Blue Economy as an ocean economy that aims at the improvement of human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. The report, assumes that Blue Economy includes activities that are not natural resource intensive, supports sustainable patterns of consumption and generates lower or no greenhouse gases emissions.

(European Commission, 2021) considers, also, a broader concept of Blue Economy, that includes all sectoral and cross-sectoral economic activities based on/or related to the oceans, seas, and coasts. These activities are divided in two:

- **i)** Marine-based activities - which include the activities undertaken in the ocean, sea, and coastal areas, such as marine living resources (capture fisheries and aquaculture), marine minerals, marine renewable energy, desalination, maritime transport, and coastal tourism; and
- **ii)** Marine-related activities - which use products and/or produce products and services from the ocean or marine-based activities like seafood processing, biotechnology, shipbuilding and repair, port activities, technology and equipment, digital services, and others.

The World Bank and The United Nations (World Bank & United Nations, 2017) define Blue Economy as comprising of a range of economic sectors and related policies that together determine whether the use of oceanic resources is sustainable. These institutions add that the "Blue Economy" concept seeks to promote economic growth, social inclusion, and preservation or improvement of livelihoods while at the same time ensuring environmental sustainability of the oceans and coastal areas.

The report (AU-IBAR, 2019) considers Blue Economy as a new approach to economic exploitation of the resources of oceans, lakes, rivers, and other bodies of water and the conservation of aquatic ecosystems. The report assumes too, that Blue Economy represents a basis for rational and sustainable use and conservation of natural resources (both renewable and non-renewable) and their natural habitat.

According to (Sari & Muslimah, 2020), Blue Economy concept is related to two principles. First, nature's efficiency, where the Blue Economy imitates the natural ecosystem and works in accordance with what nature provides efficiently and does not reduce but instead enriches nature. The second principle is zero waste, which means that waste from one source is becoming food or energy sources for the other, and the living systems in the ecosystem will become balanced and sustainable.

A Blue Economy integration model in sustainable fisheries management, necessarily involves five aspects, (Sari & Muslimah, 2020):

- **i)** Innovation and technology - that allow techniques to manage fisheries to be more efficient, and produce more than before;
- **ii)** Ecosystem and environment sustainability - the fisheries management has to be concerned with the sustainability of fish resources, since these resources are limited and need to be preserved for the future, on the other hand, the fishing methods used have to avoid damaging the ecosystem, overfishing, catching small and protected fish, and must minimize waste;

- **iii)** Alignments in fishermen and fish farmers - the economic development in the blue economy must be able to improve the people´s prosperity, and the human resource capabilities of fishermen and fish farmers, so they can improve the quality and capacity of their businesses, so in the end they can improve their fisheries and possibility to create new jobs;
- **iv)** Government policy – there are three main bases for the formulation of policies related to fisheries management, namely: First, input control, which is input from fisheries activities that can be controlled, includes policies to regulate fisheries management areas, and the number of fishing vessels allowed for fishing. Second, output control, is the output from fisheries activities that can be controlled, which includes the amount of catch allowed and the level of fish utilization analysis in a fisheries management area. Third, technical measures, that are permitted in fishing activities, including the types and methods of fishing allowed, and the time of fishing allowed;
- **v)** Research and development - includes the activities and efforts to find new ways to manage fisheries corresponding with the blue economy principles, and research and development efforts must be carried out based on open science principles, which will push fishery businesses to develop innovations and increase their fisheries production.

From the above, it is possible to conclude that Blue Economy is a comprehensive concept linked to activities related to the oceans, seas, and coasts. These activities must be carried out in a sustainable and socio-economically equitable way and without compromising the natural functioning of ocean ecosystems. In this sense, the development of fisheries sector, within the perspective of the Blue Economy, must be conducted in such a way as to ensure the sustainable growth of resources and avoid their overexploitation, besides promoting economic growth, social inclusion, and preservation or improvement of livelihoods. (Boonstra, Valman, & Björkvik, 2018) consider that capture fisheries have a large impact on marine ecologies, and the growth on the fisheries must be 'blue', i.e. sustainable.

2.2 Sustainable Growth of Fisheries Sector

There are several works that analyse the sustainability of fisheries sector growth at national, regional, or global level, using different models. Considering the objectives of the present work, the literature review is carried out, considering the studies on countries with fisheries sector characteristics close to those of Cape Verde.

The concept of sustainable development has been widely recognized since the release of the report of the United Nations' World Commission on Environment and Development, in 1987, (Flaanten, 1991). For (Flaanten, 1991), the renewable resources such as forests, wildlife, and fish, the multispecies framework sustainable development must take place for combinations of stocks within the sustainable yield area. Harvesting at the maximum sustainable yield frontier (MSF) may at first glance seem evident from a biological point of view. However, from an economic point of view, MSF harvesting is optimal only in special cases, such as when there is no discounting and harvest costs are zero.

(Evora, 2016) developed a bioeconomic model to identify optimal management of the pelagic fisheries, applied to the industrial pelagic fisheries in Cape Verde, during the period 2003 to 2012. He concluded that, in 2012, the fishery situation indicates a slightly excessive fishing effort. The result point that in order to achieve maximum sustainable profits, around 111,602 thousand CVE annually (equal to 22 percent of the total revenue), the fishing effort must be reduced from 6,264 to 3,752 days at sea in a long-term sustainable option. However, in the short term, it must only reduce from 6,264 to 5,042 days at sea, to achieve the maximum sustainable profits of around 32,827 thousand CVE annually (equal to 6 percent of the total revenue). The author proposed implementation of the individual transferable quotas (ITQ´s) system to reduce the fishing efforts and rebuild the fish stock, as the main source for improvement of fisheries management in Cape Verde.

There is another study about the management of the fisheries sector in Cape Verde, developed by (Fortes, 2019). The author analysed the economic viability of the artisanal fishery sector and the management system, in Cape Verde and by island. He concluded that the fishing effort is above the estimated level associated with maximum economic yield from most of the islands. Thereby, to move towards sustainable and efficient fishing he suggested a change in the number of vessels in the islands of Boa vista, by -60%, Brava, by 9%, Fogo, by -57%, Maio, by -30%, Sal, by 14%, Santiago, by -13%, Santo Antão, by -7%, Sao Nicolau, by -19% and Sao Vicente, by -29%. On average the reduction needed was -19%, of total number of vessels, which means a decrease from 1,827 to 1,483 artisanal vessels. The main problems identified was low salaries, weak capacity to invest and strong dependence on one fishing gear. The study suggested some measures that could help to improve the overall management and move the fisheries towards more biological, economic, and social sustainability in Cape Verde, such as limiting the level of effort, revision of legal framework, financial support to the sector, one decision centre for the sector, and more efficient control, monitoring, and surveillance systems.

(Pascoe, et al., 2020) developed a bioeconomic model that captures the key elements of such a fishery to test a range of potential harvest strategies in Australia. The model was developed as a long-term optimisation model to identify target reference points to achieve multispecies maximum economic yield, and used a dynamic recursive optimisation model, which includes more realistic representation of fishers' behaviour, such as discards and trading of under-caught species quotas. They concluded that the use of proxy target reference points can result in short-term economic benefits at the cost of slower stock recovery and higher discarding. In addition, limiting the number of species subject to quota controls may also prove beneficial in multispecies fisheries, while ensuring quota markets are efficient is likely to produce benefits irrespective of the harvest strategy adopted.

(Nguyen, Nguyen, & Le Van, 2018) assess sustainable development and the potential for green growth of the marine capture fisheries in Vietnam, by using the "standard" bio-economic models, in the period 1976 to 2016. The authors concluded that Vietnam's marine capture fisheries are unsustainable, and the fishing effort needs to be reduced about 0.35 and 0.39 of present effort to achieve the maximum sustainable yield and maximum economic yield, respectively. The results show that fishing effort since 2012 has exceeded the fishing effort at MSY, the fishing effort is more than 1.5 times higher than the fishing effort corresponding to the MSY and more than 1.6 times higher than the fishing effort corresponding to the MEY. The potential for green growth in the fisheries was estimated to be about 7.3 billion USD, which was higher than the export value for fisheries and aquaculture products in Vietnam in 2016. For better management, they suggest the inclusion of public subsidies to environmentally friendly industries, reducing the "trash" fish catch and more efficient regulations, more effectively enforced.

The effects of biological, economic and management factors on tuna and billfish stock status was studied by (Poins, Branche, Melnychuk, Jensen, & Brodziak, 2017). The study indicates that commercial tunas and billfishes (swordfish, marlins, and sailfish) provide considerable catches and income in both developed and developing countries. The study shows too, that tuna stocks were more depleted if they had high commercial value, whereas long-lived species, had small pre-fishing biomass and were subject to intense fishing pressure for a long time. The authors suggest some control rules to improve the management of this species, such as implementing and enforcing of total allowable catches (TACs), they state that where applicable, TACs should be considered as a primary tool for managing depleted stocks as they could lead to faster stock rebuilding, input controls, and minimum size regulations or seasonal closures which are important for reducing fishing pressure.

From these studies presented, we can conclude that to ensure efficient management of resources, it is necessary to identify maximum sustainable yield and implement policies, such as reducing the effort, to achieve sustainable growth in the fisheries sector.

2.3 Socioeconomic Effects of Fishing Activities to GDP: Input-Output Models

Since Leontief's seminal contributions (1936), the use of the Input-Output (I-O) framework has grown enormously, and it is currently an essential component of many types of economic analysis, (Rodríguez-Rodríguez, Ballesteros, Valeiras, & Bellido, 2019). (Lee G. & Seijo, 2010) define the I-O model as a linear inter-sectoral model indicating the relationship between the productive sectors of a given economic system.

In the literature, there are several studies that used the I-O model to analyse the direct, indirect, and induced impact of the fisheries sector on the economy. It is not the goal of this work to provide a detailed literature of studies on the I-O model, so only some references of existing works are made.

According to (Garza-Gil, Surís-Regueiro, & Varela-Lafuente, 2017), to carry out fishing activities, the economic agents must also procure goods and services from other economic sectors. Furthermore, part of the labour income generated by fishing is spent in turn on satisfying the everyday consumption needs of households. These connections and ramifications result in increased output, income, and employment in other sectors. Such effects can be estimated by using the Input-Output multipliers from the classic model of demand. These effects can be direct effects (those that the activities themselves produce e.g., level of output and contribution to GDP and employment), indirect effects (consist of outcomes in the sectors that provide the inputs for fishing as well as the subsequent, related outcomes for their respective supplier sectors), and induced effects (the effects of income on household expenditures and on gross capital formation).

(Briggs, Townsend, & Wilson, 1982) resorted to an Input-Output model to analyse the fisheries on the State of Maine in US, and they conclude that increasing herring landings by $1.00 leads directly and indirectly to an increase in income in Maine of $0.73. And the $0.73 of income is responsible, for an additional $0.74 of income (the induced income effect), since the $0.73 is spent on consumption items. Thereby, the total impact upon income per dollar of herring landings is $1.47. They, also, estimated and concluded that Maine's 1980 landings, valued at $90 million, ultimately generated $240 million in income in Maine and the fisheries related income accounted for 2.8 percent of Maine's 1980 total personal income of $8.6 billion.

In their study, (Sharma, Peterson, Pooley, Nakamoto, & Leung, 1999), also used the Input-Output model to compute output, income, and employment multipliers for Hawaii's fishery sectors, and to estimate their contributions to the state economy. The authors modified the I-O table to contain 72 industry sectors, including 4 fishery sectors and 68 non-fishery sectors. They conclude that in 1992, altogether Hawaii's fisheries generated $98.2 million of output, $33.2 million of labour income, $37.1 million of value added, and generated 1,426 jobs.

(Lee & Yoo, 2014) demonstrate the feasibility of extending the application of the I-O analysis. They examined some useful models (the demand-driven model, inter-industry linkage effects, the supply-driven model, and the Leontief price model) in applying I-O analysis to the fishery sectors in the Korean national economy, for the period 1995-2010. The study indicated that relative to the two fishery sectors, aquaculture ranks higher than capture fisheries overall. Sectoral impacts in all the fishery industries appear to rank higher in specific sectors. The inter-industry linkage effect analysis reveals that fishery industries are more able to absorb the products of related industries, rather than other industries using them as inputs. Whereby, the results of the study provide useful insights for formulating fishery policies in Korea.

Using the I-O methods to assess the effects of fishing and aquaculture on the Galicia economy, (Garza-Gil, Surís-Regueiro, & Varela-Lafuente, 2017) found that the combined production, in 2013, was almost a million euros (direct effects), and that production was estimated to account for nearly 2% of Galicia economy's value added and for more than 17,000 full-time jobs. Together these contributions generate an estimated carryover (indirect and induced) effect of about €1.7 billion and €975 million, respectively, on the production and gross value added to Galicia's economy. Fishing and aquaculture were responsible for creating the equivalent of more than 14,000 full-time jobs in other economic activities.

The I-O framework can, also, be used for policy and investment targeting propose. (Morrissey & O'Donoghue, 2013) analysed the role of the marine sector in the Irish national economy, by using the I-O framework. They concluded that three marine sectors, water transport, seafood processing and water construction, have backward linkages greater than one, which indicate that the Irish marine sector has more strength in absorbing products of related industries, rather than being used as an input by other industries. This implies that the marine industry has greater impacts in terms of investment expenditures on the national economy than other sectors. This conclusion can be used to guide public investment decisions.

In the literature, there are other authors who chose to make some changes to the I-O model. It is the case of (Failler, Pan, Thorpe, & Tokrisna, 2014), who developed a hybrid input-output model (combines both the Ghosh supply-driven model and the Leontief demand-driven model into a unique model framework) to quantify the economy-wide impact of capture fisheries on the economy. The authors elaborated the sectoral linkage between the fisheries and non-fisheries sectors and the fish chain from harvesting to processing and marketing, connecting "bottom-up" capture fisheries to "top-down" economic structure, which allowed for the development of a new input-output linkage model to measure the multiplier effect of a change in fishing effort of bottom-up harvesters on the whole economy. They concluded that capture fisheries make a much greater contribution to the economy than is traditionally thought. A US$1 million increase in fishing effort applied within most fisheries can generate as much as a tenfold increase in the value of GDP. On the other hand, if fisheries (such as the Otter board trawler and the Anchovy purse seiner) are regulated to protect fish stocks, economic losses are relatively modest, unless all fisheries operations cease, when GDP will drop by around one-fifth.

(Seung & Waters, 2006) presented three reasons why the I-O models have been extensively used on analysing the fisheries economic impact: first, within the I-O framework, it is possible to investigate the detailed inter-industry relationships in a regional economy; second, the models are relatively easy to implement with available software and data; third, I-O models have less extensive data requirements than Computable General Equilibrium (CGE) models.

According to (Garza-Gil, Surís-Regueiro, & Varela-Lafuente, 2017) the I-O methods have been applied to the fisheries sector for two purposes: analysing the relevance of marine activities for coastal economies in terms of production, income, and employment; and estimating the possible socioeconomic effects of political decisions made about the management of coastal and marine activities. Also, the authors defend that Input–output analysis should be of interest to policy makers because it enables ex-ante simulations of the impact of maritime policy measures (under various scenarios and while quantifying the effects in terms of income and employment), and so provides a solid basis for political decision making.

(Lee & Yoo, 2014) propose the Input-Output model as quite a useful framework for analysing fisheries-related issues in the context of economic impacts, as it recognizes the interdependence of all sectors of the economy.

3 BLUE ECONOMY AND THE FISHERIES SECTOR IN CAPE VERDE

3.1 Blue Economy: Policies and Perspectives for the Fishery Sector

In 2015, Cape Verde adopted the Charter to promote blue growth, by stimulating the sustainable development of the ocean and coastal areas and maximising economic and social benefits for populations, (UNESCO - IOC, 2021). The Charter is based on eight strategic options: fishing and aquaculture; trade, food security; environment; aquatic ecotourism; maritime transport and port development; urban development and responsible coastal management; maritime services and scientific research; and maritime safety. In 2020, Cabo Verde announced the Charter for the Blue Economy Policy, which adds the following strategic areas: ocean, climate change and pollution; maritime spatial planning and enhancement of coastal areas; and renewable energies, (UNESCO - IOC, 2021).

The Agenda 2030 of Cape Verde assumes “The Blue Economy” as an important pillar to promote a model of safe, equitable and sustainable socio-economic development. In the Strategic Plan for Sustainable Development 2017-2021 of Cape Verde, the Government endorse Blue Economy through the following: promoting the exploitation of the economic potential of the oceans; encouraging activities that lead to decent employment and professional training in Research & Development (R&D) for the development of the Blue Economy; and, inspiring multidisciplinary approaches to Research, Development & Innovation (R&D&I), and innovative consortium projects between companies and R&D institutions.

According to (UNESCO - IOC, 2021), on September 29, 2020, the Declaration of Commitment to Sustainable Development - Cabo Verde Ambition 2030 was adopted, and Cape Verde assumed the ambition that, in 2030, the country will be a consolidated, modern, and inclusive democracy, as well as a blue, digitalised, emerging and resilient nation that promotes a circulation economy integrated into the Economic Community of West African States (ECOWAS) in the Middle Atlantic.

Cape Verde identified the following eight sectors as part of Blue Economy, (UNESCO - IOC, 2021): i) Ports, development of maritime transport and logistics; ii) Fisheries and aquaculture; iii) Tourism and water sports; iv) Maritime services; v) Ship repair and construction; vi) Environmental and marine ecosystem protection, coastal and marine land management; vii) Desalination of water, marine energy, and ocean resources; and, viii) Education and research.

3.2 Fishery Sector - An Overview

The Exclusive Economic Zone of Cape Verde (800,000 km^2) represents about 9.4 percent of the total area of Sub-Saharan Africa. The estimated fish stocks in Cape Verde range from 35,000 to 43,000 tons. Nonetheless, the direct contribution of fisheries to Cape Verde's GDP (1 to 3 percent) is much lower than that of other countries in the region, such as in Guinea-Bissau (7 to 10 percent), Senegal (4.9 percent) or Sierra Leone (9.4 percent), (Ferreira, 2011).

The fishing in Cape Verde is divided into artisanal fishing, which is carried out in vessels called "open mouth vessels" and directed towards coastal fishing, and semi-industrial and industrial fishing, which is carried out in larger vessels, that support engines with greater autonomy. In 2011, there were 1,239 artisanal boats and 3,717 fishermen, and, in 2017, it increased to 1,583 boats and 5,078 fishermen, respectively. For the semi-industrial and industrial fishing, there were 90 vessels and 1,092 fishermen in 2011, and it grew to 119 vessels and 1,209 fishermen, in 2018, according to data from (INE, 2015) and (INE, 2022). In 2021, the information contained in (INE & IMar, 2022) shows that were about 1,463 artisanal vessels, of which only 70 percent was active, and around 127 national semi-industrial and industrial vessels, of which only 58 percent was active.[2]

Figure 1 demonstrates that from 1975 (year of Cape Verde independency) to 1980, there is a considerable increase in the capture of fish (going from around 3,500 tons to 14,500 tons), which is associated, in part, with the increase in the number of vessels and captures of new species (as skipjack tuna and yellowfin tuna). In the eighties and nineties there is an oscillating behaviour in fish capture, varying between 6,500 tons to 11,500 tons, which can be explained, partly, by the fact that the main species fished in Cape Verde are migratory (the tuna species). There is a strong growth since 2005, which is associated with the partnership agreement in the field of fisheries between the European Community and the Republic of Cape Verde. The larger growth in fish capture in the period 2013 to 2016 is linked with the greater capture of the species skipjack tuna (which is a migratory species).

[2] The artisanal vessels usually are 3.5 to 8 meters long and 9 years old. Most are constructed by wood and fibre (48%) and wood (44%). Regarding the types of gear used by these vessels and respective types of fish, Cabo Verde had, essentially: Beach seines (for sardinella, clupeids); Purse seines (for small coastal pelagic fish); Hand lines (for coastal demersal fish and pelagic fish); Stick-and-line (for tuna and related species); and, Fixed gillnets (for black-spotted gillnets, other demersal or epibenthic species). The industrial vessels are heterogeneous, ranging in length from 8 to 25 meters. The types of gear used by these vessels are, mainly: Purse seine (for mackerel scads and others) and Specialized bottom traps (for Cape Verde spiny lobster).

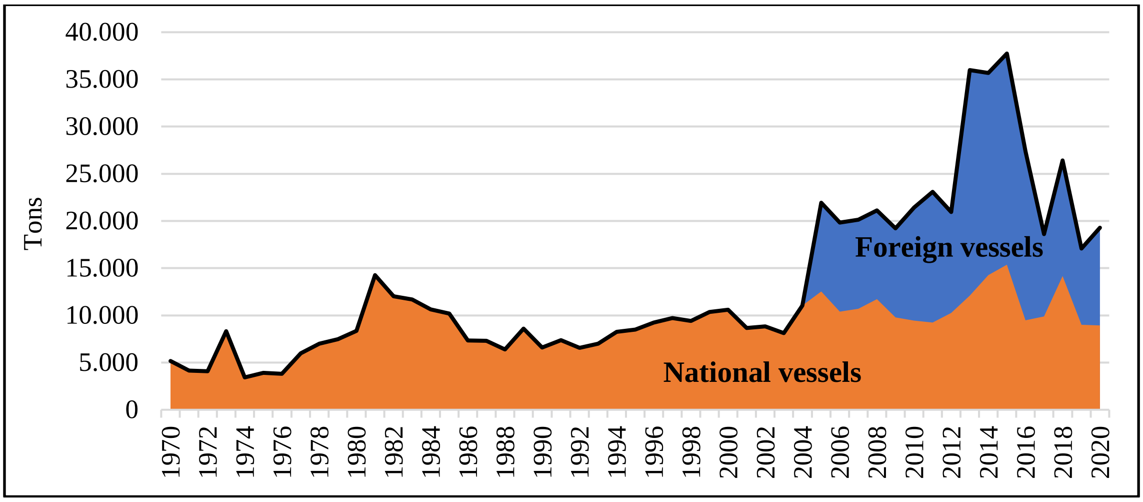

Figure 1 - Evolution of Fish Captured in Cape Verde
Source: (FAO, 2022)

According to Figure 2 tuna is, by far, the most fish species captured in Cape Verde, representing around 60 percent of the total fishery between 1970 and 2020. Follow the marine fishes with a weight of 18 percent, as the second most fished species. The tuna fishing began in 1970, but it was only from 1980s that tuna became the most fished species in Cape Verde. The most fished tuna species are skipjack (43%) and yellowfin tuna (37%).

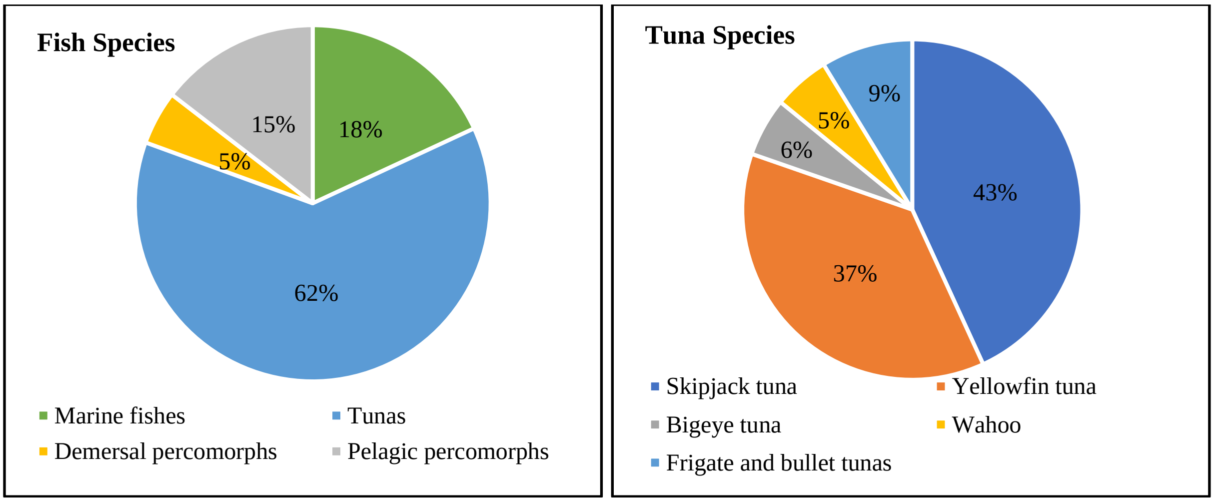

Figure 2 - Fish Species and Tuna Species Captured in Cape Verde
Source: (FAO, 2022)

When considering only the national vessels, Figure 3 presents that the capture of fish by artisanal vessels has remained more or less constant, around 4,000 tons, in the period 1990 to 2021, but on the other hand, semi-industrial and industrial national vessels registered a growing trend during the 90s. In the period from 2000 to 2004 there was a reduction in fishing due to the EU embargo, because Cabo Verde not complying with sanitary conditions. A new growing trend is registered in the period 2012 to 2015, the catches go from 6,000 to 11,000 tons, which is explained, essentially, by the increase in the number of vessels and because the main species fished are migratory. After this period, the capture has been oscillating, around 5,500 tons.

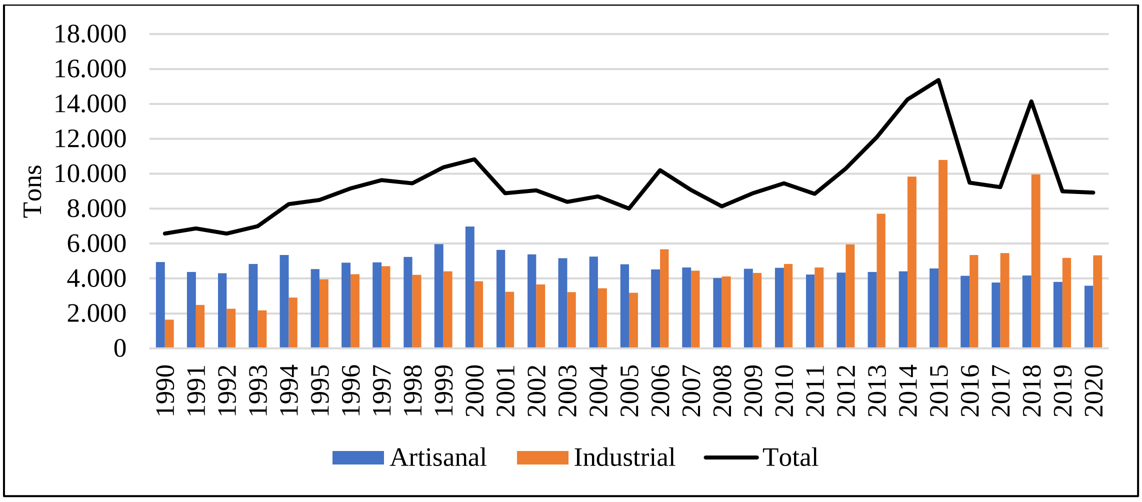

Figure 3 - Evolution of Fish Captured (tons) by National Vessels
Source: (INE, 2015), (INE, 2017), (INE, 2018) (INE, 2022)

Analysing the impact of the fisheries sector on the economy, by figure 4, the contribution of fisheries sector on Cape Verde economy decreases from around 10 percent of GDP in 1980 to less than 1 percent of GDP in 2020. This demonstrates a significant loss in the value of the fisheries sector in the economy, despite the increase in the number of vessels and the fisheries agreement with the European Union, which allowed for increased financing of the economy.

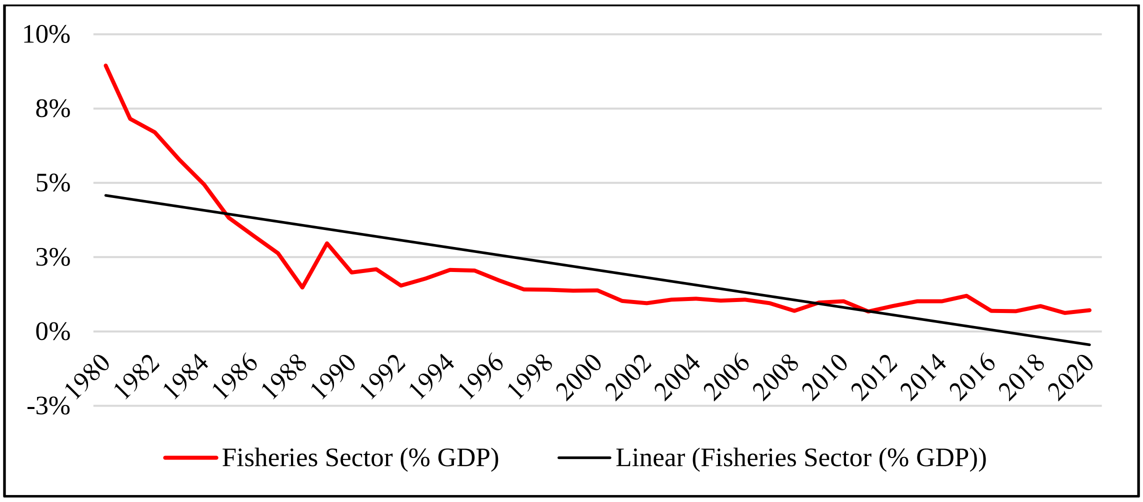

Figure 4 - Fisheries Sector (% GDP)
Source: (INE, 2022)

The data in figure 5 indicate that in the period between 1980 and 2004, fish exports were reduced. The strong growth after 2004 is explained by the termination of the EU embargo on Cape Verdean fish. Tuna and small pelagic constitute the largest percentage of fish species exported, around 97 percent of total exported tons. Among the tuna, the yellowfin and skipjack species are the most exported, and among the small pelagic is the mackerel species. Imports represents around 5 percent of total exports. The main imported products are fishmeal (37 percent of total imported in tons), fish fillets (6 percent of total imported in tons), shrimps and prawns (6 percent of total imported in tons) and cod (5 percent of total imported in tons).

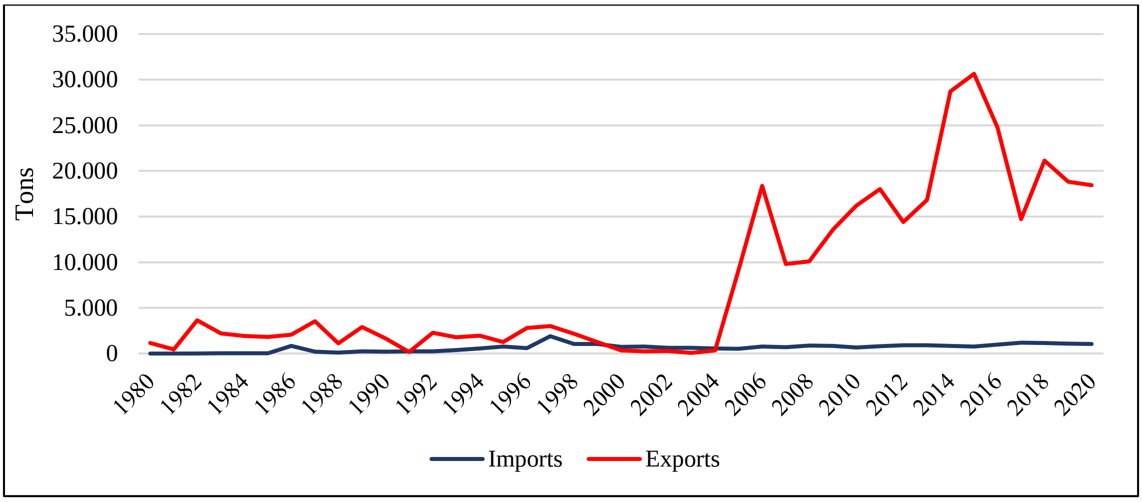

Figure 5 - Import and Export of Fish (tons)
Source: (FAO, 2022)

From the above, it can be concluded that fisheries are an important sector of the Blue Economy and Cape Verde has an EEZ with great potential. However, Cape Verde still has an underused catchment capacity, consisting of a small number of industrial and semi-industrial vessels with low capacity. The techniques used in fishing are still rudimentary. Large numbers of fishermen are involved in artisanal fisheries, which means that they have little economic power and capacity for innovation. Tuna and small pelagic are the most caught species both in artisanal fisheries and in semi-industrial and industrial fisheries. The fisheries sector has been reducing its impact on the economy of Cape Verde.

4 METHODOLOGY AND DATA

The methodology applied in this study is divided into two parts. In the first part, the standard bioeconomic model is used to estimate the potential for an ecological sustainable growth and the economic sustainability rent of the fishing sector in Cape Verde. The second part consists in utilizing the results from the first part, to analyse the effects of the fisheries sector on GDP, using the Input-Output Model.

4.1 Standard Bioeconomic Model

The model to be used in the present study was developed by (Gordon H. S., 1954), which is based on the general biological production model of a fishery. It follows the Schaefer model, which is described by (Gordon M. R., 1992) and adapted by (Nguyen, Nguyen, & Le Van, 2018) as:

$$\frac{dX}{dt} = F(X) - H(E, X) \tag{1}$$

where ***F (X)*** is the biological growth of the stock; ***H (E, X)*** is the production function or harvest function of the fishery, which depends on fishing effort ***(E)*** and stock biomass ***(X)***. If ***F (X) = H (E, X)***, then $\boldsymbol{\frac{dX}{dt} = 0}$, mean that the resource is being harvested on a sustained yield basis.

The biological growth of the stock ***F (X)***, is determined by:

$$F(X) = rX\left(1 - \frac{X}{K}\right) \quad (2)$$

where ***r***, a constant, denotes the intrinsic proportional growth rate of the resource, and where K, a constant, denotes the "carrying capacity", or natural equilibrium level of the resource. It is assumed that: ***F (0) = F (K) = 0, F (X) > 0***, for ***0 < X < K*** and ***F''(X) < 0***.

The harvest function ***H (E, X)*** of a fishery is often assumed to be expressed by:

$$H(E, X) = qEX \quad (3)$$

where ***q***, a constant, is the catchability coefficient, where ***E*** denotes fishing effort (combine the flow of labour service and capital service devoted to harvesting), and **X** is the stock biomass.

At the equilibrium, the ***F (X) = H (E, X)***, then $\boldsymbol{\frac{dX}{dt} = 0}$, whereby, a sustained yield-fishing can be derived. From equations (2) and (3), there is:

$$qEX = rX\left(1 - \frac{X}{K}\right) \leftrightarrow qE = r\left(1 - \frac{X}{K}\right) \leftrightarrow qE = r - \frac{rX}{K} \leftrightarrow X = K - \frac{KqE}{r} \quad (4)$$

The harvest function (the "standard" sustainable yield for a given level of effort), can be rewritten as:

$$H(E) = qE\left(K - \frac{KqE}{r}\right) \leftrightarrow H(E) = qKE - \frac{Kq^2}{r}E^2 \quad (5)$$

Considering: $\alpha = qK$ and $\beta = -\frac{Kq^2}{r}$, and replacing the equation (**5**):

$$H(E) = \alpha E + \beta E^2 \quad (6)$$

The sustainable Catch Per Unit of Effort (**CPUE**), for a given level of effort is:

$$H(E) = \alpha E + \beta E^2 \leftrightarrow \frac{H(E)}{E} = \alpha + \beta E = CPUE \quad (7)$$

The Maximum Sustainable Yield (**MSY**), that describing the relationship between sustainable yield and fishing effort, is obtained from the following:

Taking the partial derivative of equation **(5)** with respect to ***E***:

$$\frac{\delta H(E)}{\delta E} = \left(qKE - \frac{Kq^2}{r}E^2\right)' = 0 \leftrightarrow qK - 2\frac{Kq^2}{r}E = 0 \quad (8)$$

The expression of Effort at Maximum Sustainable Yield **(E_{MSY})** results by considering the equality in the equation **(6)**, and rewrite the equation **(8)** as:

$$\frac{\delta H(E)}{\delta E} = \alpha + 2\beta E = 0 \leftrightarrow E = -\frac{\alpha}{2\beta} = \frac{r}{2q} = E_{MSY} \quad (9)$$

Replacing the **E_{MSY}**, equation **(9)**, into the harvest equation **(6)**, the **MSY** function is obtained by:

$$H(E_{MSY}) = \alpha E_{MSY} + \beta {E_{MSY}}^2 = \alpha\left(-\frac{\alpha}{2\beta}\right) + \beta\left(-\frac{\alpha}{2\beta}\right)^2 = -\frac{\alpha^2}{2\beta} + \frac{\beta\alpha^2}{4\beta^2} = -\frac{\alpha^2}{4\beta} = MSY \quad (10)$$

The analysis of the economic sustainability rent (the Maximum Economic Yield - **MEY**) is done through a simple profit analysis model, as defined by (Gordon M. R., 1992) (Schaefer, 1957) and (Nguyen, Nguyen, & Le Van, 2018):

The total sustainable revenue (**TR$_s$**) and total cost (**TC**) from the fishery is:

$TR_s = pH(E)$ and $TC = cE$

where ***p*** is the constant price per unit of harvested fish, and ***c*** is the constant cost per unit of fishing effort.

The difference between the total sustainable revenue (**TR$_s$**) and the total cost (**TC**) of effort is referred to "resource rent" (**π_s**) provided by the fishery resource at each given level of effort ***E***.

$$\pi_s = TR_s - TC = pH(E) - cE = p(\alpha E + \beta E^2) - cE \quad (11)$$

The equilibrium level of the fishing effort that produces the **MEY** is determined by taking the partial derivative of equation **(11)** with respect to ***E***. Therefore, the effort at **MEY** is:

$$\frac{\delta \pi_s}{\delta E} = [p(\alpha E + \beta E^2) - cE]' = 0 \leftrightarrow p\alpha + 2p\beta E - c = 0 \leftrightarrow E = \frac{c - p\alpha}{2p\beta} = E_{MEY} = \pi_{MEY} \quad (12)$$

Replacing the **E$_{MEY}$**, equation **(12)**, into the harvest, equation **(6)**, the **MEY** function is:

$$H(E_{MEY}) = \alpha E_{MEY} + \beta {E_{MEY}}^2 = \alpha\left(\frac{c - p\alpha}{2p\beta}\right) + \beta\left(\frac{c - p\alpha}{2p\beta}\right)^2 = \frac{c^2 - p^2\alpha^2}{4p^2\beta} = MEY \quad (13)$$

The other reference point of equilibrium that is calculated, occurs in an open access regime. According to (Lee G. & Seijo, 2010) in the open access operation of a fishery, each participant will have incentives to make his or her independent decisions based on private returns. And, if each participant uses individual revenue and cost as the basis for making those decisions, the fishery will end up at a bioeconomic equilibrium at the intersection of total fishing costs and total fishing revenue **(TR$_E$ = TC$_E$)**. Under open access, rents are dissipated, and the fisheries sector only contributes to the national economy through remuneration of labour and capital, (Nielsen, Ravensbeck, & Nielsen, 2014). Therefore, using the Gordon-Schaefer model, the bioeconomic equilibrium level of effort **(E$_{BE}$)** is:

Considering: $TR_E = pH(E)$, $TC_E = cE$ and $H(E) = \alpha E + \beta E^2$

$$TR = TC \rightarrow pH(E) = cE \rightarrow p(\alpha E + \beta E^2) = cE \rightarrow E = \left(\frac{c/p - \alpha}{\beta}\right) = E_{BE} \quad (14)$$

The harvest at open access equilibrium **(BEY)** is calculated using the following function:

$$H(E_{OAY}) = \alpha E_{OAY} + \beta {E_{OAY}}^2 = BEY \quad (15)$$

4.2 Input-Output model

According to (Amaral & Lopes, 2018), the Input-Output analysis was a creation of Wassily Leontief, in the early forties of the twentieth century. An Input-Output Model depicts a comprehensive and detailed set of accounts of sales and purchases of goods and services among producers, final consumers, and resource owners in an economy during a particular period. The I-O table can be described in terms of three major components: inter-industry transaction, final demand and value added, (Sharma, Peterson, Pooley, Nakamoto, & Leung, 1999). (Briggs, Townsend, & Wilson, 1982) consider that the I-O analysis provides a simple general equilibrium approach to quantitative economic analysis. So, an increase in the output of one sector increases the demand for output in its supplying industries, and in industries which supply the suppliers, and so on.

This sub-chapter presents the Input-Output Model to be used in this study, which consists of the essence of Leontief's inverse matrix model with adaptations made by (Sharma, Peterson, Pooley, Nakamoto, & Leung, 1999), (Garza-Gil, Surís-Regueiro, & Varela-Lafuente, 2017) and (Lee & Yoo, 2014). More detailed descriptions of I-O analysis are in (Miller & Blair, 2009). The standard I-O model may be represented compactly through the expression:

Intermediate goods + Final Demands = Total Output (16)

Using **X** to represent the total output. Total Output (**X**) consists of intermediate goods (**AX**: where **0 < A < 1**), and Final Demand (**Y**). The equation (**16**) can be expressed as:

$$AX + Y = X \tag{17}$$

where: **A** an *n X n* matrix of technological coefficients; **X** an *n X 1* vector of gross output; **Y** an *n X 1* vector of final demand. The elements of the matrix of technological coefficients (matrix of input) are obtained by dividing each element $\mathbf{X_{ij}}$ (intermediate demand for inputs between sector *i* and supply sector *j*) by the total output of sector *j*, $\mathbf{X_j}$: $\left(\boldsymbol{X_{ij}}/\boldsymbol{X_j}\right)$. Each element of this division indicates the part of the value produced by sector *j* that is due to the consumption of product *i*.

The equation **(17)** can be written as:

$$Y = X - AX \tag{18}$$

Simplifying

$$Y = (I - A)X \leftrightarrow (I - A)^{-1}Y = X \tag{19}$$

where: **I** is the identity matrix; $\mathbf{(I - A)^{-1}}$ is the inverted technology matrix (known as Leontief Inverse Matrix and represents the total direct and indirect outputs in sector *i* per unit of exogenous final demand).

Add **Δ** (“delta”) to the equation **(19)**, which can be read as Δ = “change in”, so that it can make this equation more relevant to Input-Output based economic impact analysis:

$$(I - A)^{-1}\Delta Y = \Delta X \tag{20}$$

(Leontief Inverse Matrix multiplied by a change in Final Demand yields a change in Total Output)

In the I-O models, the effects of changes in exogenous final demand on total output are calculated using multipliers. The multipliers are important to estimating the direct, indirect, and induced effect of a given economic variable. There are two types of multipliers in I-O model, that differ depending on what parts of the economy are endogenous in the **A** matrix:

1. Type I multiplier - only interindustry linkages are included.

$$\text{Type I} = \frac{direct\ effects + indirect\ effects}{direct\ effects}$$

2. Type II multiplier - make household spending and wages endogenous. The additional spending that occurs in the economy due to new household income is called an induced effect.

$$\text{Type II} = \frac{direct\ effects + indirect\ effects + induced\ effects}{direct\ effects}$$

But, in this study due to data limitations, it is chosen to present only the multiplier results of the total impact (direct effect + indirect effect).

The use of I-O models includes certain assumptions and it is necessary to know these beforehand in order to interpret results correctly, according to (Miller & Blair, 2009): (i) production function is homogeneous and linear for each sector, which translates into the assumption of constant technical coefficients, absence of economies or diseconomies of scale and externalities, and non-substitution between inputs, in addition to the stability of trade patterns between sectors and between these and the rest of the world; (ii) the economy operates with idle capacity, this means that any increase in final demand can be met by an increase in sectorial production; and, (iii) with regard to employment, it is assumed that there is unemployment in the economy, whereby any additional demand for labour translates into an increase in the number of employees.

4.3 Data

The time-series data on harvest and effort, for the period 1993 to 2021, are collected from the statistical reports of National Fisheries Development Institute (in Portuguese INDP – Instituto Nacional de Desenvolvimento das Pescas, de Cabo Verde) and Sea Institute (in Portuguese IMar – Instituto do Mar, de Cabo Verde). The data are divided according to artisanal fishing and industrial fishing. For the artisanal fishing the catch has been expressed in tonnes and effort has been expressed in terms of number of fishing trip by vessels. Regarding industrial fishing, the catch has been expressed in tonnes and the effort in terms of days at sea.

The data about fish price is obtained from the National Statistics Institute (in Portuguese INE – Instituto Nacional de Estatística de Cabo Verde), and is the price paid in the retail market. Like (Lindroos, Nieminen, & Heikinheimo, 2012), it is assumed in this study that the price is constant for each species, and it does not vary within the amount of harvested fish or for any other reason, despite this different variables exist that affect the fish price, and the amount of harvests cannot explain the price alone. In this regard, a weighted average of fish prices was considered, according to each species, applied between 2019 and 2021.

The annual cost per vessel was considered separately for industrial fishing and artisanal fishing. The vessels are considered homogeneous between those of industrial fishing and between those of artisanal fishing. The total cost per vessel was divided into fixed and variable cost. Regarding variable costs it is assumed that vessels, normally, work 11 months a year.

For the artisanal vessels an average of 3 fishermen per boat was considered to determine the total wages, and for industrial vessels an average of 11 fishermen per vessel was considered to determine the total wages (see table 1).[3]

The cost data were obtained through interviews with fishermen and fishing boat owners in several municipalities in Cape Verde. Subsequently, an average value of the costs was estimated, to determine a constant cost per artisanal and industrial vessels.

[3] The depreciation rates registered in the Official Bulletin of Cape Verde nº42/2015, (Ministério das Finanças e do Planeamento, 2015) were used.

Table 1 - Artisanal and Industrial Costs Per Vessels and Per Year

Cost/vessel/year/Artisanal			
Variable		**Fixed**	
Fuel & lubricant	385	Insurance	13
Ice on board	110	Fishery license	1. 32
Food & supplies	88	Wages	739. 2
Miscellaneous	66	Maintenance	22
Gear	88	Depreciation Engine	58. 4
		Depreciation vessel	18. 3
Total	**737**	**Total**	**852. 22**

Cost/vessel/year/Industrial			
Variable		**Fixed**	
Fuel & lubricant	3 300	Insurance	450
Ice on board	1 760	Fishery license	30
Food & supplies	1 100	Wages	3 960
Gear	220	Maintenance	1 110
		Depreciation vessel	900
Total	**6 380**	**Total**	**6 450**

Note: The value is Thousands CVE (1€ = 110.265 CVE).

The data for the Input-Output model are collected in the input-output matrix produced by the National Statistics Institute (in Portuguese INE – Instituto Nacional de Estatística, de Cabo Verde).

5 MODEL ESTIMATION AND RESULTS ANALYSIS

5.1 Standard Bioeconomic Model

5.1.1 Maximum Sustainable Yield

Considering the objectives of this study, the Maximum Sustainable Yield (MSY) analysis is carried out in aggregate way, i.e., the catches made by artisanal and industrial vessels were added. Since, the efforts are different between artisanal and industrial fishing, the effort was standardized, transforming the artisanal fishing effort (number of fishing trips by vessels), into industrial fishing effort (fishing days by vessels), following the methodology suggested by (Sparre & Venema, 1998).

Regarding harvest data (per tonnes), the five species of fish (Tuna, Demersal, Small Pelagic, Crustaceans & Molluscs and Others), were aggregated, after standardization in terms of Tuna price, which is the main fish species in Cape Verde. Table 2 presents a summary statistic of the time-series data, from 1993 to 2021, on catch, effort and CPUE of marine fisheries done by industrial and artisanal Cape-Verdean vessels. The catch by foreign vessels in Cape Verde Exclusive Economic Zone is not considered in this study.

Table 2 - Summary Statistics of Catch, Effort, and CPUE (1993-2021)

Variables	Nº observations	Mean	St. deviation	Min value	Max value
Catch (tons)	29	8 162	2 015	5 704	14 332
Effort	29	8 113	1 646	4 509	10 432
CPUE	29	1,04	0,31	0,72	1,76

Source: Author's calculations

Figure 6 presents the evolution of the variables catch (tonnes) and catch per unit effort (CPUE) in the period between 1993 and 2021. The CPUE shows a fluctuating behaviour over the period under analysis, without a well-defined trend. These fluctuations in CPUE can be explained in part by the heterogeneous characteristics of the boats. The number of boats operating, which present a certain oscillation, can also contribute to justify the behaviour of the CPUE.

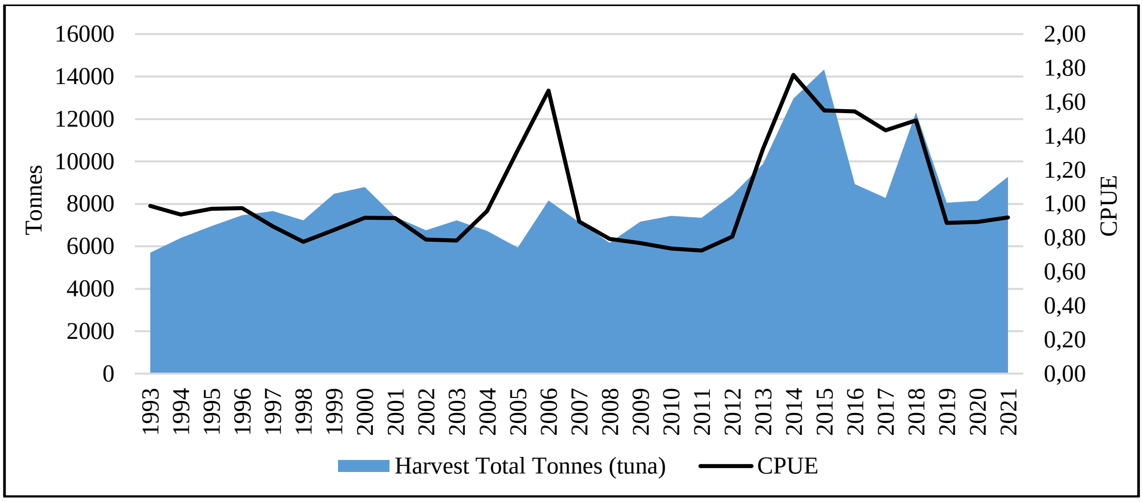

Figure 6 - Catch and CPUE Marine Capture Fisheries in Cape Verde
Source: Author's calculations

Since data on catch and effort are available for the fisheries, it allows to estimate the parameters $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ by linear regression of the equation (**7**). Table 3 indicates the parameters estimated by linear regression of the CPUE data on the corresponding effort data, and statistical tests of the linear regression. The regression analysis reveals that about 36 percent of the CPUE variation is explained by the linear model, and the parameters $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$, are statistically significant at one percent.

Table 3 - Estimated Coefficients of Verhulst–Schaefer Model

Variables	**Coefficients**	**St.deviation**	**t-Stat**	**P-value**	
Alfa (α)	1.96811933	0.24119987	8.1597	9.176E-09***	***R^2:*** *0.36*
Beta (β)	-0.0001141	2.91561E-05	-3.912	0.0005583***	***F statistic:*** *15.30*

*Note: *** statistically significant at one percent*

The harvest function (the “standard” sustainable yield for a given level of effort), corresponding to equation (**6**) is:

$$\boldsymbol{H(E) = 1.968E - 0.0001E^2}$$

The values of reference points (E_{MSY} and MSY), were calculated by the equation (**9**) to obtain the effort at MSY, while harvests at MSY, were calculated by using the harvest function:

$$\mathbf{E_{MSY}} = -\frac{\mathbf{1.968}}{\mathbf{2 \times (-0.0001)}} = \mathbf{8,628}\ \boldsymbol{days\ at\ sea}$$

$$\mathbf{H(E_{MSY}) = MSY = 1.968 \times (8,628) - 0.0001 \times (8,628)^2 = 8,490}\ \boldsymbol{tonnes}$$

The MSY was at 8,490 tonnes and produced at effort value of 8,628 days at sea (see figure **7**). When these estimated values were compared with the recorded catch and effort values, it has been found that for the latest data available (the value in 2021) the catch level (9.270 tonnes) and effort level (10,081 days at sea) are superior to the values obtained from this empirical model.

Regarding historical data, in the last 15 years, there is a higher level of effort recorded compared to the empirical value of the model, in the periods between 2009 and 2012, in 2015 and between 2019 and 2021. Relative to the harvest, the recorded data exceed the estimated value, in the periods between 2013 and 2016, in 2018 and 2021, (see figure 8). This points to a certain overexploitation of Cape Verde's seafood, which is an indicator of unsustainability, despite the fluctuating behaviour. Also, the recorded data point out that in some periods the optimal effort is exceeded but catch continues to increase. According to (Nguyen, Nguyen, & Le Van, 2018), this can be explained, in part, by the fact that the catch increases but the efficiency (CPUE) of the fisheries is in decline, as seen in figure 6, since CPUE is one index of stock, then maybe the catch increased by running down the stock.

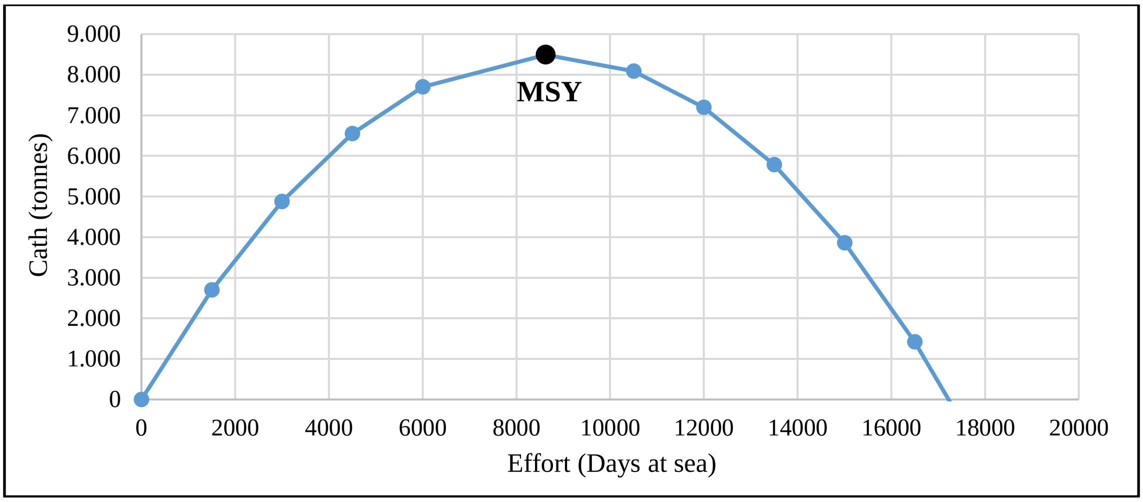

Figure 7 - Sustainable Yield
Source: Author's calculations

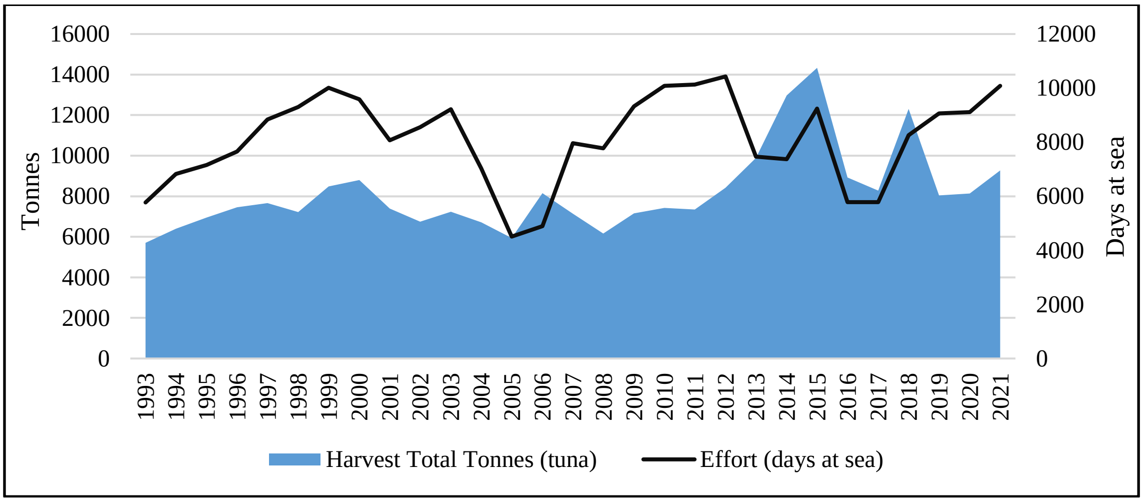

Figure 8 - Catch and Effort Marine Capture Fisheries in Cape Verde
Source: Author's calculations

In conclusion, the results from the Verhulst–Schaefer models show that, in 2021, the fishing effort was around 17 percent larger than the fishing effort corresponding to the MSY, and the harvest was 9 percent superior to the value of maximum sustainable harvest level, thus indicating an overexploitation. However, this behaviour has been fluctuating over the last 15 years, i.e., there is no trend. This result, in part, is in line with the result of (Evora, 2016), who concluded that in 2012 the situation presented a slightly excessive fishing effort.

5.1.2 Maximum Economic Yield and Open Access Equilibrium

The Maximum Economic Yield (MEY) and the Open Access Equilibrium (BEY) are analysed assuming the same fish selling price (using the tuna price per kg, which is 544 CVE), but relative to costs, three hypotheses are considered:

1- All fishery is carried out by industrial vessels;
2- All fishery is carried out by artisanal vessels;
3- Current situation: 60 percent of fishery is carried by industrial vessels and the rest by artisanal vessels.

The MEY is attained as the profit maximizing of effort, which is obtained using the equation (**13**), and the corresponding effort is calculated using equation (**12**). The BEY is calculated by the equation (**15**) and the effort necessary by the equation (**14**).

1 – All fishery is carried out by industrial vessels

The average cost per unit effort of industrial vessel (**cIV**) is calculated as follows:

$$\mathbf{cIV} = \frac{\mathbf{FC_{p/v} + VC_{p/v}}}{\mathbf{DAS_{p/v}}} = \frac{\mathbf{6,450 + 6,380}}{\mathbf{47,7}} = \mathbf{271}\ \boldsymbol{thousand\ CVE}$$

where, $\mathbf{FC_{p/v}}$ the annual fixed cost per vessel, $\mathbf{VC_{p/v}}$ the annual variable cost per vessel, $\mathbf{DAS_{p/v}}$ days at sea per vessel (corresponds to the total number of days at sea in the year, divided by the number of industrial vessels). As the data considered are in tonnes, the total cost is in thousands CVE, to maintain the same base value as the sales price.

The E_{MEY}, MEY, E_{BE} and BEY are calculated as follows:

$$\mathbf{E_{MEY}} = \frac{\mathbf{c - p\alpha}}{\mathbf{2p\beta}} = \frac{\mathbf{271 - 544 \times 1.968}}{\mathbf{2 \times 544 \times (-0.0001)}} = \mathbf{6,444}\ \boldsymbol{days\ at\ sea}$$

$$\mathbf{H(E_{MEY}) = MEY = 1.968\ \times (6,444) - 0.0001 \times (6,444)^2 = 7,946}\ \boldsymbol{tonnes}$$

$$\mathbf{E_{BE}} = \left(\frac{\mathbf{{}^{c}/_{p} - \alpha}}{\mathbf{\beta}}\right) = \frac{\mathbf{{}^{271}/_{544} - 1.968}}{\mathbf{-0.0001}} = \mathbf{12,888}\ \boldsymbol{days\ at\ sea}$$

$$\mathbf{H(E_{BE}) = BEY = 1.968\ \times (12,888) - 0.0001 \times (12,888)^2 = 6,420}\ \boldsymbol{tonnes}$$

The results of the estimation are in figure 9. Considering the hypothesis that there are only industrial vessels in Cape Verde, the harvest at MEY level will be 7,946 tonnes and obtained at effort value of 6,444 days at sea. The fishing effort and the harvest registered in 2021, would be around 60 and 17 percent higher than the fishing effort and harvest at the MEY level, respectively. The BEY will be 6,420 tonnes and produced at an effort level of 12,888 days at sea, that will be around 30 percent superior to the effort level in 2021.

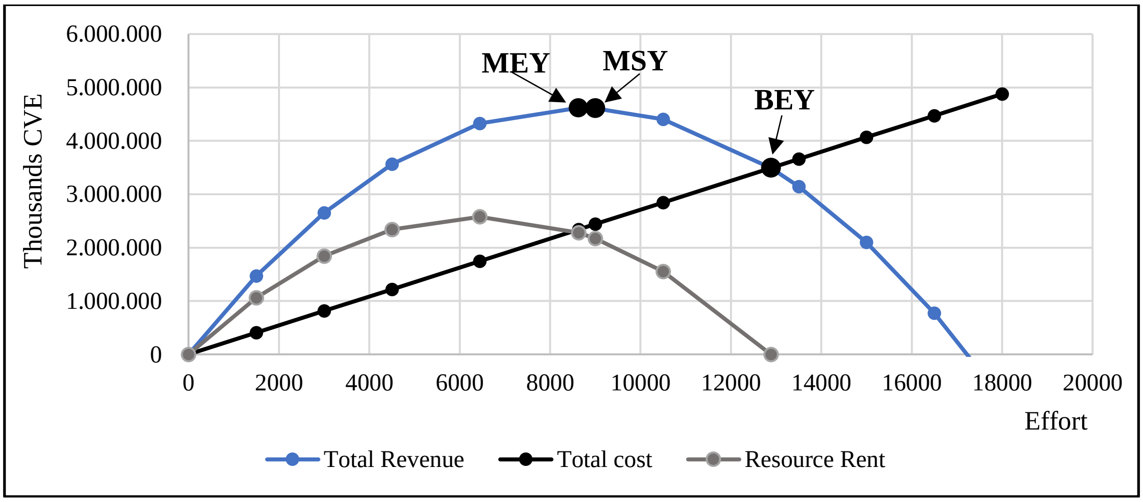

Figure 9 - Maximum Economic Yield and Open Access Equilibrium, Industrial Vessels
Source: Authors' calculations

2 – All fishery is carried out by artisanal vessels

The average cost per unit effort of artisanal vessels (**cAV**), E_{MEY}, MEY, E_{BE} and BEY are calculated as follows:

$$\mathbf{cAV} = \frac{\mathbf{FC_{p/v} + VC_{p/v}}}{\mathbf{DAS_{p/v}}} = \frac{\mathbf{737 + 855}}{\mathbf{2,8}} = \mathbf{573}\ \boldsymbol{thousand\ CVE}$$

$$\mathbf{E_{MEY}} = \frac{\mathbf{c - p\alpha}}{\mathbf{2p\beta}} = \frac{\mathbf{573 - 544 \times 1.968}}{\mathbf{2 \times 544 \times (-0.0001)}} = \mathbf{4,010}\ \boldsymbol{days\ at\ sea}$$

$$\mathbf{H(E_{MEY}) = MEY = 1.968\ \times (4,010) - 0.0001 \times (4,010)^2 = 6,058}\ \boldsymbol{tonnes}$$

$$\boldsymbol{E_{BE}} = \left(\frac{c/p - \alpha}{\beta}\right) = \frac{\mathbf{573/544 - 1.968}}{\mathbf{-0.0001}} = \mathbf{8,021}\ \boldsymbol{days\ at\ sea}$$

$$\boldsymbol{H}\mathbf{(E_{BE}) = BEY = 1.968\ \times (8,021) - 0.0001 \times (8,021)^2 = 8,448\ (tonnes)}$$

The results of the estimation are in figure 10. Assuming the hypothesis that exist only artisanal vessels in Cape Verde, the harvest at MEY level will be 6,058 tonnes and obtained at effort value of 4,010 days at sea. The fishing effort and the harvest registered in 2021, would be around 150 and 50 percents superior to the fishing effort and harvest at the MEY level, respectively. The BEY will be 8,448 tonnes and produced at an effort level of 8,021, that will be around 20 percent inferior to the effort level in 2021.

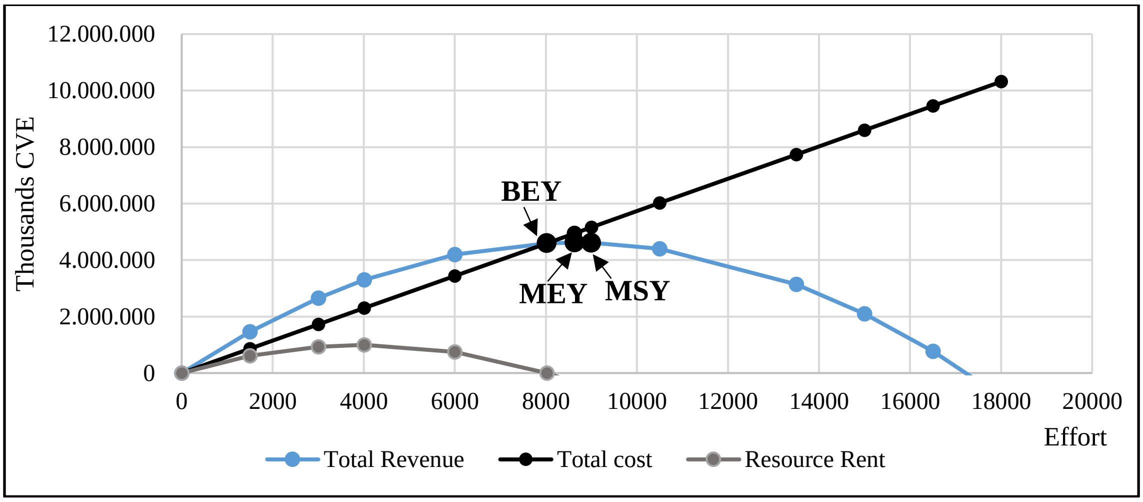

Figure 10 - Maximum Economic Yield and Open Access Equilibrium, Artisanal Vessels
Source: Authors' calculations

3 – Current situation: 60 percent of fishery carried out by industrial vessels and the rest by artisanal vessels

The average cost per unit effort (**c**) is calculated as follows:

$$\mathbf{c} = \frac{\mathbf{cIV \times DAS_{IV} + cAV \times DAS_{AV}}}{\mathbf{TDAS}} = \frac{\mathbf{271 \times 6017 + 573 \times 4063}}{\mathbf{10,080}} = \mathbf{393}\ \boldsymbol{thousand\ CVE}$$

where, **DAS_{IV}** days at sea by industrial vessels, **DAS_{AV}** days at sea by artisanal vessel, **TDAS** total days at sea.

The E_{MEY}, MEY, E_{BE} and BEY are calculated as follows:

$$E_{MEY} = \frac{c - p\alpha}{2p\beta} = \frac{393 - 544 \times 1.968}{2 \times 544 \times (-0.0001)} = 5,461 \; days \; at \; sea$$

$$H(E_{MEY}) = MEY = 1.968 \times (5,461) - 0.0001 \times (5,461)^2 = 7,346 \; tonnes$$

$$E_{BE} = \left(\frac{c/p - \alpha}{\beta}\right) = \frac{393/544 - 1.968}{-0.0001} = 10,922 \; days \; at \; sea$$

$$H(E_{BE}) = BEY = 1.968 \times (10,922) - 0.0001 \times (10,922)^2 = 7,890 \; tonnes$$

The results of the estimation are in figure 11. Considering the current situation, where about 60 percent of fishery is carried out by industrial vessels and the rest by artisanal vessels in Cape Verde, the harvest at MEY level is 7,346 tonnes and obtained at effort level of 5,461 days at sea. The fishing effort and the harvest registered in 2021, were around 85 and 26 percents higher to the fishing effort and harvest at the MEY level, respectively. The BEY are 7,890 tonnes and produced at an effort level of 10,922 days at sea, that is close to the effort level in 2021.

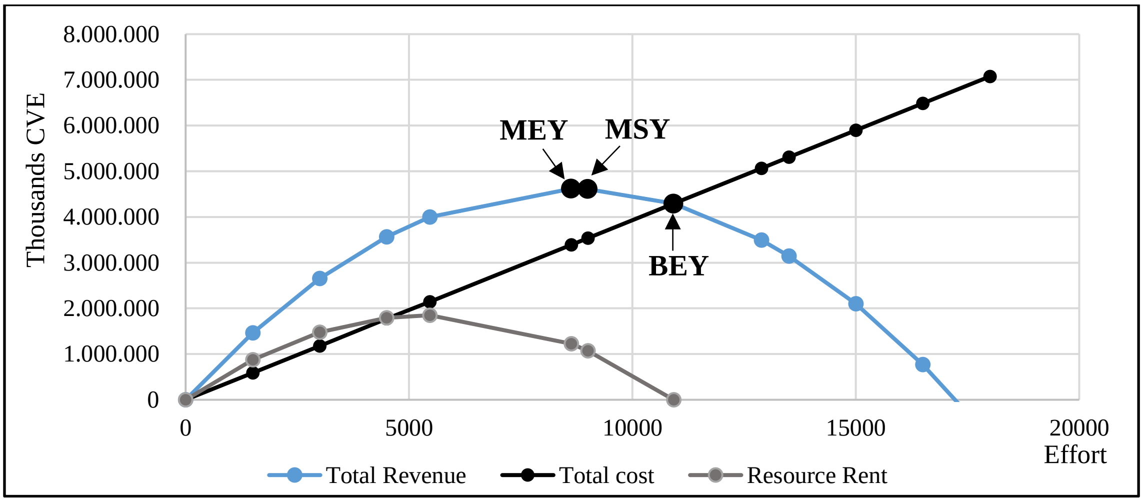

Figure 11 - Maximum Economic Yield and Open Access Equilibrium, Industrial and Artisanal Vessels
Source: Author's calculations

The results presented in the three hypotheses considered, allow to conclude that, in economic terms, the resource rent is more favourable if the fisheries sector in Cape Verde was constituted only by industrial vessels. Since, MEY are valued at resource rent of around 2,576.5 million CVE, for the hypothesis that there only industrial vessels, which are 160 percent higher than the resource rent (997.9 million CVE) for the hypothesis that there only artisanal vessels, and 40 percent superior to the resource rent (1,850.3 million CVE), for the hypothesis that 60 percent of fishery is carried by industrial vessels. The results also indicate that in the hypothesis that there are only artisanal vessels, the level of effort to reach the harvest at Open Access Equilibrium (BEY) is lower than the level of effort to reach the harvests at the Maximum Sustainable Yield (MSY), thus indicating that the economic costs would be very high for the fisheries sector.

The third hypothesis, which represents the current situation in Cape Verde, the existing level of effort is practically similar to the level of effort at the Open Access Equilibrium level, but the harvest level is about 17 percent higher than the harvest at Open Access Equilibrium (BEY).

5.2 Input-Output model

The Input-Output matrix is used to estimate the total effect of fisheries sector on the production and employment in Cape Verde. Table 4 indicates the main economic aggregates for fisheries and aquaculture sector in 2018 (last year data was available). Most of the production value from fisheries and aquaculture sector comes from domestic products (56 percent) followed by GVA (43 percent). Majority of the GVA is destined to gross operating surplus, and only 9 percent goes to employee salaries. The final demand of fisheries and aquaculture represent about 51 percent of total production in the sector. Fisheries and aquaculture sector employs about 2.1 percent of total employees in Cape Verde and contributes to around 1,42 percent of total GVA.

Table 4 - Economic Aggregates of Fisheries and Aquaculture in Cape Verde (2018)

	Fisheries & Aquaculture (value)
Domestic Products	3,241
Imported Products	13
Intermediate Consumption	3,257
Gross Value Added (GVA)	2,482
Employee Remuneration	234
Gross Operating Surplus	2,245
Final Demand	2,931
Production/Input at basic prices	**5,739**
Number of Employees	4,166

Source: (INE, 2022), Author's calculations. Unit: million CVE. 1€ = 110.265 CVE

The current Input-Output matrix of Cape Verde's economy considers 52 branches of activity. Table 5 presents the ten main branches of domestic activities, that, in 2018, fisheries and aquaculture sector purchased and provided inputs. These ten main branches of input activities constitute about 94 percent of the sector's intermediate consumption. Major sectors supplying inputs to fisheries and aquaculture were oil and fossil fuels (23 percent), rental of machinery and equipment (17 percent), fisheries and aquaculture (13 percent) and storage and services annexed to transport (12 percent). On the other hand, fisheries and aquaculture activities also are a source of production inputs for nine sectors. About 96 percent of the fisheries and aquaculture outputs go to only four branches of domestic activities, and the main recipient is the food industry, representing 63 percent of the total output consumed by domestic activities.

Table 5 - Main Branches of Economic Activity Related with Inputs and Output on Fisheries and Aquaculture in Cape Verde (2018)

Branch of activity	Value of Inputs
Oil and fossil fuels	741
Rental of machinery and equipment	547
Fishing and Aquaculture	414
Storage & service annexed to transport	388
Food industries	354
Electricity and gas	202
Repair services and maintenance	132
Telecommunications	125
Land transport	98
Restaurants & drinking establishments	57

Branch of activity	Value of Outputs
Food industries	2,564
Accommodation	683
Fishing and Aquaculture	414
Restaurants & drinking establishments	235
Public administration	69
Education Services	38
Human Health Services & Social Action	27
Trading of food and other products	6
Wood industries	1

Source: (INE, 2022), Author's calculations. Unit: million CVE

Following the methodology presented in the previous subchapter, referring to Input-Output model, the multipliers shown in table 6 were estimated for the fisheries and aquaculture sector in Cape Verde, for the year 2018. The total of all activities that exhibit an interrelation with fisheries and aquaculture are included in the estimations.

Table 6 points out that the fisheries and aquaculture output multiplier is 1.743, which means if final demand of fisheries and aquaculture sector increase by 1 million CVE, the economy's total output will increase by 1.743 million CVE. The net additional increase is 743 thousand CVE, if the net increase is defined as the difference between the initial change in final demand and the resulting change in total output. The employment multiplier is 1.265, which means that for every 1 million CVE invested in fisheries and aquaculture sector, 1.265 individuals are employed.

Table 6 - Multipliers of Fisheries and Aquaculture Sector

	Total effects (direct + indirect effects)
Output multiplier	1.743
Employment multiplier	1.265

Source: Author's calculations

Considering the goals of the present study, the data obtained by the estimation of Standard Bioeconomic Model is used to analyse the total effect of fisheries and aquaculture sector on the total output and employment in Cape Verde. The values of the multipliers are presented, considering that fishing is carried out at Maximum Economic Yield level, in terms of effort and harvest. The variation in input-output matrix were calculated considering proportional changes, i.e., the inputs and outputs of the fisheries sector are changed from the current situation, considering the proportions of the variations obtained. This means that there are no changes in technologies and constant returns to scale are assumed. The analysis is carried out assuming the three hypotheses considered:

1- All fishery is carried out by industrial vessels;
2- All fishery is carried out by artisanal vessels;
3- Current situation: 60 percent of fishery is carried out by industrial vessels.

1 – All fishery is carried out by industrial vessels

The values calculated of the fishing effort (6,444 days at sea) and the harvest (7,946 tonnes) imply a total cost of 1,746 million CVE and total revenue of 4,323 million CVE. This represents a reduction of 55.92 percent in total costs and 14.28 percent in total revenues, compared to the current situation. Regarding employment, it will decrease 78.47 percent compared to the current situation. Table 7 presents the results of output and employment multipliers.

Table 7 - Multipliers: All Fishery is Carried out by Industrial Vessels

	Total effects (direct + indirect effects)
Output multiplier	1.775
Employment multiplier	0.508

Source: Author's calculations

2 – All fishery is carried out by artisanal vessels

The values calculated of the effort (4,010 days at sea) and the harvest (6,058 tonnes) imply a total cost of 2,298 million CVE and total revenue of 3,296 million CVE. This represents a reduction of 42 percent in total costs and 34.64 percent in total revenues, compared to the current situation. Regarding employment, there will be decrease 21.14 percent compared to the current situation. Table 8 presents the results of output and employment multipliers.

Table 8 - Multipliers: All Fishery is Carried out by Artisanal Vessels

	Total effects (direct + indirect effects)
Output multiplier	1.742
Employment multiplier	1.688

Source: Author's calculations

3 – Current situation: 60 percent of fishery carried by industrial vessels

The values calculated of the effort (5,461 days at sea) and the harvest (7,346 tonnes) imply a total cost of 2,146 million CVE and total revenue of 3,996 million CVE. This represents a reduction of 45.83 percent in total costs and 20.75 percent in total revenues, compared to the current situation. Regarding employment, it will decline 46.15 percent compared to the current situation. Table 9 presents the results of output and employment multipliers.

Table 9 - Multipliers: Current Situation

	Total effects (direct + indirect effects)
Output multiplier	1.756
Employment multiplier	1.202

Source: Author's calculations

Table 6 presents multiplier of the current fisheries sector situation in Cape Verde. Considering the current situation, if the public policies concerning the fisheries sector in Cape Verde operate at the level of Maximum Economic Yield (see table 9), the output multiplier of the fisheries sector would increase 0.75 percent, but there would be a decrease of -5.0 percent in the employment multiplier.

If public policies for fishing were to be only concerned with industrial vessels (see table **7**), this would imply an increase of 1.84 percent in output multiplier, while in terms of employment the multiplier would decrease considerably, about -59.84 percent, compared to the current situation (table 6). On the other hand, if the fishing is only carried out by artisanal vessels (see table 8) there would be a slight decrease of -0.057 percent in the output multiplier, but relative to the employment multiplier it would increase substantially, about 33.44 percent given the current situation (see table 6).

However, when comparing the three hypotheses presented, given the situation that the fisheries operate at the level of Maximum Economic Yield, the hypothesis of operating only with industrial vessels (table **7**) presents the best result in terms of the output multiplier (which is 1.86 and 1.07 percent higher than the hypothesis of operating only with artisanal vessels and with 60 percent of industrial vessels, respectively), but the employment multiplier is the lowest among the hypotheses (which is -232.28 and -136.61 percent smaller than the hypothesis of operating only with artisanal vessels and with 60 percent of industrial vessels, respectively).

The hypothesis of operating only with artisanal vessels (see table 8) would be advantageous for job creation, as it has the highest employment multiplier (70.00 and 28.79 percent higher than the hypothesis of operating only with industrial vessels and with 60 percent of industrial vessels, respectively), but in terms of output multiplier, it would be less advantageous for the Cape Verdean economy (-1.89 and -0.80 percent smaller than the hypothesis of operating only with industrial vessels and with 60 percent of industrial vessels, respectively).

The current situation hypothesis, that 60 percent of fishing is carried out by industrial vessels, corresponds to an intermediate situation, that is, it has a lower employment multiplier (-40.43 percent) and a greater output multiplier (0,80 percent) than the hypothesis of operating only with artisanal vessels, and it has greater employment multiplier (57.74 percent) and a lower output multiplier (-1,08 percent) than the hypothesis of operating only with industrial vessels.

In conclusion, the results from the Input-Output model show that, depending on the policy makers' goals, public policies may be aimed at encouraging fishing through industrial vessels if a greater output multiplier effect is intended, or if the objective is job creation, the appropriate public policies would be to encourage fishing through artisanal vessels.

5.3 Results Analysis and Recommendations

5.3.1 Results analysis

The development of Blue Economy, with a sustainable growth of the fisheries sector, is defined in the Cape Verde economic development plan as a source to diversify the economy, increase the income of the population and provide greater social well-being. The establishment of goals and activities for a sustainable biological and economic growth of fisheries sector requires a deep knowledge of the sector and the definition of appropriate public policies.

The application of the Verhulst–Schaefer models points to a certain overexploitation of the fisheries sector in Cape Verde. Thus, policies are needed to move the fisheries from the current situation, where is unsustainable, to a sustainable path with the reference points, E_{MSY} and MSY. In this regard, is necessary to reduce the fishing effort by 17 percent, and the harvest by 9 percent, to ensure sustainable growth at the biological level of the fisheries in Cape Verde.

The others reference points, MEY and BEY, are analysed considering three hypotheses: all fishery is carried out by industrial vessels; all fishery is carried out by artisanal vessels; and current situation: 60 percent of fishery is carried by industrial vessels. With these hypotheses, this study intends to analyse which option can have the greatest contribution to economic development in Cape Verde.

The hypothesis that only industrial vessels exist in Cabo Verde is the most advantageous in economic terms, since the MEY is valued at resource rent of around 2,576.5 million CVE, which is 160 percent higher than the resource rent (997.9 million CVE), for the hypothesis that there only artisanal vessels, and 40 percent higher than the resource rent (1,850.3 million CVE), for the hypothesis that 60 percent of fishery are carried by industrial vessels. The results also indicate that in the hypothesis that there are only artisanal vessels, the level of effort to reach the harvest at Open Access Equilibrium is lower than the level of effort to reach the harvests at the Maximum Sustainable Yield (MSY), thus indicating production costs are quite high in the artisanal fisheries sector. According to (Obegi, et al., 2020) in situations of open access resource scenarios, biological overfishing may be experienced when fishing boats and activities are not simply regulated over a given period. Therefore, poor regulation may be one of the problems faced by the fisheries sector in Cabo Verde.

To reach the harvest level of MSY or MEY a reduction in fishing effort is necessary, which will allow for an increase in the productivity in the fisheries sector. However, it will also result in the unemployment of fishermen who will ease out of fisheries. This can be a serious problem for fishing areas in Cape Verde, where fishing is the main (or only) source of income for the population. Thus, in defining public policies, it is important to define income alternatives, mainly for the population of coastal areas.

The policymakers are frequently preoccupied with employment creating effects of the expansion of activities. So, it is important to derive the employment and output multipliers of the various branches of economic activities.

The Input-Output model points to the importance of the fisheries sector in terms of job creation and impact on GDP. The current situation indicates that the fisheries and aquaculture sector employ about 2.1 percent of total employees in Cape Verde and contributes to around 1.42 percent of total GVA. The fisheries output multiplier is 1.743, which means if final demand of fisheries sector increases by 1 million CVE, the economy's total output will increase by 1,743 million CVE. The employment multiplier is 1.265, which means that for every 1 million CVE invested in the fisheries sector, 1,265 individuals are employed.

Considering the Government's objective of guaranteeing a biologically and economically sustainable growth of the fisheries sector, it is necessary to analyse the impacts of the fisheries on GDP and employment, if is there a reduction in effort and harvest to reach the MEY level. Thus, the output and employment multipliers were calculated, given the three hypotheses analysed by the Verhulst–Schaefer model.

In the extreme situation of only industrial vessels existing in Cabo Verde, the output multiplier will be 1.775, which is about 1.86 and 1.07 percent higher than the hypothesis of operating only with artisanal vessels and with 60 percent of industrial vessels, respectively, but the employment multiplier will be 0.508, that is the lowest among the hypothesis (is -232.28 and -136.61 percent smaller than the hypothesis of operating only with artisanal vessels and with 60 percent of industrial vessels, respectively).

The other extreme situation of only artisanal boats operating in Cabe Verde is advantageous for job creation, as the employment multiplier will be 1.688, that is the highest value (is 70.00 and 28.79 percent higher than the hypothesis of operating only with industrial vessels and with 60 percent of industrial vessels, respectively), but the output multiplier will be 1.742, that is the lowest value (is -1.89 and -0.80 percent smaller than the hypothesis of operating only with industrial vessels and with 60 percent of industrial vessels, respectively).

According to these two extreme situations, depending on the objective of the political decision-makers, public policies can be aimed at increasing industrial vessels, if they want a greater product multiplier, or increasing artisanal vessels, if they want a higher employment multiplier.

These conclusions are in line with (Surís-Regueiro & Santiago, 2018) results which identified output and employment multipliers of 1.285 and 0.051 for artisanal fishing, respectively, and for industrial fishing the output and employment multipliers were 1.6796 and 0.0095, respectively. Industrial fishing has the highest output multiplier, but the lowest employment multiplier, which is similar to the deduction of the present study.

5.3.2 Recommendations

The analysis of the results points to an overexploitation of the fishing sector in Cape Verde and a low income from the sector. Thus, several recommendations are suggested, according to studies carried out in peer countries, which can be applied in Cape Verde, to improve the stock management in the fisheries sector (biological sustainability) and increase the economic impact (economic sustainability).

Several authors have proposed policies to achieve a biological and economic sustainable growth in fisheries. (Evora, 2016) advises to achieve long-term sustainable fisheries in Cape Verde, i.e., to control the input or fishing effort management, through the control of the output or catch management by the implementation of the ITQs, an individual transferable quota (ITQ) system which has been successfully used to promote economic efficiency as well as biological conservation in some of the world`s most developed fisheries.

(Fortes, 2019) recommend nine measures to improve the management and move the fisheries towards more biological, economic and social sustainability in Cabo Verde, such as: Limit the level of effort, by introducing a mechanism that, in the medium term, reduce the number of vessels; Revision of legal framework, in order to improve the incomes of the vessels and reduction in fishing pressures of traditional coastal target species; Real-time management, to put in place measures that can effectively protect the biodiversity and management system; Local management, so that the evaluation and management of fish stock is done by islands or by groups of islands; Extension network, to allow close collaboration between different communities, to create alternative economic activities for those who decide to abandon the fishing activity; and, Financial support to create an economic fund to support the development of the artisanal vessels, with improvements on the capacities to explore further fishing grounds and different target species.

In Cape Verde, the institutions linked to the fisheries management face several problems such as lack of staff and budget resources, which makes difficult the management, monitoring, surveillance, and regulation enforcement in Cape Verde waters. (Nguyen, Nguyen, & Le Van, 2018) suggest a co-management model with shared responsibility management between local communities and government agencies, as an option to overcome these problems.

Cape Verde has a fisheries agreement with the European Union, allowing European vessels to fish in the country's EEZ, which impacts heavily on specific fisheries (e.g., Tuna). Thus, the sustainability of Cape Verde fisheries also requires a strong involvement of the partners that fish in Cape Verdean waters.

(Obegi, et al., 2020) point out some measures that can be adopted, when a country intends a sustainable growth of the fisheries sector, such as develop more policy-frameworks to reduce operational vessels to a level of effort that guarantees the MSY; provision and development of protected areas, imposition of taxes, license and enforcement of stringent regulations to limit efforts, which allow an increase in fish stock and maximizes the profit; broader consultation and participation in developing policy framework to prevent possible conflicts bearing the nature of poverty related issues and traditional societies resorting to fishing for employment; and government interventions through restocking, price control mechanisms to withstand market shocks (uncertainty) as well as sensitization programs among fisher folks to ensure stock size are not overexploited.

6 CONCLUSION

The aim of this study was to analyse the sustainable growth of fisheries sector through the Bioeconomic Model and quantify the total impact (direct + indirect effects) of fisheries and aquaculture on Cape Verde economy, by using an input–output model that accounts for these inter-sectoral transactions.

The results of the Bioeconomic Model point out that given the current situation, in 2021, the level of effort and harvest is higher than the level that guarantees the maximum sustainable yield, so it is necessary to reduce the fishing effort by 17 percent, and the harvest by 9 percent, to ensure sustainable growth at the biological level of the fisheries in Cape Verde. On the other hand, to assure the level of maximum economic yield, assuming the current situation, it is necessary to reduce the fishing effort by 85 percent and the harvest by 26 percent, which will allow a level of resource rent around 1,850.3 million CVE. However, the highest level of resource rent (2,576.5 million CVE) would be reached, if in Cape Verde there were only industrial vessels.

The results of the Input-Output model indicate that the output multiplier for the fishing sector is 1.743, which means if final demand of fishing sector increases by 1 million CVE, the economy's total output will increase by 1.743 million CVE. The employment multiplier is 1.265, which means that for every 1 million CVE invested in the fishing and aquaculture sector, 1.265 individuals are employed.

The three analysed hypotheses suggest that, if the objective of policy makers is to increase the output multiplier effect, they should seek to increase the number of industrial vessels, but if they want a higher employment multiplier, promoting the artisanal vessels is the best solution.

This study offers the first view of the economic multiplier effects of fisheries sector in Cape Verde, considering the hypothesis that fisheries is at the level of maximum economic yields. This hypothesis analysed by Bioeconomic and Input-Output models can be a useful instrument for policy makers, marine planning and investment decisions that seek to quantify the level of effort and harvest which ensures a sustainable growth of the fisheries sector and the socioeconomic importance of fisheries sector in promoting the output/resource rent and employment growth.

In terms of future research, the analysis of other economics multipliers such as income, Gross Value Add and the induced effect resulting from the increase in fishermen's income, will be relevant for the definition of public policies. Also, an assessment of the variability in the multipliers of other branches of activities when changes occur in the fisheries sector, is another interested study to be conducted. A practical extension of this study would be a comparison of the multiplier effects of fisheries sector and non-fisheries sector. A study focusing on the trade-offs between the economic multiplier effects and the environmental impacts of fisheries industries would be important for predicting the implications of green growth.

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